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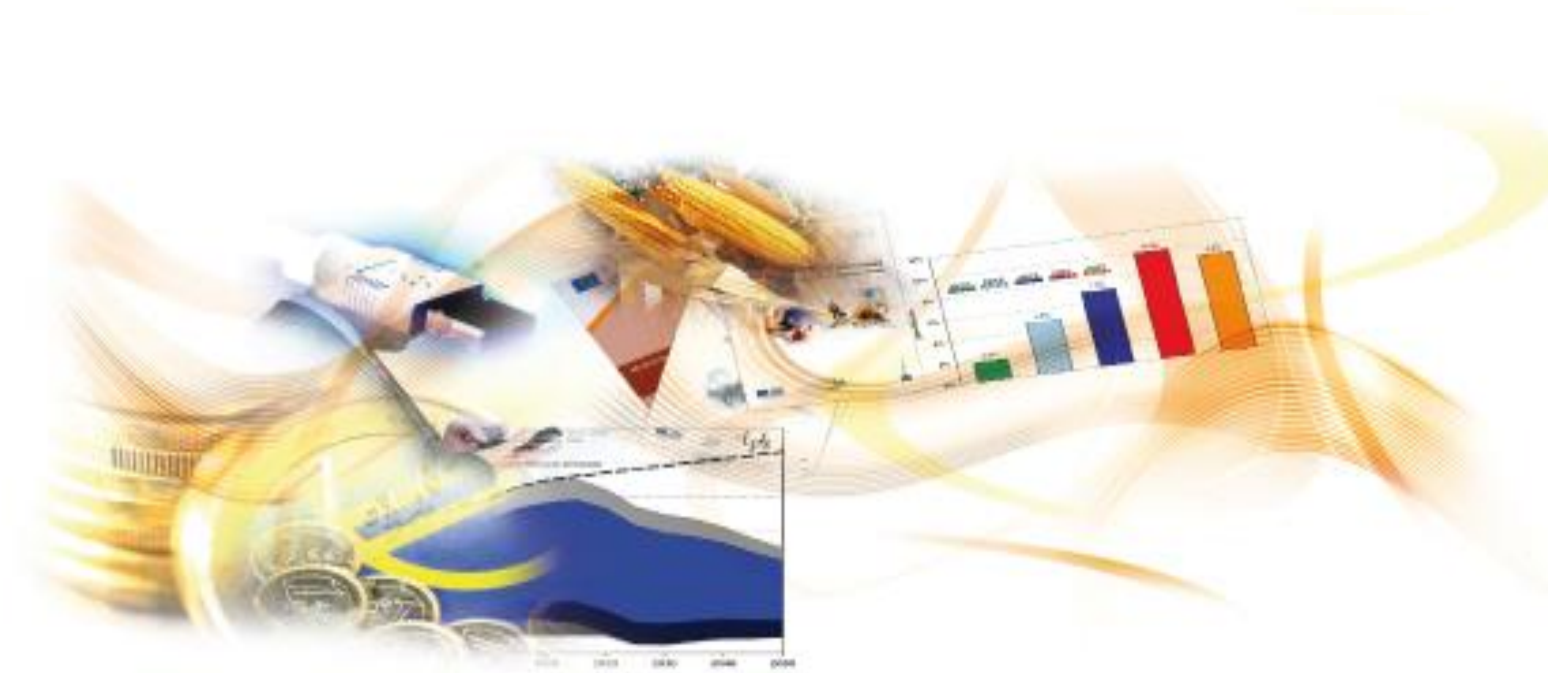

The Economic Impacts of Increasing Public Support to ICT R&D: A Modelling Approach

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Abstract
The report provides a quantitative analysis of the economic impacts of national public support to ICT R&D in the European Union, considering a number of policy scenarios covering different amounts of public spending, policy instruments and sources of financing. For this purpose we use a macroeconomic model with ICT and R&D-driven endogenous growth. The model accommodates a range of policy instruments that may be used to stimulate R&D activity (ICT or non-ICT) in the economy, and it captures multiple channels through which R&D activity affects the economy.
The policy scenarios are simulated with the model. The simulation exercise provides some preliminary evidence that an increase in public expenditure to support ICT R&D might have a significantly positive impact on ICT sector BERD and on economic growth and employment in the EU. It also shows that the strength of this impact can be influenced by policy instruments and financing source. Additional work is needed to gain further insights into the sensitivity of these results to the assumptions and parameter settings used in the model.

Acknowledgements

The author acknowledges helpful comments and suggestions from Andries Brandsma, Wojciech Szewczyk, Marc Bogdanowicz, Andrea de Panizza, Giuditta De Prato, Ibrahim Rohman (JRC-IPTS), Christophe Doin (DG CNECT) as well as participants of seminars and workshops at the European Commission. Finally, thorough checking and editing of the text by Patricia Farrer is gratefully acknowledged.

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Executive Summary

The EU's *Digital Agenda for Europe* (DAE) is one of the seven flagship initiatives under the *Europe 2020* strategy for smart, sustainable and inclusive growth. The DAE aims to help Europe's citizens and businesses to get the most out of digital technologies and to stimulate the economy. One of its targets in this respect is that EU Member States double their annual public spending on ICT R&D by 2020 in real terms with respect to the 2007 level.

This report examines how public spending on ICT R&D may affect private R&D spending and the economy, considering a number of policy scenarios covering different amounts of spending, policy instruments and sources of financing. The policy scenarios were selected by IPTS[1] together with DG CNECT as the most relevant to explore. To examine the effect of public ICT R&D spending, a macroeconomic model[2] with ICT and R&D-driven endogenous growth was developed and used.

The **main observations** emerging from the analysis are the following:

- Preliminary evidence from the simulations performed confirms that additional public expenditure to support ICT R&D may have positive effects on business R&D expenditure in the ICT sector and also on GDP and employment. In the most favourable case, each additional euro spend on public support to ICT R&D would raise ICT sector BERD in the long term (2040) by as much as 1.6 euros, and raise GDP by 2.8 euro. EU employment in the long term would increase by about 150 thousand full-time equivalent persons, mostly in high-skilled jobs. A J-shaped response of net exports and overall competitiveness is also envisaged, with long-term gains in productivity.
- The simulations consider cases of full and partial achievements of the DEA spending target. Results suggest that marginal returns to public spending only slightly diminish for the expenditure levels considered (i.e. a partial achievement of the spending targets is associated with a marginal impact per euro just above that of full achievement). This indicates that there are still substantial gains to be made from reaching the spending target, even from a position of partial achievement. The simulation results also suggest that the level of expenditures chosen by Member States affects not only domestic growth and employment, but also the economy in other Member States. However, this cross-border effect is found to be small. For example, if Germany fully achieves the DEA spending target rather than reaching 75% of it, this would only marginally affect GDP and employment in the other EU Member States. Likewise the effects on German GDP and employment from changes in expenditure levels by other EU Member States are found to be small.
- The choice of the policy instrument affects the policy outcome. Two policy instruments are considered: ICT R&D subsidies and ICT R&D public procurements. Results from the simulations suggest that using ICT R&D public procurements results in a comparatively higher impact on GDP and employment in the short term. However, this effect fades over time. In the model, technological spillovers from ICT R&D public procurement do not fully compensate for the lower productivity gains due to the crowding out of ICT sector private R&D expenditures. In the long-term, R&D subsidies have the most positive effect on business R&D expenditure in the ICT sector and on GDP and employment.
- The source of finance of the public expenditures also affects outcomes, with distortionary effects which reduce benefits. Two sources of finance are considered: lump sum taxation and changes in income tax rates. Lump sum taxation generates minimal distortionary effects and

[1] The Institute for Prospective Technological Studies (IPTS) is one of the seven research institutes of the European Commission's Joint Research Centre.

[2] The model was developed under the project Prospective Insights on R&D in ICT (PREDICT 2), a research project co-financed by the Directorate General for Communications Networks, Content and Technology and the JRC-IPTS. The Institute for Prospective technological Studies (IPTS) is one of seven research institutes of the European Commission's Joint Research Centre (JRC).

allows us to examine the policy outcome of public expenditures on ICT R&D in a nearly neutral context. The results suggest that the financing of expenditure by means of income taxation instead of lump sum taxes reduces the policy outcome, particularly in the case of procurement. This is due to model assumptions about the negative effects of higher income taxes on labour supply.

A modelling approach relies by its nature on assumptions, most of them sustained by earlier empirical results and scientific consensus about relations among variables. The **main limitations** of the exercise proposed in this report result from assumptions and parameter settings pending empirical testing. The model is calibrated to replicate a given reference year (2007) and a specified reference growth path. The elasticities of substitution in the model are set to reflect estimates in the literature. Parameters governing spill-over effects from accumulation of knowledge to R&D production in the ICT sector and other sectors are set at levels compatible with estimates reported in Coe et al. (2008). Nonetheless, the sensitivity of our finding to assumptions regarding the impact of taxation on labour supply, spill-over effects from accumulation of knowledge to R&D production in the ICT sector and other sectors, and price elasticities of foreign trade will need to be further tested. Envisaged enhancements to the model include considering the Member States on an individual basis (currently done for Germany and France only). Further work could also include the assessment of other policy instruments such as tax credits or subsidies targeted at ICT R&D employment. Further work could also consider alternative sources of financing such as corporate taxes, value added taxation or taxes levied on products or production.

The report is organised as follows. Chapter 2 briefly presents the model and how it can be used for policy analysis. Chapter 3 describes the set of policy scenarios examined. Chapter 4 explores the model dynamics and examines the effect of public spending on ICT R&D in detail. Chapter 5 contrasts and compares the impact of the set of policy scenarios we examine. Chapter 6 offers our conclusions.

1. Introduction

Taking outset in the policy actions identified in the EU "*Digital Agenda for Europe*" (DAE)[3], this report explores the economic impact of increasing public spending on information and communication technology (ICT) research and development (R&D) by EU Member States. For this purpose we develop a macroeconomic model[4] with ICT and R&D-driven endogenous growth.

One of the DAE objectives is that EU Member States double their annual public spending on ICT R&D from 2007 to 2020. The notion is that public spending on ICT R&D would leverage private R&D spending, help accelerating time-to-market and opening up new markets for ICT solutions across the EU. We examine these effects by simulating a set of policies, varying the amount of public expenditures on ICT R&D by EU Member States, the policy instrument used and the way in which the policy is financed. The model used for the analysis accommodates a range of policy instruments that may be used to stimulate R&D activity (ICT or non-ICT) in the economy. It captures multiple channels through which R&D activity affects the economy, including the allocation of labour and capital, changes in relative prices, consumption and investment decisions, as well as foreign trade and productivity.

The simulation exercise provides some preliminary evidence that an increase in public expenditure on ICT R&D might have a significantly positive impact on ICT sector BERD as well as on economic growth and employment in the EU. The simulation results suggest that, marginal returns to public spending are only slightly diminishing (i.e. a partial achievement of the spending targets, say 75 % would result in a marginal impact per euro just above that of full achievement). This indicates that there are still substantial gains from reaching the spending target, even from a position of partial achievement. The simulation results also suggest that the level of expenditures chosen by Member States affects not only domestic growth and employment, but also the economy in other Member States. However, this cross border effect is found to be small.

The simulation exercise also shows that the strength of the policy impact can be influenced by the choice of policy instruments. The analysis considers two policy instruments; ICT R&D subsidies and ICT R&D public procurements. Results from the simulations suggest that using ICT R&D public procurement result in a comparatively higher impact on GDP and employment in the short run. However, this effect would fade with time. In the model, technological spillovers from ICT R&D public procurement do not fully compensate the lower productivity gains due to crowding out of ICT sector private R&D expenditures. In the long run R&D subsidies would thus have the most positive effects on business R&D expenditure in the ICT sector as well as on GDP and employment.

The source of finance of the public expenditures also affects the policy outcome, with distortionary effects reducing benefits. The results suggest that the financing of expenditure by means of income taxation instead of lump sum taxes adversely affects the policy outcome, in particular for the case of procurement. This is due to model assumptions concerning the negative effects of higher income taxes on labour supply. Additional work is needed to gain further insights on the sensitivity of these results to the assumptions and parameter setting used in the model.

The report is organised as follows. Chapter 2 shortly presents the model and how it can be used for policy analysis. Chapter 3 describes the set of policy scenarios examined. Chapter 4 explores the model dynamics and presents the effects of higher public spending on ICT R&D in the model. Chapter 5 contrasts and compares the impact of the different policy scenarios. Chapter 6 concludes.

[3] The DAE is one of the seven flagships initiatives under the "Europe 2020" strategy for smart, sustainable and inclusive growth, and is aimed at helping Europe's citizens and businesses to get the most out of digital technologies and to stimulate the economy (http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52010DC0245R%2801%29)

[4] The model was developed under the project *Prospective Insights on R&D in ICT (PREDICT2)*, a research project co-financed by the Directorate General for Communications Networks, Content and Technology and the JRC-IPTS. The Institute for Prospective technological Studies (IPTS) is one of seven research institutes of the European Commission's Joint Research Centre (JRC).

2. The model

The model[5] has been developed to analyse how an increase in public spending on ICT R&D affects the economy. It belongs to the family of dynamic Computable General Equilibrium Models (CGE). The CGE modelling approach attempts to reproduce the structure of the whole economy and to capture economic transactions among different types of economic agents. The present model is a multi-country, multi-sector dynamic CGE with R&D-driven endogenous growth. Indeed, the model specifically considers businesses, households, and the public sector as separate actors, and contains a set of country blocs: in this report, these consist of Germany, France, the rest of the EU (REU) and the rest of the World (RoW).[6] Germany and France have been selected because of their sizable amount of R&D spending in the EU region. Combined these two countries comprise about 49 % of the total EU BERD, 43% of Total R&D public funding and 47% of total Gross Expenditure on R&D (GERD)[7]. In this report, we report the economic impact on public ICT R&D expenditures on the EU as a whole, and on Germany and France. Results for the country bloc *Rest of the EU* are not reported separately as this consists of a very diverse group of economies with respect to their industry structure and public spending on ICT R&D.

In the model, each country bloc consists of a set of representative households which consume final goods and supply labour of a given skills level (low, medium or high) to the domestic production sectors. Each country bloc also contains a set of final goods producing sectors, homogenous capital producers, differentiated capital producers and R&D producers. The national government in each region collects taxes, pays out transfers and purchases government consumption. The EU Member States also pay contributions to the EU and receive EU transfers.

The model includes two types of R&D, R&D by the ICT sector and R&D by the non-ICT sectors. It has been designed to address some of the issues that are central to the assessment of alternative ICT R&D funding policies.

- First, the model accommodates a range of policy instruments to finance public R&D spending and contains multiple transmission channels through which this can stimulate private R&D and affect the economy.
- Second, in the model R&D output contributes to a common pool of intangible knowledge capital available to firms across sectors and countries. However, while, a firm's R&D-produced knowledge serves as a non-rival non-excludable public good benefitting all firms, the new knowledge is also sold as blueprints that provide the purchasing firm with the exclusive right to its use in production. In the model, this excludable knowledge entitles the purchasing firm to a monopoly rent that covers the initial R&D expenditures.
- Third, the model captures multiple channels through which R&D activity affects the economy, including the allocation of labour, capital and goods. Also, R&D producing firms compete for scarce resources with firms in other sectors. Hence, a change in R&D activity affects relative prices and the allocation of resources across the economy. For example, if the supply of skilled labour responds slowly to increasing demand from a growing R&D activity, this affects skilled labour wages and production costs across the economy. R&D in the model serves as an engine for growth through multiple channels. Firstly, R&D-produced

[5] The model is extensively described in two separate reports:
Christensen, M. A. (2015a). A CGE model with ICT and R&D-driven endogenous growth: A general description.
Christensen, M. A. (2015b). A CGE model with ICT and R&D-driven endogenous growth: A detailed model description.
These two reports were preceded by several preparatory studies:
Stančík J., Rohman I.K. (2014). Public ICT R&D funding in the European Union.
Szewczyk W., Stančík J., Christensen M. A. (2014). Investigation of ICT Firms' Decisions on R&D Investment.
Szewczyk W., Sabadash A. (2012). Macroeconomic Modelling of Public R&D Expenditures on ICT
Stančík J. (2012). A Methodology for Estimating Public ICT R&D Expenditures in the EU.
All reports are available at: http://is.jrc.ec.europa.eu/pages/ISG/PREDICTreports.html

[6] An extension could consider separately several other Member States.

[7] JRC-IPTS. (2015). THE 2015 PREDICT Report: An Analysis of ICT R&D in the EU and Beyond.

knowledge expands the common pool of knowledge, which spills over into increased productivity in R&D production as firms' benefit from the production of new knowledge and insights. Secondly, R&D leads to the development of new designs or blueprints, expanding the range of available production technologies. This is the case for ICT and for non-ICT production technologies. Thirdly, ICT technology in the model is a multipurpose technology, widely adopted across the economy in combination with skilled labour. Hence, an R&D-induced increase in new ICT technologies affects the production of goods and services across a broad range of sectors in the economy.

The model is calibrated to replicate a given reference year (2007) and a specified reference growth path. The elasticities of substitution in the model are set to reflect estimates in the literature. Parameters governing spill-over effects from accumulation of knowledge to R&D production in the ICT sector and other sectors are set at levels compatible to estimates reported in Coe et al. (2008).

A more detailed non-technical presentation of the model can be found in Christensen (2015a) while a more technical presentation of the model can be found in Christensen (2015b).

A strength of the CGE modelling approach is that it allows for flexibility in building the policy scenario one wishes to examine. Having defined the policy objective the choice of policy scenario can be presented, by analogy, as a 3 dimensional Rubik's cube, where one chooses as input the policy specifications along the following 3 dimensions:

- Dimension 1: Expenditure. The model allows specifying how much money is allocated to the policy. Most relations in the model are non-linear, hence, doubling the money spent on a policy does not necessarily double the policy outcome.
- Dimension 2: Policy instruments. One can specify which policy instruments to use to fulfil the policy objectives. Different policy instruments work through different channels in the economy and may largely influence how successful the policy is in reaching the desired objective. The model allows us to examine a large range of policy instruments including general subsidies, tax credits, public procurement and subsidies targeted at employment.
- Dimension 3: Sources of finance. It can be decided how the public expenditure for the chosen policy is financed. Choices on resource allocation include reducing other expenditures (e.g. public consumption or public transfers), increasing fiscal revenues (e.g. income or, value added tax) or public borrowing (this corresponding to an inter-temporal shift of future public expenditures to now). One needs to be aware that a given policy action carry opportunity costs in the form of foregone alternative use of the resource allocated to the policy.

In addition the choice of policy scenario involves a decision on the timing of the policy. Should the policy change be introduced immediately in one single step or gradually phased in over time.

The policy scenario may also cover multiple country blocs in the model at the same time. One may vary the policy choice per country blocs to illustrate varying policy priorities across EU Member States.

3. Selection of policy scenarios

In this report we examine the economic impact of the European Commission policy objectives of increasing public spending by EU Member States on ICT R&D. Taking outset in the DAE policy action we build a set of alternative policy scenarios. These policy scenarios vary with respect to expenditures allocated to the policy, policy instruments and sources of financing.[8]

The DAE, in its R&D-related pillar, expects Member States to double their annual public spending on ICT research and development. In Action 55, the DAE states that EU Member States should, by 2020, double annual total public spending on ICT R&D from € 5.5 billion to € 11 billion (which include EU programmes).[9] The notion is that this should leverage an increase in private R&D spending and contribute to sustainable growth.

Analysis of public spending on ICT R&D by EU Member States shows that Member States still have a way to go to reach the DAE target of doubling public spending on ICT R&D. Assuming a unified growth rate in national public spending[10] on ICT R&D, the difference between the compound growths rates (estimated and target) increased from only 1.2% in 2008 to 25.2% in 2013. At levels, the EU should have achieved €7.6 billion in 2013 while the actual spending only amounts to €6.2 billion. (see Rohman (2015)). In addition the gap between the spending target and actual spending varies greatly amongst the EU Member States. For example the ICT R&D public spending in 2013 was 41% below the target in France, 17% below target in Germany, 14% below target in the UK, and 24% above target in Sweden.

Having knowledge of this situation, we now elaborate the scenarios that will be submitted to the model.

- In this report, we consider **three alternative developments in public spending** on ICT R&D. In the first, we assume that public spending on ICT R&D in all EU Member States amounts to 75 % of the spending target in 2020. In the second, we assume that the public spending target on ICT R&D is reached in Germany by 2020 while ICT R&D public spending make up 75 % of the target in all other EU Member States. We choose Germany as this is the country block with public spending closest to the DAE target in 2013. In the third we assume that the DAE spending target is reached by 2020. Hence, public spending on ICT R&D doubles from 2007 to 2020 in all EU Member States.

  For the timing of the policy it is assumed that the public spending on ICT R&D increases at a constant growth rate from 2007 to 2020. After 2020 the public expenditures are assumed to grow at the model long term trend rate.

- Action 55 in the DAE mentions a number of policy instruments that could be used to increase public spending on ICT R&D. These include research grants, tax credits, public support to universities and pre-commercial procurement of ICT R&D[11]. In this report we consider **two different policy instruments**. Firstly we consider the use of a general ad valorem subsid to the ICT R&D sector. This policy instrument targets the market price of R&D output. Secondly, we examine a policy of pre-commercial procurement of ICT R&D. This policy instrument targets the demand for ICT R&D.

[8] The selection has been discussed with DG CNECT representatives as to target a set of feasible and policy most relevant scenarios.

[9] These figures are estimations based on the methodology proposed in Stančík J., Rohman I.K. (2014) to compute by industry (NACE) shares of Government Budget Appropriations or Outlays on R&D (GBAORD), starting from data available according to the NABS classification (Nomenclature for the Analysis and comparison of Scientific programmes and Budget). This methodology has also been used to produce the input data used for the simulations.

[10] The DAE specifies that public ICT R&D expenditures should double over the period 2007-2020. It does not, however, specify a rate of progress over time. Therefore, Stancik and Rohman (2014) assigned in the analysis a uniform progress rate: a 5.48% annual growth rate.

[11] Pre-Commercial Procurement (PCP) is the procurement of research and development of new innovative solutions before they are commercially available.

- Finally, we consider **two alternative ways to finance the policy**. One consists in allowing the policy to be fully financed by an increase in lump sum taxes paid by households to governments. The national governments each year increase the lump sum payments by non-liquidity constrained households, such that the primary budget balance is unaffected by the policy change. Financing the policy by the use of a lump sum taxes in the model generate minimal distortionary effects and allows examining the economic effects of increased public expenditures on ICT R&D in a nearly neutral context. In the second alternative, the policy action is assumed to be fully financed by an increase in income taxes. The national government adjust each year the income tax rates of all employees such that the primary budget balance is unaffected by the policy change. All household types are subject to identical percentage point changes in their income tax rate. This introduces distortionary effects that will affect labour supply and relative prices within the economy.

The chosen policy specifications provide us with a total of 12 alternative policy scenarios, which can be aggregated into four groups based on the policy instrument and the source of financing (Table 1). Comparing scenarios within a group allow us to examine effects of changing expenditure levels holding policy instruments and sources of financing constant. For example, comparing scenario 1 to scenario 2 allows us to examine the effects of higher public spending in Germany (holding policy instrument and financing constant). Comparisons of scenarios between groups allow us to examine the effects of policy instrument or sources of financing. For example, comparing scenario 1 in group 1 to scenario 4 in group 2 allow us to examine the effects of varying the policy instrument (holding expenditure and financing constant). All 12 policy scenario have been simulated with the model and compared to a reference scenario, in which no policy changes are introduced and public expenditure on ICT R&D is assumed to make up a constant proportion of GDP[12].

Table 1: Policy scenarios examined

		Expenditure	Policy instruments	Financing
Group 1	Scenario 1	Spending target reached 75 pct. in all member states	R&D subsidies	Lump sum taxes
	Scenario 2	Spending target reached 100 pct. in Germany Spending target reached 75 pct. in other member states	R&D subsidies	Lump sum taxes
	Scenario 3	Spending target reached 100 pct. in all member states	R&D subsidies	Lump sum taxes
Group 2	Scenario 4	Spending target reached 75 pct. in all member states	Public procurements	Lump sum taxes
	Scenario 5	Spending target reached 100 pct. in Germany Spending target reached 75 pct. in other member states	Public procurements	Lump sum taxes
	Scenario 6	Spending target reached 100 pct. in all member states	Public procurements	Lump sum taxes
Group 3	Scenario 7	Spending target reached 75 pct. in all member states	R&D subsidies	Income tax rates
	Scenario 8	Spending target reached 100 pct. in Germany Spending target reached 75 pct. in other member states	R&D subsidies	Income tax rates
	Scenario 9	Spending target reached 100 pct. in all member states	R&D subsidies	Income tax rates
Group 4	Scenario 10	Spending target reached 75 pct. in all member states	Public procurements	Income tax rates
	Scenario 11	Spending target reached 100 pct. in Germany Spending target reached 75 pct. in other member states	Public procurements	Income tax rates
	Scenario 12	Spending target reached 100 pct. in all member states	Public procurements	Income tax rates

12 In the reference scenario we assume that public expenditures on ICT R&D grow at the same nominal rate as GDP. Hence, public expenditures as a proportion of GDP will remain as they were in 2007. This is the reference which this model release is calibrated to replicate. The model is calibrated to a dataset constructed from GTAP, national account data, OECD data and the PREDICT database. The reference year is 2007 as this corresponded to the latest available GTAP dataset, at the time of calibration of this model release. A description of the model calibration can be found in Christensen (2015b).

Chapter 4 is dedicated to a full presentation of the economic impacts that would result from reaching the spending target in all Member States: it consists in doubling of public expenditures in all Member States by 2020, as expected by the DAE policy (scenario 3). Chapter 5 contrasts and compares the impact of different policy scenarios

4. Impact of higher public ICT R&D spending

In this chapter, we explore the model dynamics by considering in detail the results of scenario 3, in which all EU Member States double public spending on ICT R&D from 2007 to 2020. The additional public expenditure is given as a general ad valorem subsidy to the ICT sector R&D and is financed by an increase in public lump sum taxes paid by the non-liquidity constrained households[13]. We choose scenario 3 to illustrate the impact of higher public spending for the following reasons. Firstly, in scenario 3 we assume that the DAE spending target is reached by all Member States. This scenario, hence, gives an indication of the potential benefits from fulfilling the policy objectives set out in DAE. Secondly, the public expenditures in scenario 3 is financed by lump sum taxes which allows us to examine the potential effects of increasing public spending in a near neutral context. We consider the economic impact on the EU as a whole, and on Germany and France. Results for the country bloc *Rest of the EU* are not reported as this consists of a very diverse group of economies with respect to their industry structure and public spending on ICT R&D.

The public expenditure on ICT R&D by the EU Member States was 5.3 billion € in 2007. This corresponds to 0.043 % of EU GDP.[14] The public spending on ICT R&D varies between the EU Member States. In 2007 the public spending on ICT R&D was 0.044 % of GDP in Germany and 0.037 % of GDP in France.[15] In scenario 3 we assume that the public expenditure on ICT R&D doubles by 2020. The full increase in public expenditures is given in the form of a general ad valorem subsidy to R&D providers in the ICT sector.

The model contains various transmission channels that affect the economic impacts of a given policy. In the remaining of this chapter we systematically analyse the impacts of the policy on:

1. ICT sector business R&D expenditures
2. GDP and macroeconomic aggregates
3. Production in the manufacturing sectors
4. Employment
5. Foreign trade
6. Private consumption.

4.1. *Impact on ICT sector business R&D expenditures*

Higher public subsidies to ICT R&D reduce the relative price of ICT R&D output and thereby reduce the cost of developing and introducing new production technologies in the economy. In the model this takes the form of new ICT capital varieties. The additional ICT R&D subsidies spur an increase in ICT R&D expenditures that leads to an increase in the accumulated knowledge stock. In the model a higher stock of knowledge in turn increases productivity of the domestic ICT R&D producers and spills over into productivity increases by other R&D producers. The spill-over occurs both between sectors and across-borders.

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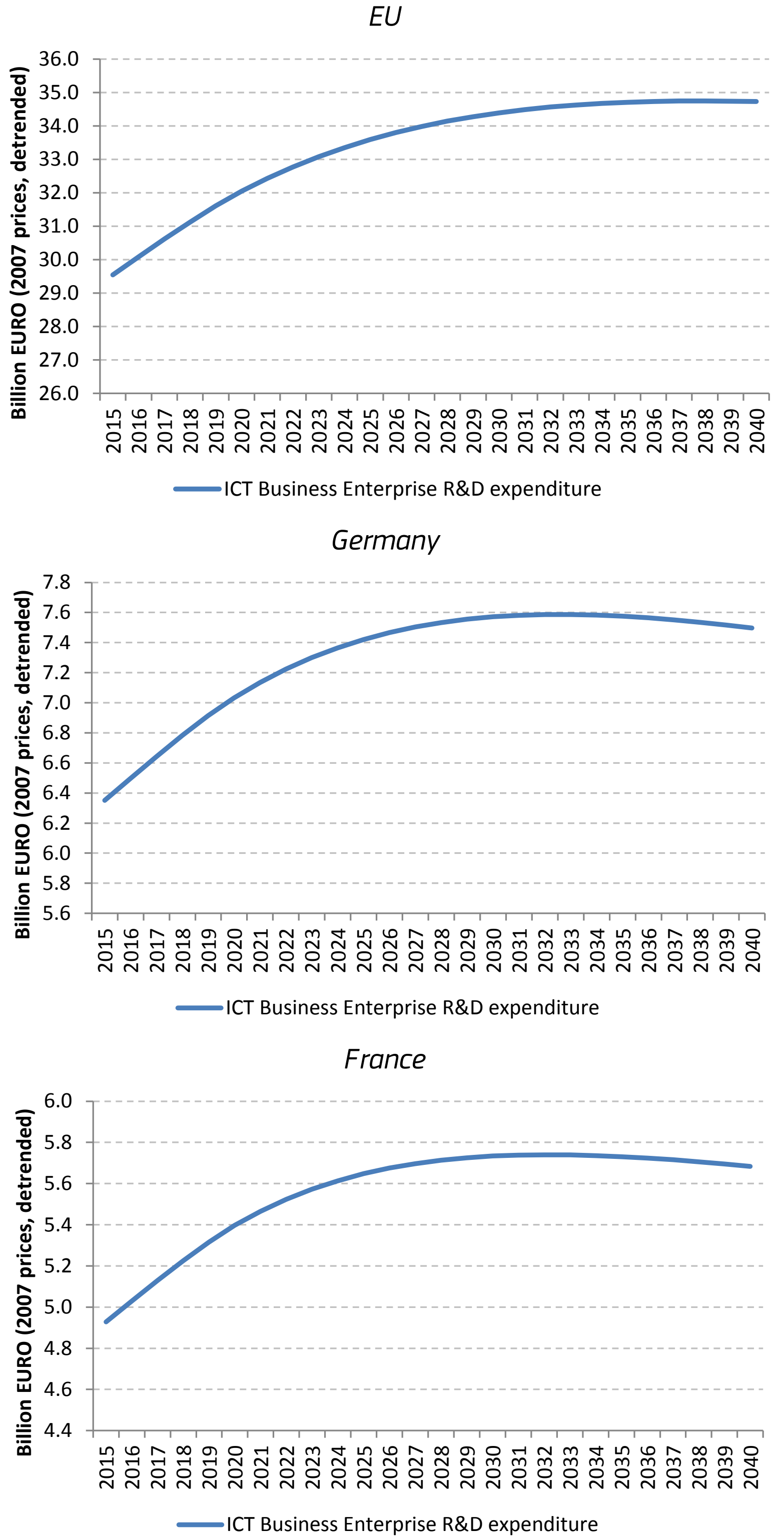
[13] Our analysis defines public expenditures on ICT R&D as those given to the ICT sector. In practice a part of public expenditures to ICT R&D is given to ICT R&D projects that take place in other sector than the ICT sector. A lack of quality data on public ICT R&D expenditure to projects outside the ICT sector means that the model has been calibrated to R&D expenditures by sector definitions (rather than by function). One could thus allocate part of the public expenditure as subsidies to R&D in the non-ICT sector. However, in this analysis all additional public spending on ICT R&D is given to the ICT sector, since the non-ICT sector cover a very broad and diverse selection of R&D projects.

[14] Estimates on public expenditure on ICT R&D have been revised sine the release of the model version used in this study. Public expenditure on ICT R&D by member states in 2007 was estimated at 5.5 billion € (or 0.44 % of GDP). The values for public expenditures used for the calibration of the model are 5.33 billion € for the EU, 1.07 billion € for Germany and 0.70 € Billion for France.

[15] The estimated share of ICT GBAORD for France is smaller due to missing data in two NABS chapters (Education and Culture). See detail in Stancik and Rohman (2014).

Figure 1 shows ICT sector Business Enterprise R&D (BERD) expenditure in scenario 3. R&D expenditure is shown in 2007 prices and the series has been de-trended, so that an increase equivalent to the model long term trend growth rate of 1.64 % p.a. would correspond to a horizontal line. Higher ICT R&D subsidies lead to a gradual and prolonged increase in ICT sector BERD. The ICT sector BERD still grows at a rate higher than the trend growth rate more than 10 years after the public subsidy expenditures is again growing at the model's trend growth rate.

Figure 1: Evolution of ICT sector BERD, 2007 prices (scenario 3)



The increased public subsidies to ICT R&D lead to an increase in the EU ICT sector's BERD expenditure of 7.3 billion € (in 2007 prices) by 2020 rising to 14.8 billion € (in 2007 prices) by 2040. In 2040, the ICT sector's BERD expenditure increases by 3.4 billion € in Germany and by 2.2 billion € in France.

The higher ICT R&D subsidies lead to modest fall in the BERD expenditures by non-ICT sectors of the economy. Non-ICT sector BERD in the EU is 0.1 Billion € (2007 prices) lower in 2020 and 0.2 Billion € lower in 2040 compared to the reference scenario.

Figure 2: Impact of policy on ICT sector BERD, per public EURO spent on ICT R&D funding (scenario 3)

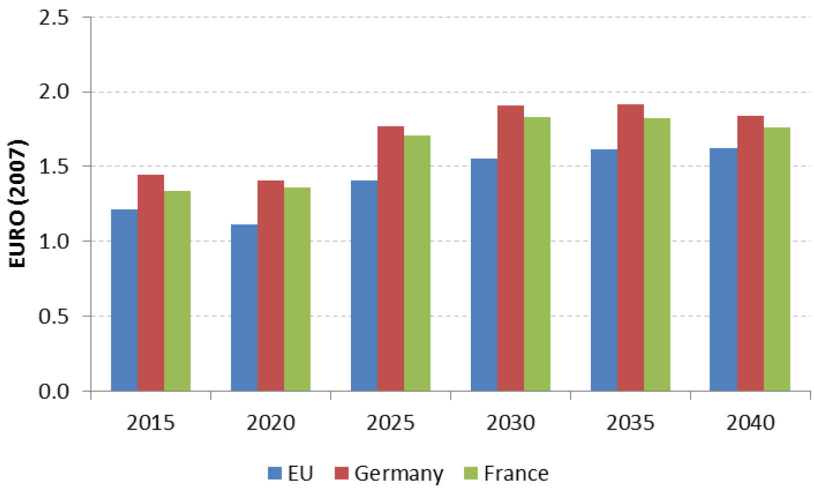


Figure 2 shows the impact on ICT sector BERD expenditure per Euro spent on public ICT R&D subsidy. The impact of ICT R&D subsidies increases gradually. In 2020 each extra Euro allocated to ICT R&D subsidy within the EU leads to an increase in ICT sector BERD expenditure of 1.1 € (2007 prices). In 2040 each extra Euro allocated to ICT R&D subsidy within the EU leads to an increase in ICT sector BERD expenditure of 1.6 € (2007 prices). The impact of doubling ICT R&D subsidies varies across Member States. The impact of ICT R&D subsidies is higher in Germany and France than in the EU as a whole. Each additional Euro allocated to public subsidies to ICT R&D raises ICT sector BERD expenditures in 2040 by 1.8 € in Germany and by a similar magnitude in France.

4.2 Impact on GDP and macroeconomic aggregates

The doubling of public expenditures to ICT R&D results in a sustained increase in ICT sector BERD. In turn the higher public ICT R&D expenditure gradually spurs the introduction of new ICT technologies and an expanding spectrum of ICT capital. This allows firms to produce more from a given amount of factor inputs. Because ICT is a general propose technology the introduction of new ICT technologies improves productivity across all manufacturing sectors in the economy. The extent to which productivity increases in a given sector depends on the intensity by which ICT is used in production.[16]

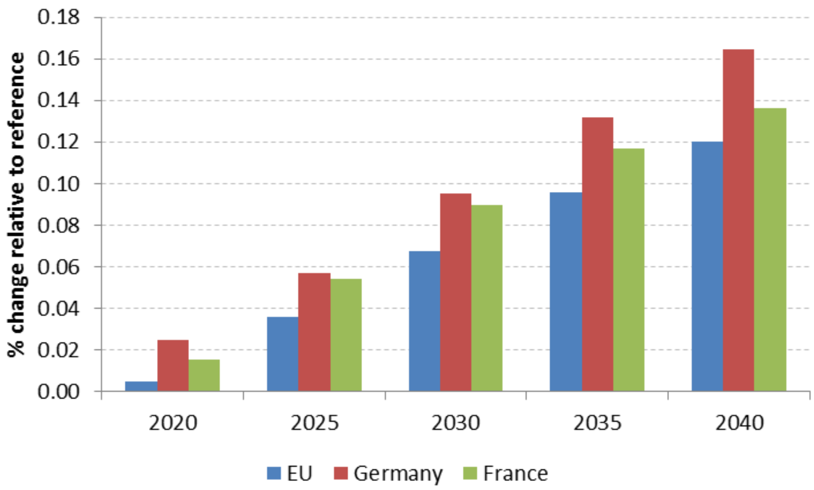
The increases in GDP as a result of the higher public subsidies to ICT R&D are shown in figure 3. The higher ICT R&D subsidies lead to a gradual increase in GDP relative to the reference scenario.[17] The EU GDP is only marginally higher than in the reference scenario in 2020, but is 0.12 % higher in 2040. This corresponds to an increase in EU GDP measured in 2007 prices of 0.7 billion € by

[16] The intensity to which ICT is used in production by the different sectors in the model follows the composition of material and factor inputs used by the sector in the base year to which the model is calibrated.

[17] The reference scenario describes the situation in which no policy changes have been introduced. In this scenario public expenditure on ICT R&D is assumed to make up a constant proportion of GDP.

2020, and 25.6 billion € by 2040. Doubling of ICT R&D subsidies leads to higher GDP increases in Germany and France than in the EU. By 2040 GDP is 0.17% higher in Germany and 0.14% higher in Fance, relative to the reference scenario.

Figure 3: Change in GDP relative to the reference scenario (scenario 3)



The change in GDP can be decomposed into macroeconomic aggregates as shown in figure 4. The higher public subsidies to ICT R&D gradually increase ICT R&D relative to the reference scenario and this contributes the most to the higher GDP. In 2040 the contribution of ICT R&D to the change in GDP is 0.07 percentage point. Private consumption also gradually increases relative to the reference scenario as households benefit from higher income due to productivity increases. Public consumption rises in proportion to GDP. Hence, in the long run the contribution from domestic consumption makes GDP higher. In 2040 the contribution from domestic consumption within the EU to the change in GDP is 0.06 percentage point.

The EU net exports contribute negatively to the change in GDP. The negative net export is mainly due to the following effects. Firstly, the increase in domestic activity pushes up the price of EU goods relative to the RoW, which reduces export demand and at the same time shifts domestic demand towards imports.[18] Secondly, the ICT R&D contains a relative high share of material inputs imported from the RoW. Private consumption also has a relatively high import share. Increases in ICT R&D and private consumption, therefore, lead to a rise in the demand for imported goods relative to the reference scenario. These two effects combined worsen the EU trade balance initially. In 2020 the contribution from net export to the change in EU GDP is 0.04 percentage point. Higher productivity due to expanding ICT varieties gradually raises exports and improves the trade balance. In 2040 the contribution from EU net export to the change in GDP is still negative but very small. However, the contribution from EU net export to the change in GDP becomes positive from 2043 and onwards. In Germany and France the GDP increase is also mainly driven by higher ICT R&D activity and higher domestic demand. Net exports in both countries initially contribute negative to GDP but the contribution of net export has become positive by 2040.

The impact of public expenditures to ICT R&D can also be illustrated by the development in value added. Figure 5 shows the development in value added decomposed into the contribution from the ICT sector (R&D and manufacturing) and non-ICT sectors of the economy.

[18] The extent to which net export changes in response to price change in domestic goods relative to RoW depends on the price elasticities for foreign trade. Trade elasticties are normally found to be higher in the long term than in the short term. Parameters for trade elasticities in the current model release are assumed to be constant in all time period. Hence, the model probably overshoots short run adjustments to foreign trade. Further work will be done to examine the sensitivity of results to assumption about trade elasticities.

The doubling of public expenditures to ICT R&D through subsidies results in a gradual increase in total value added relative to the reference scenario. In 2020 total value added in the EU is 0.01% higher than in the reference scenario. In 2040 it is 0.13% higher. A large part of the rise in total value added can be contributed to the ICT sector. In 2020 the contribution from the ICT sector to total value added in the EU is 0.03 percentage point. This is mainly due to higher R&D activity. The value added of the ICT sector gradually increases and contribute 0.05 percentage point to the change in total value added in 2040. The long term rise in value added of the ICT sector is driven by productivity increases in R&D production due to knowledge accumulation and to introduction of new production technologies in manufacturing of ICT goods and services. The other sectors of the economy contribute negatively to the change in total EU value added in 2020 (-0.03 percentage point). This is driven by the fall in net exports and the migration of production factors towards the ICT sector (especially to R&D production). However, as the introduction of new ICT production technologies spreads to the other sectors of the economy the value added rises[19]. The non-ICT sectors, thus, contribute 0.08 percentage point to the change in total value added in the EU in 2040. This is mainly driven by a rise in value added in the service sector.

A similar impact on value added to that of the EU as a whole can be seen in Germany and France. However, the rise in total value added is higher in these two countries. In 2020 total value added is 0.02% higher than the reference scenario in Germany, and in France. In 2040 total value added in Germany and France is 0.17% and 0.14% higher than the reference scenario respectively.

[19] The knowledge accumulation from ICT R&D also spreads into R&D in other sectors raising productivity of non-ICT R&D production. This in turn leads to introduction of new non-ICT production technologies.

Figure 4: Change in GDP decomposed into macroeconomic aggregates (scenario 3)

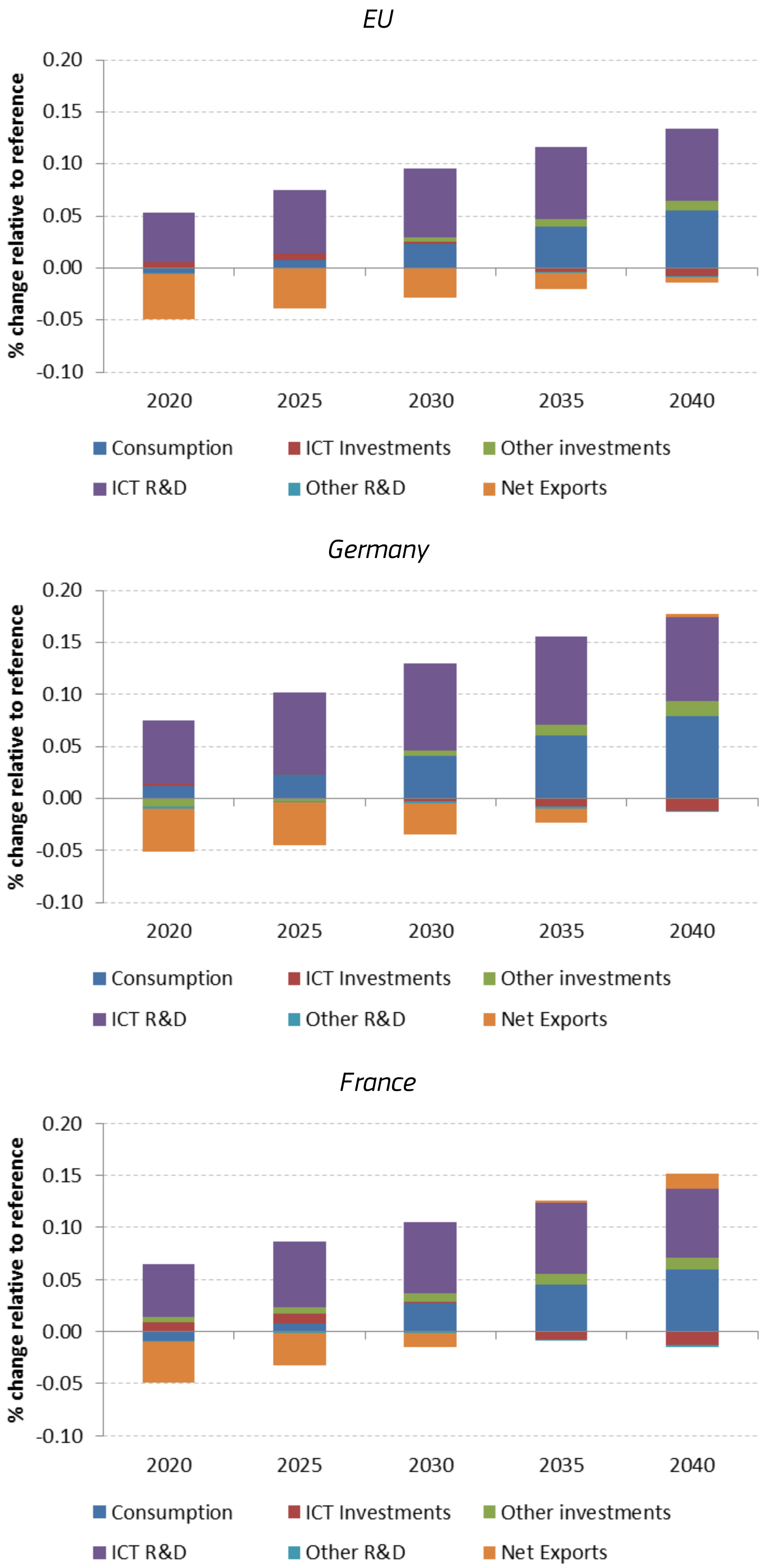


Figure 5: Change in value added decomposed into ICT on non-ICT sectors (scenario 3)

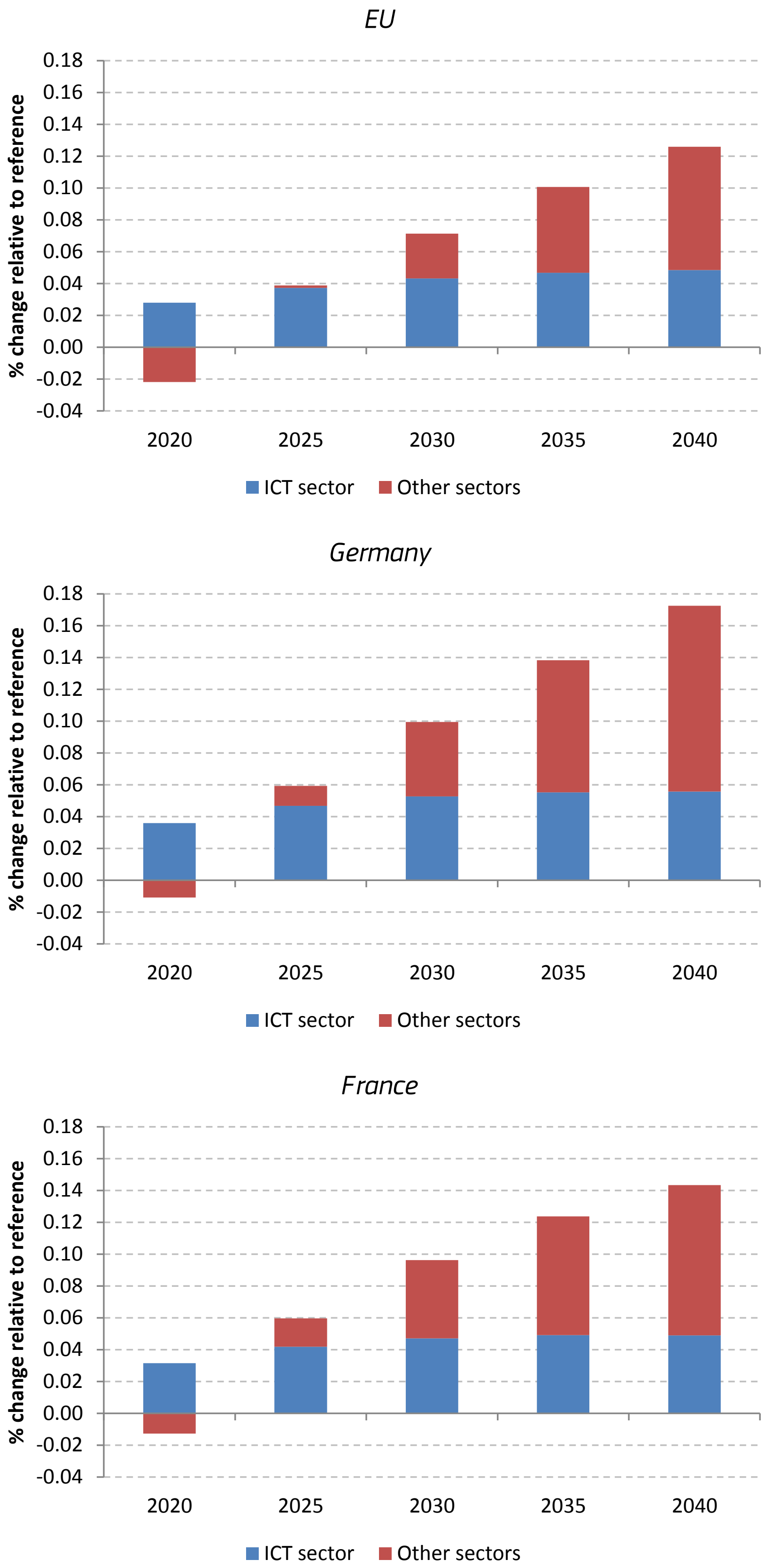
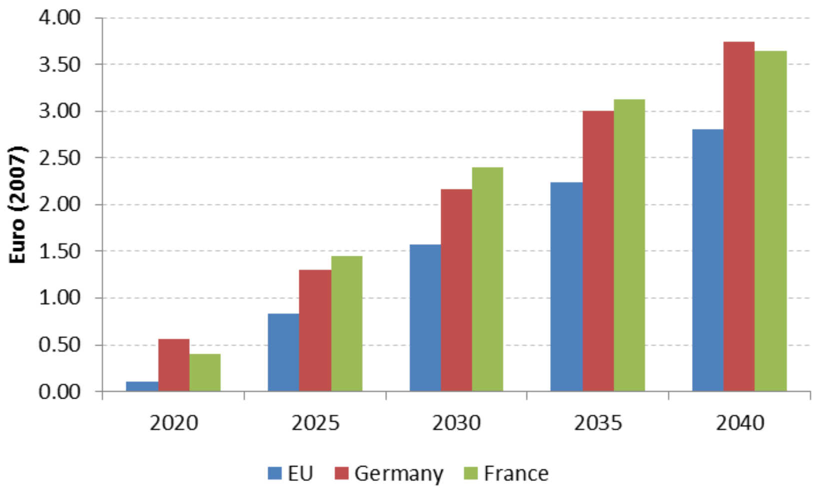


Figure 6 shows the impact on GDP per additional Euro allocated to ICT R&D subsidies. Higher ICT R&D subsidies increase ICT R&D activity, this expands the spectrum of ICT production technologies and raises productivity, and this in turn leads to higher GDP. Hence, by 2040 each extra Euro annually allocated to public ICT R&D within the EU leads to an increase in GDP of 2.8 € (2007 prices). The impact of the policy varies across Member States. Each additional Euro allocated to public ICT R&D subsidies raises GDP by 3.75 € in Germany and by 3.65 € in France in 2040.

Figure 6: Impact of policy on GDP per public EURO spend on ICT R&D (scenario 3)



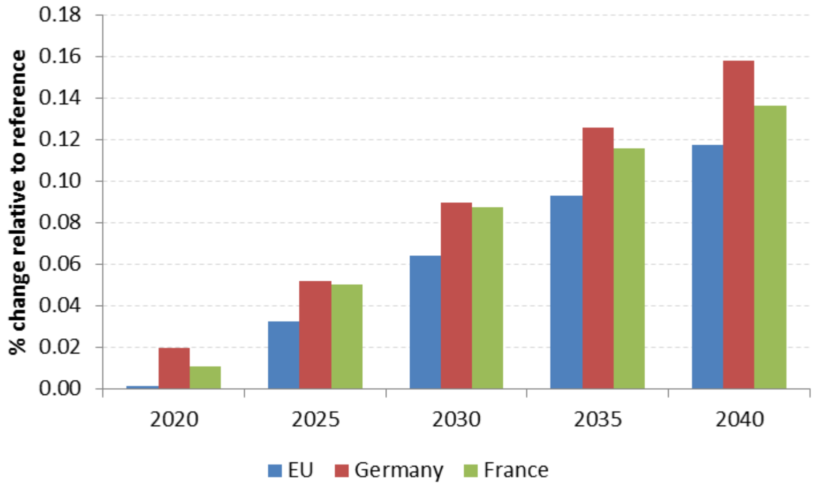
4.3 Impact on production in the manufacturing sectors

The increase in ICT R&D subsidies leads to a rise in R&D production by the ICT sector. The change in R&D output also affects the production by other sectors in the economy. Figure 7 show the change in total output (including R&D and manufacturing of goods and services) relative to the reference scenario. In 2020 EU total output increases only marginally as a result of the additional ICT R&D subsidies. However, the policy brings about significant changes in output by the different sectors of the EU economy. The higher R&D activity in the ICT sector makes production factors migrate from other sectors to the ICT sector. The allocation of production factors also gives rise to some friction due to adjustment costs in the model. This brings about costs in the form of foregone output. Changes in R&D activity in the ICT sector also leads to a shift in demand for domestically produced and imported material inputs. This affects relative prices of manufactured goods and services and the composition of domestic outputs across sectors.

In the long term the higher R&D production leads to the introduction of new ICT production technologies and more intensive ICT use by the manufacturing sectors. This leads to a rise in total production. In 2040 the EU total output is 0.12% higher than in the reference scenario.

Figure 8 shows the change in manufacturing output of goods and services (excl. R&D production) relative to the reference scenario. The higher R&D activity in the EU ICT sector initially crowds out production by other sectors within the EU. In 2020 manufacturing output of goods and services is 0.02% lower than in the reference scenario. The change in manufacturing output can be decomposed into types of goods and services, as shown in Figure 9. The change in output can largely be attributed to lower production of high tech goods, and low tech goods. In the long term manufacturing output becomes higher than in the reference scenario. In 2040 manufacturing output is 0.08% higher than in the reference scenario. Most of the increase (0.05 percentage point) is due to higher output of services.

Figure 7: Change in total production relative to the reference scenario (scenario 3)



We may also consider changes in total output by individual EU Member States in the model. Total output in Germany and France in 2020 is respectively 0.02 and 0.01% higher than in the reference scenario as a result of the additional subsidies to ICT R&D. In 2040 the total output in Germany and France is respectively 0.16% and 0.14% higher than the reference scenario. Hence, production increases relative more in Germany and France than in the EU as a whole. The higher R&D activity in the ICT sector initially crowds out production of goods and services. In 2020 manufacturing output of goods and services (excluding R&D production) is 0.01% lower in Germany and 0.02% lower in France. The initial lower manufacturing output can in both countries largely be attributed to lower production of high tech goods. In 2040 manufacturing output is 0.12% higher in Germany and 0.10% higher in France relative to the reference scenario. The increase can mainly be contributed to higher output of services.

Figure 8: Change in manufacturing production relative to the reference scenario (scenario 3)

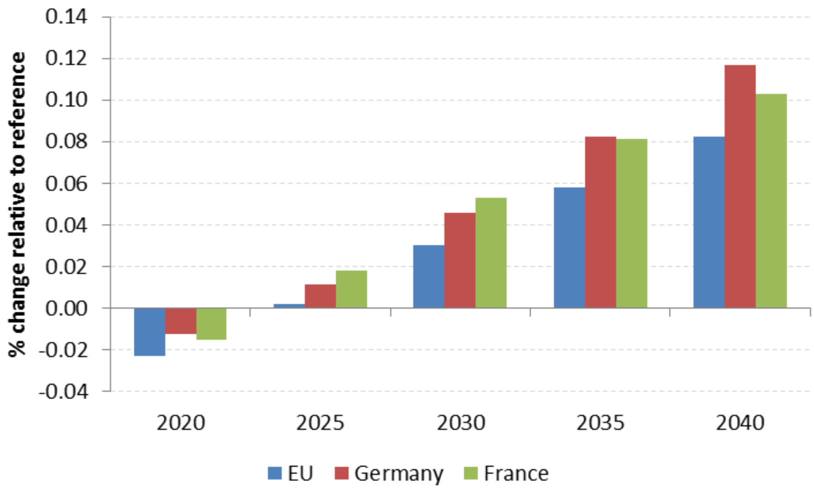
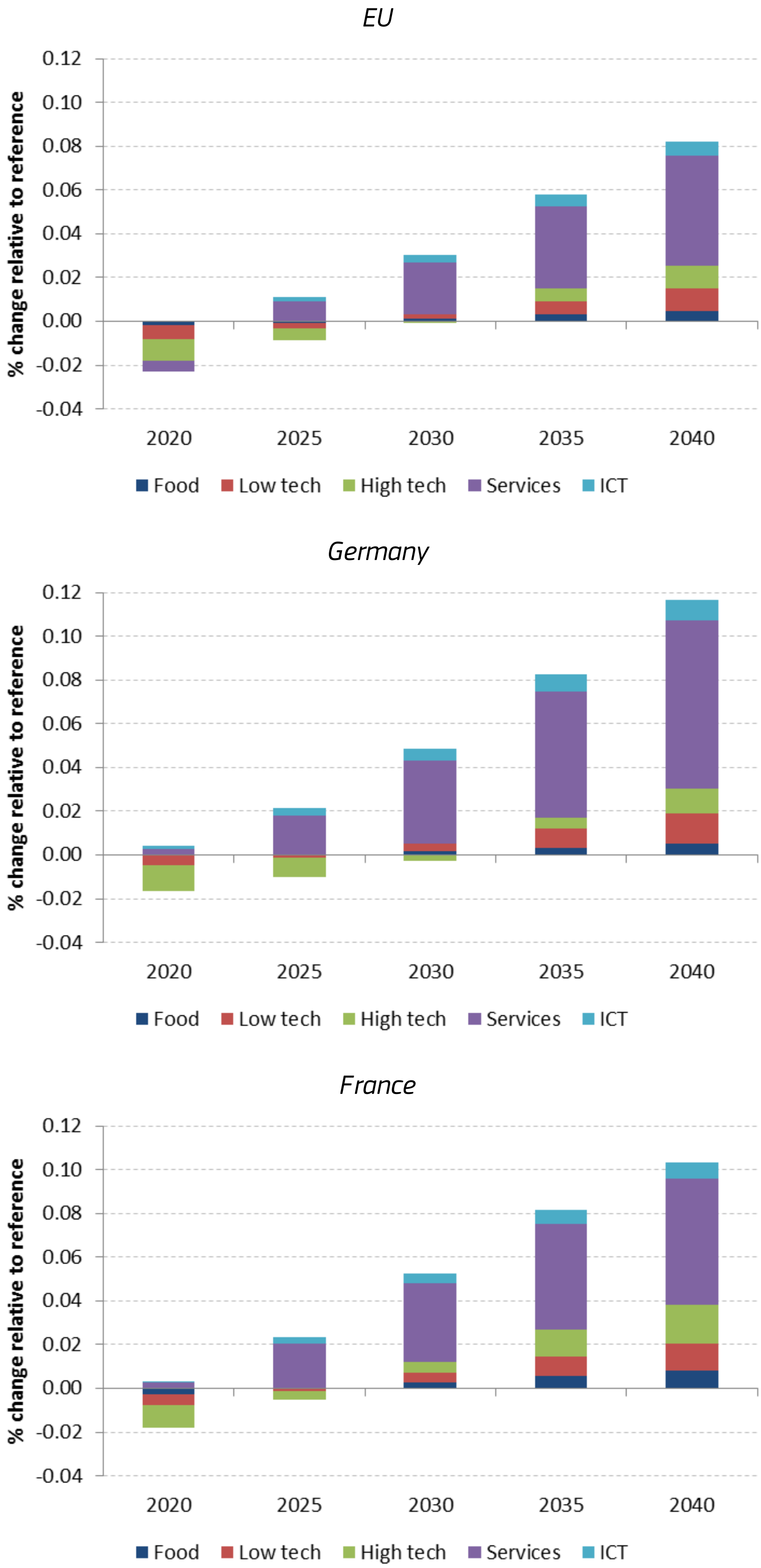


Figure 9: Change in manufacturing production decomposed by types of commodity (scenario 3)



4.4 Impact on employment

Doubling of ICT R&D subsidies also affects the labour market. Total EU employment increases by 22,000 full-time-equivalent persons in 2020 and by 148,000 full-time-equivalent persons in 2040. Figure 10 shows changes in employment by skills level. The rise in employment is mainly driven by an increase in employment of high skilled labour. Employment of high skilled labour in the EU increases by 3,100 full-time-equivalent persons in 2020 and by 111,000 full-time-equivalent persons in 2040. Employment of low skilled labour in the EU increases by 5,400 full-time-equivalent persons in 2020 and by 2,700 full-time-equivalent persons in 2040. Employment of medium skilled labour in the EU increases by 13,400 full-time-equivalent persons in 2020 and by 34,200 full-time-equivalent persons in 2040. The shift in employment towards high skilled labour is mainly driven by three developments. Firstly, a structural shift in the economy, secondly, substitution between labour types as a result of more intensive ICT use in production, and, thirdly an increase in productivity of high skilled labour employed in R&D production as a result of a higher stock of accumulated R&D knowledge.

Let us first examine the effects of structural shifts in the economy. Figure 11 shows the change in total employment by different production sectors in the economy.[20] The largest contribution to the change in employment is caused by ICT sector R&D, production of other services and manufacturing of ICT goods and services. These three activities lead to increases in employment of respectively 73,800 full-time-equivalent persons, 60,500 full-time-equivalent persons and 7,300 full-time-equivalent persons in 2040. In the model these three sectors are characterised by the most intensive use of high skilled labour within the EU and the least intensive use of low skilled labour. Hence, the shift in employment towards ICT sector R&D, other services and manufacturing of ICT goods and services, leads to a large increase in high skilled employment and a more modest increase in low skilled employment.

We may also examine the effects of substitution between labour types. The higher R&D activity by the ICT sector leads to the introduction of new ICT production technologies and to a more intensive use of ICT capital in production of goods and services. ICT capital in the model is operated by high skilled labour. Hence, the more intensive use of ICT in production brings about a substitution of employment from low and medium skilled labour to high skilled labour. For example, in 2040 high skilled employment in the EU service sector increases by 80,400 full-time-equivalent persons, while medium skilled employment declines by 7,400 full-time persons and low skilled employment decline by 12,500 full-time-equivalent persons.

Finally, the higher stock of accumulated knowledge due to increased ICT R&D activity raises productivity of high skilled labour employed in the R&D production. In 2040 the productivity of high skilled labour employed in ICT R&D production is 2.0% higher than in the reference scenario.

These three effects combined raise the total demand for high skilled labour and drive up wages. As a result labour supply of high skilled labour increases.

Employment in Germany and France are subject to the same effects as the EU total. In 2040 high skilled employment in Germany increases by 29,900 full-time persons, medium skilled employment increases by 11,000 full-time-equivalent persons, and low skilled employment increases by 1,700 full-time-equivalent persons. In France high skilled employment increases by 17,400 full-time-equivalent persons and medium skilled employment increases by 3,600 full-time-equivalent persons in 2040. Low skilled employment in France in 2040 is 300 full-time-equivalent persons lower than the reference scenario. This decline in low skilled employment is caused by two effects. Firstly, employment of low skilled labour decline as a result of a shift in production towards sectors with less intensive use of low skilled labour. Secondly, employment of low skilled labour falls as a result of ICT driven substitution towards high skilled labour. These two effects dominate the extra labour demand for low skilled labour due to higher total output.

[20] Note that we distinguish between production of ICT goods and services and ICT sector R&D.

Figure 10: Change in employment by types of skills (scenario 3)

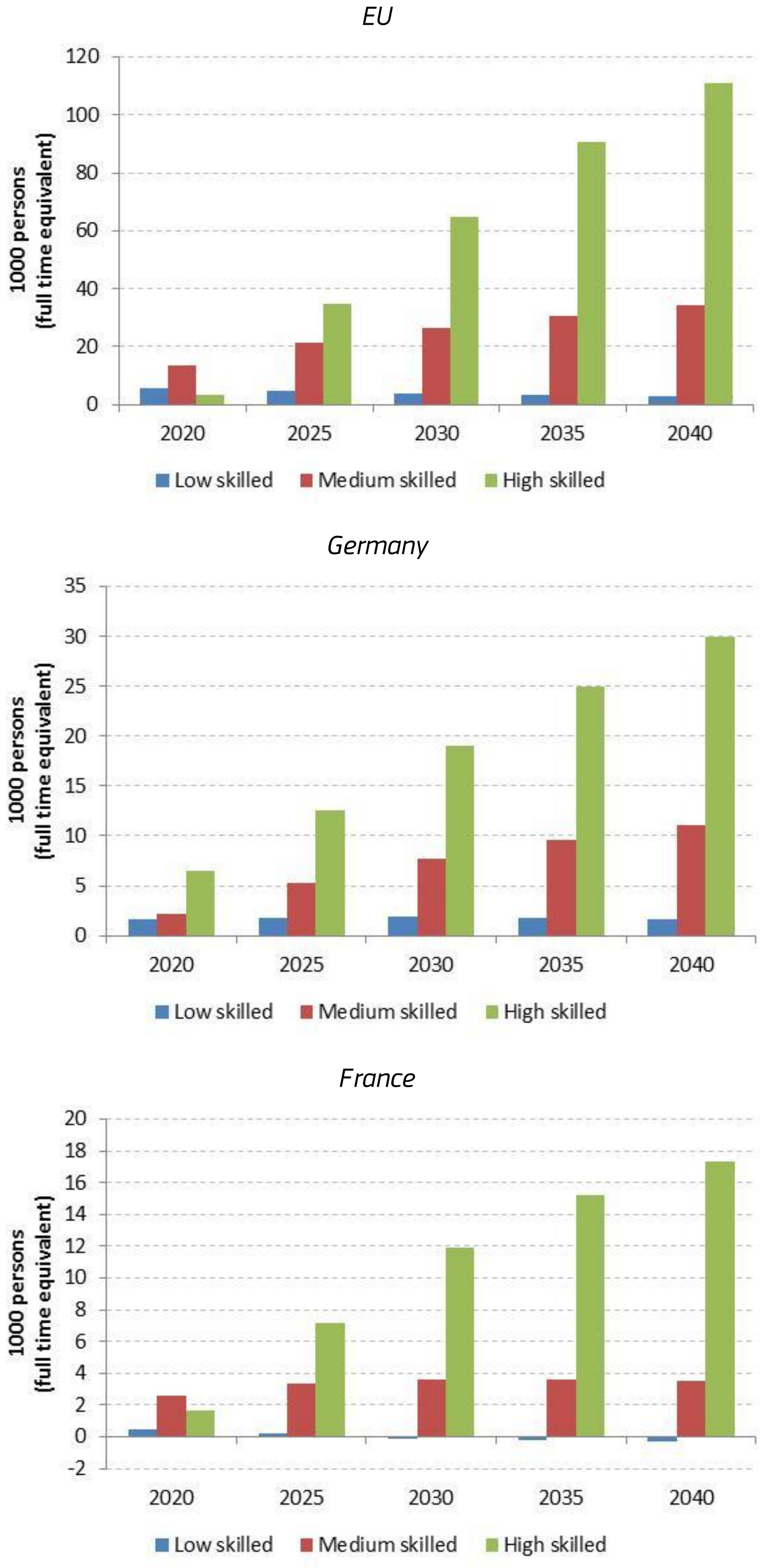
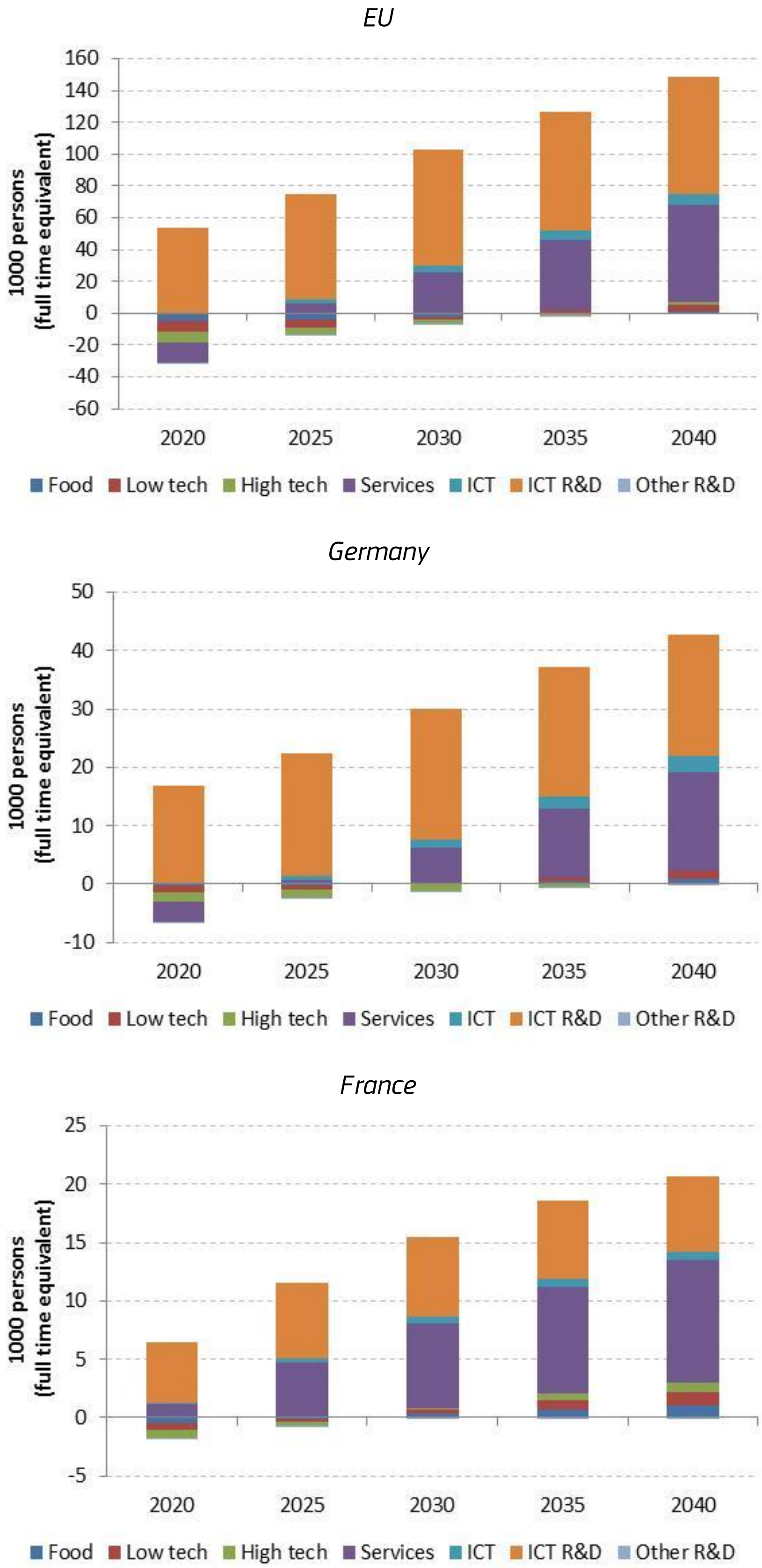


Figure 11: Change in employment by sector (scenario 3)



Examining the changes in employment due to policy changes one had to bear in mind that the model does not include endogenous changes in the skills composition of the work force driven by e.g. unemployment or wage differentials. In the model the proportion of say high skilled labour is exogenous given, while the households at the margin decide how many hours to work[21].

4.5 Impact on foreign trade

As discussed above, the EU net exports contribute negatively to the change in GDP.[22] This is mainly due to two effects. Firstly, a rise in the price of domestic goods and services relative to the RoW lowers demands for EU exports and at the same increases EU demand for imports from the RoW. Secondly, public ICT R&D subsidies result in higher ICT R&D activity and as the production of ICT R&D uses imported inputs more intensively this shifts demand towards imported goods and services. EU net exports gradually improve as a result of productivity increases from the introduction of new production technologies. In the long term (after 2043) the contribution from EU net export to GDP becomes positive.

Figure 12 shows the contribution to GDP from net export decomposed by trade partners. For the EU any change in GDP from net export is per definition due to change in trade position against the rest of the world. For Germany and France the bulk of the change in GDP from net export can also be contributed to the trade position against the RoW. The trade position against the RoW gradually improves for both countries. Germany and France also gradually improve their trade position against the rest of the EU, as a result of higher productivity increases in those two countries. In 2040 net exports to the rest of the EU contribute positively to the change in GDP in both countries.

Figure 13 shows the contribution from net exports to the change in GDP decomposed into types of commodities. The contribution to GDP from net exports is at first negative for all types of goods and services. The numerically largest contribution to the change in GDP from net exports is due to trade in high tech manufacturing and to trade in services. The gradual improvement in net exports is seen across all commodity types.[23]

[21] Allowing for endogenous shifts between skills categories in the work force would possibly affect the results, and may lead to even larger increases in high skilled employment.

[22] The extent to which net export changes in response to a relative price increase in domestic goods relative to the RoW depends on the price elasticities for foreign trade.

[23] German net export of high tech manufactured goods improves slowly. German manufacturers of high tech goods do not experience the same productivity gains as producers in other sector. This is because they intensively use non-ICT high-tech variety capital in production. They, therefore, do not benefit to the same extent from higher ICT R&D expenditures as producers in other sectors.

Figure 12: Change in GDP from net exports decomposed by trade partner (scenario 3)

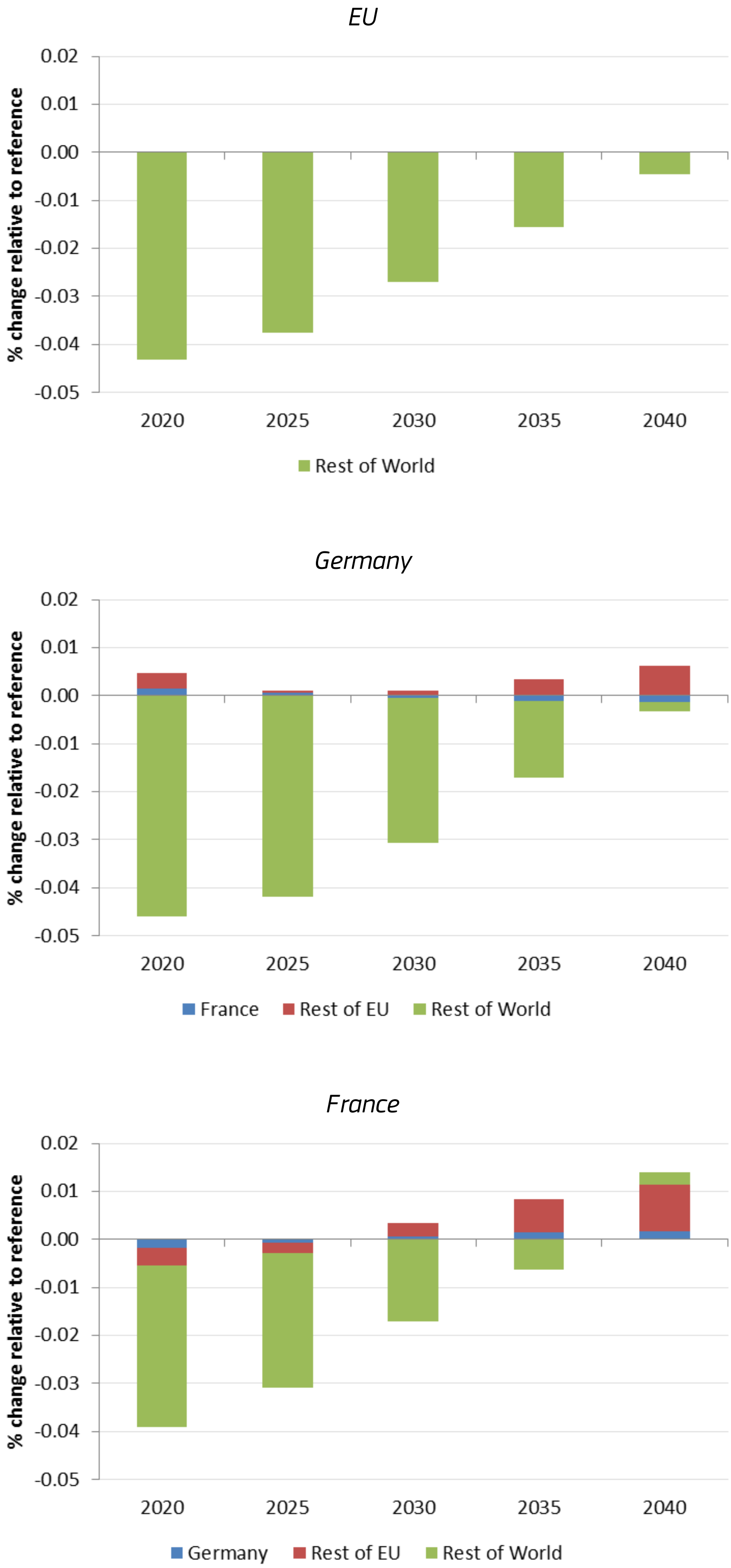
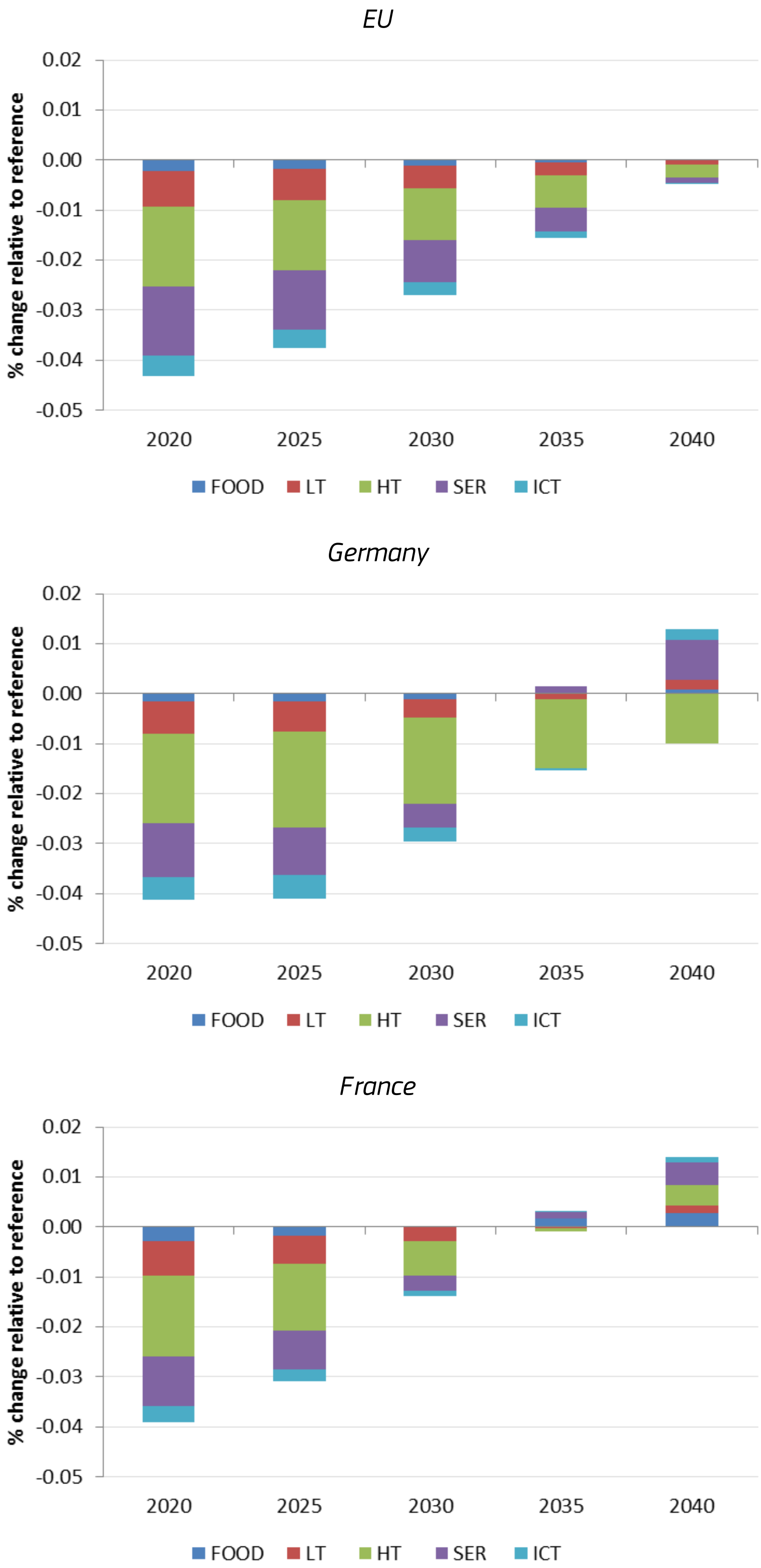


Figure 13: Change in GDP from net exports decomposed by commodity types (scenario 3)

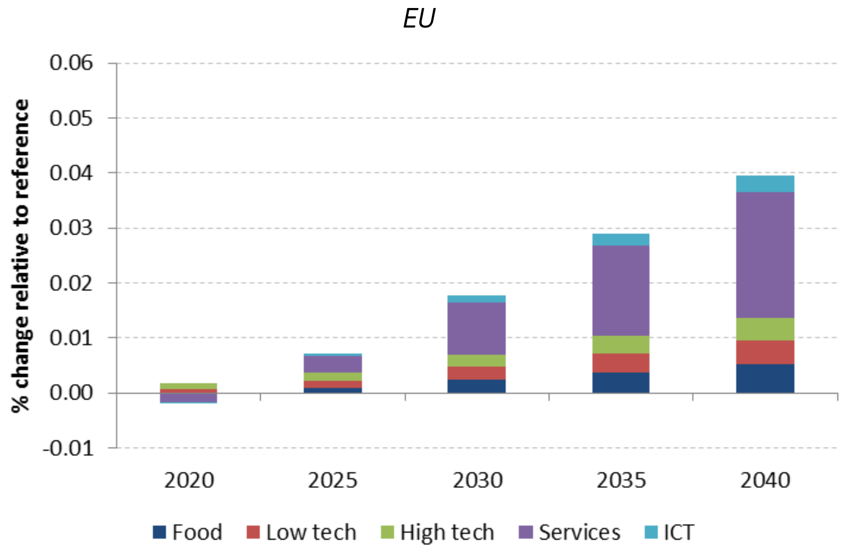


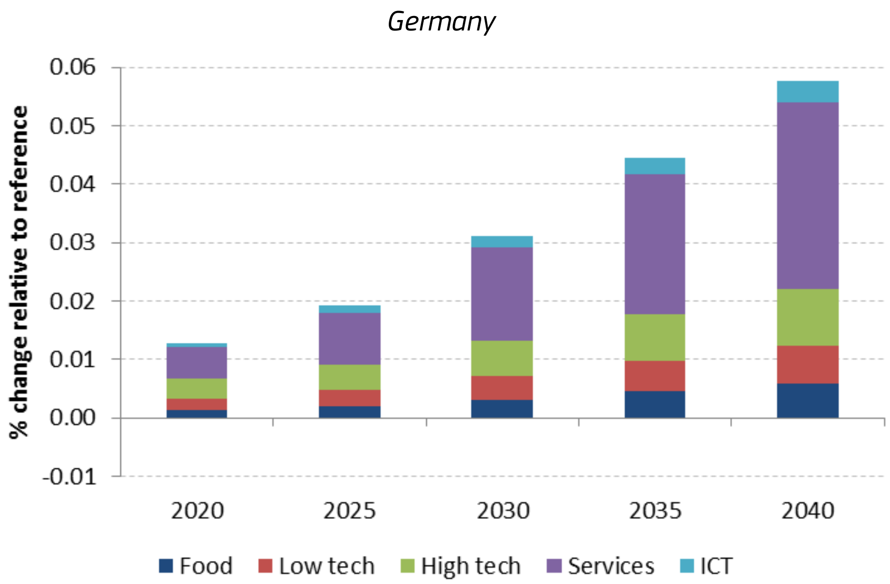
4.6 Impact on private consumption

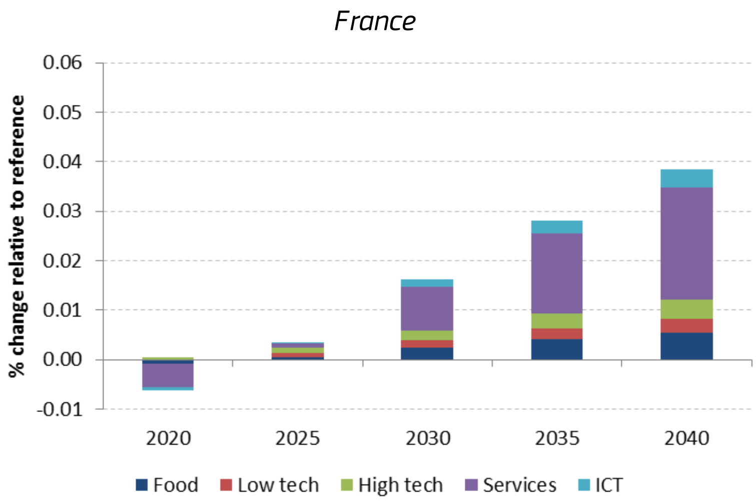
The rise in public subsidies to ICT R&D affects the consumption possibilities of households in the EU. At first the increase in ICT R&D expenditures crowds out household consumption: in 2020, private consumption is marginally lower than in the reference scenario. However, households gradually increase consumption relative to the reference scenario. This long term increase in consumption is induced by productivity gains from the introduction of new ICT technologies in production of goods and services.

Figure 14 shows the contribution from private consumption to the change in GDP. The contribution has been decomposed into commodity types. Private consumption in the EU contribute 0.02 percentage point to the change in EU GDP in 2030 and 0.04 percentage point to the change in EU GDP in 2040 (in total EU GDP is 0.07 % higher than the reference scenario in 2030 and 0.12% higher.in 2040). The bulk of the rise in private consumption is due to higher consumption of services. The consumption of services corresponds to more than half of the rise in private consumption. Considering Germany and France show a similar gradual rise in private consumption, with more than half of the rise in private consumption due to the consumption of services. The contribution to GDP from private consumption is higher in Germany than in France. In 2040 German private consumption contributes 0.06 percentage points to the rise in German GDP, while French private consumption contributes 0.04 percentage points to the rise in French GDP.

Figure 14: Change in GDP from private consumption decomposed commodity types (scenario 3)

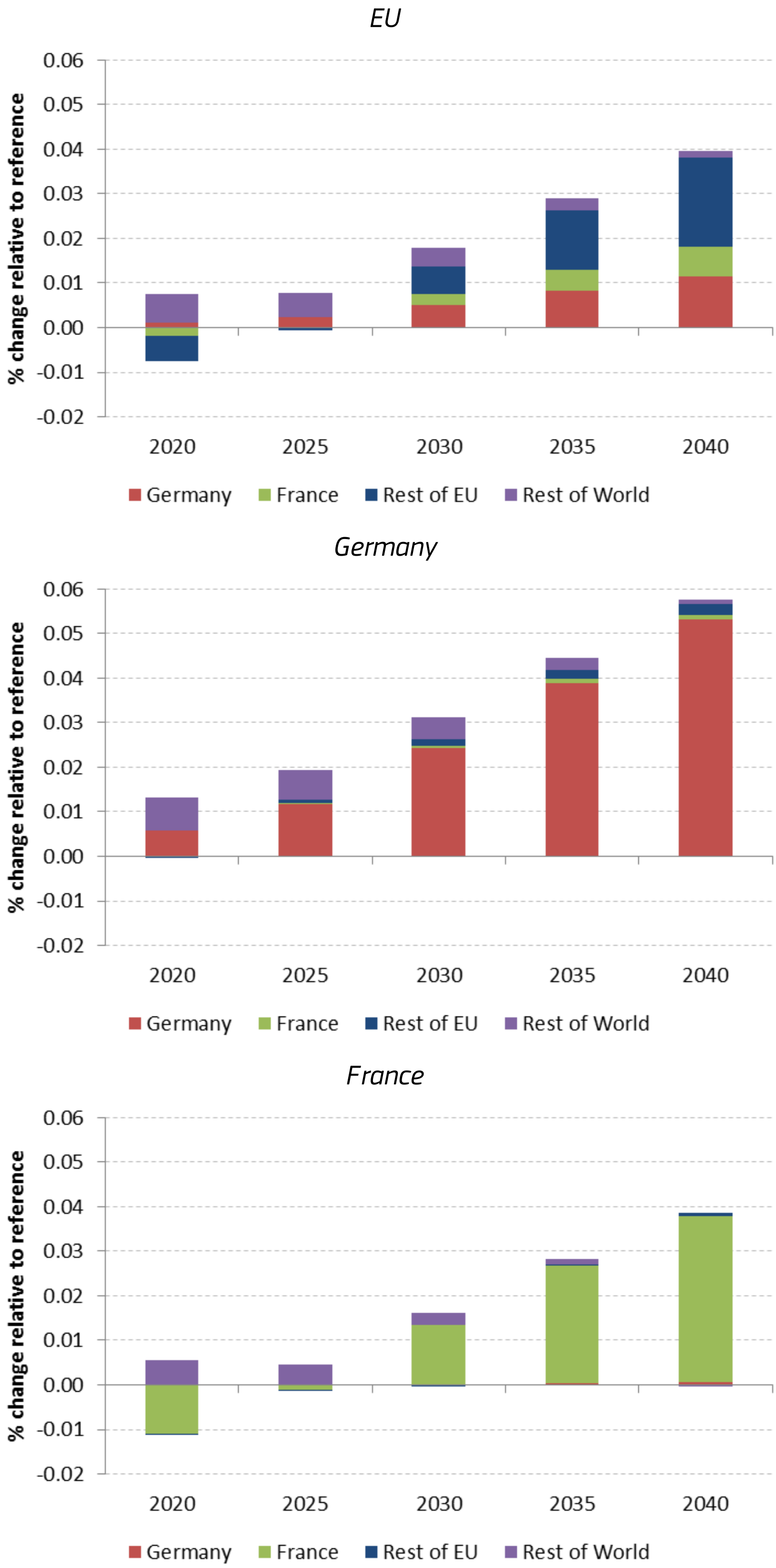






As illustrated in Figure 15, most of the long term rise in private consumption is due to higher consumption of domestic (within country block) produced consumer goods and services.

Figure 15: Change in GDP from private consumption decomposed by country of origin (scenario 3)



5. Alternative policy scenarios

In the previous chapter we examined the dynamics of the model using scenario 3 in which public ICT R&D expenditure double by 2020 in all Member States, R&D subsidies is used as policy instrument and the policy is funded by an increase in lump sum taxes paid by the non-liquidity constrained households. In the following, we will use the model to contrast and compare the 12 policy scenario outlined in section 3, where three different levels of target achievement are grouped with respect to the policy instrument used (subsidies or procurement) and financing sources (lump sum taxes vs. increase in income tax rates). The comparison is made within and between groups.

5.1 Varying the level of expenditure

One of DAE objectives is that EU Member States double their annual public spending on ICT R&D from 2007 to 2020. However, as discussed above, EU countries combined still have a way to go to reach this target, and some of them are very far from it.

We therefore examine the economic impact of varying spending levels of public expenditure on ICT R&D. Figure 16 shows the change in GDP at varying public spending levels, if ICT R&D subsidies are used as policy instrument and the policy is funded by lump sum taxes paid by households.

The figure shows that the impact of ICT R&D subsidies on GDP materialises slowly. In 2020 EU GDP is almost unaffected by rises in ICT R&D public subsidies, even when the public spending target is reached. Changes in German and French GDP in 2020 are also minimal.

In the longer run, the impact on GDP becomes higher. The change in GDP is driven by productivity improvements following the introduction of new ICT production technologies resulting from the higher ICT sector BERD. In the range of public expenditures we consider, returns to public ICT R&D expenditure are only slightly diminishing, so that the impact of different levels of public spending on GDP is almost linear. For example, increasing ICT R&D public expenditures in all Member States by 50 % (scenario 1) leads to a rise in EU GDP of 0.06 %, while doubling ICT R&D public expenditures in all EU Member States (scenario 3) leads to an increase in EU GDP of 0.12 %. This indicates that there are substantial benefits from increasing ICT R&D public expenditures further even from a position where Member State already partially have reached the spending target.

The only slightly diminishing returns to public ICT R&D expenditures can also be seen by considering the policy impact per Euro spend. In 2040 each additional euro spent on ICT R&D subsidies in the EU leads to a rise in EU GDP of 2.87 € if the spending target is reached 75% (scenario 1). The impact indicator is slightly lower when the spending target is fully reached in scenario 3 (2.81 for EU GDP). The highest impact on EU GDP per Euro spent on ICT R&D subsidies is found in scenario 2 in which Germany is the only country that reaches the spending target. In this scenario each additional Euro that is spent on ICT R&D subsidies in 2040 increases EU GDP by 2.95 €. Each Euro spent on ICT R&D subsidies in Germany has a higher impact on GDP than in the other two country blocks of EU Member States in the model. The long term impact on German GDP of ICT R&D subsidies in Germany is between 3.6 and 3.9 times the expenditure in 2040, depending on the scenario considered.

Our results show that Germany would benefit from a higher GDP in the long term if ICT R&D public expenditures in Germany increases relative more than in other Member States. German GDP in 2040 rises 0.16% instead of and 0.09% if Germany reaches the spending target by 2020 and other Member States reach 75% of the target only. However, in the medium term German GDP would be negatively affected. In 2020, German GDP would become 0.03 percentage point lower due to a worsening of net exports[24], while GDP in other Member States would rise marginally as a

[24] This is mainly due to two effects. Firstly, an increase in the price of German goods relative to other countries, which reduced export demand for German goods and shift domestic demand in Germany towards imports. Secondly, the relative high share of material inputs imported from RoW in German ICT sector BERD which raises import demand.

result of improvements in the bilateral trade balance with Germany. In the long term this effect would fade.

Figure 16 also shows (comparing scenario 2 to scenario 3) that Germany benefits from a small rise in GDP in the short term as well as in the long term as a result of higher ICT R&D public spending in the other Member States. This suggests that increasing ICT R&D public expenditure across many Member States generate small positive spill-overs.

The impact of varying public spending levels on employment is portrayed in Figure 17. EU employment in 2040 in scenario 1 (in which Member States reach the spending target by 75%) rises by 75,200 full-time-equivalent persons. It is interesting to note that the largest part of the rise (56,600 full-time-equivalent persons) is due to higher employment of high skilled labour. The rise in high skilled employment is driven by higher R&D activity and more intensive use of ICT in production that leads to a substitution from low skilled and medium skilled labour towards high skilled labour.

Similarly to the case of GDP, employment returns to ICT R&D public expenditures in the model are weakly diminishing: a 50% increase in ICT R&D public spending raises EU employment by 75,200 full-time-equivalent persons while a doubling of public ICT R&D spending raises employment by an additional 72,800 full-time-equivalent persons.

If all Member States reach the DAE ICT R&D public spending target by 2020 then EU employment in 2040 would increase by 148,000 full-time-equivalent persons relative to the reference scenario, with high skilled labour increasing by 111,100 full-time-equivalent persons.

Looking at Scenario 2, where Germany reaches the DAE ICT R&D public spending target by 2020 and other Member States reaches 75% of the target, employment in Germany would increase by 42,800 full-time-equivalent persons relative to the reference scenario,. Results show that ICT R&D spending in Germany only marginally affects long term employment in other Member States, while Germany would be affected from a change in ICT R&D public spending by all other Member States, especially with respect to the skills composition of employment.[25]

Considering the impact on ICT sector BERD in 2040 each additional Euro spent on ICT R&D subsidies in the EU leads to a rise in ICT sector BERD of 1.65 € in scenario 1 in which the spending levels in all Member States corresponds to 75% of the spending target. Returns are slightly lower (1.62 €) in scenario 3 in which the spending target is fully reached. A similar result can be observed for the impact indicators for Germany holding public spending levels constant in all other Member States at 75% of the spending target. In Germany each additional EURO spent on ICT R&D subsidies leads to a rise in ICT sector BERD of 1.87 € if Germany reaches 75% of the DAE spending target (scenario 1), compared to 1.84 € if Germany reaches the DAE spending target in full (scenario 2).

Our results indicate that the impact of ICT R&D subsidies on ICT sector BERD in a given EU Member State is largely unaffected by the spending levels in other EU countries. The impact per Euro spent on ICT R&D subsidies in Germany is stable irrespectively on whether all other Member States reaches the spending target in full or reaches it by 75%. Similarly, the impact per Euro spent on ICT R&D public subsidies in France is stable whether Germany reaches the target in full or reaches it by 75%, all else being equal.

[25] Figure 17 shows that the skills composition of employment in Germany changes as a result of higher ICT R&D public spending in other Member States. German employment of high skilled labour rises by an additional 2,200 full-time-equivalent persons if other member states move from 75 % of the spending target to fully reaching the target. However, the rise in high skilled employment is offset by a decline in employment of low and medium skilled labour.

Figure 16: Changes in GDP at varying ICT R&D public expenditure levels

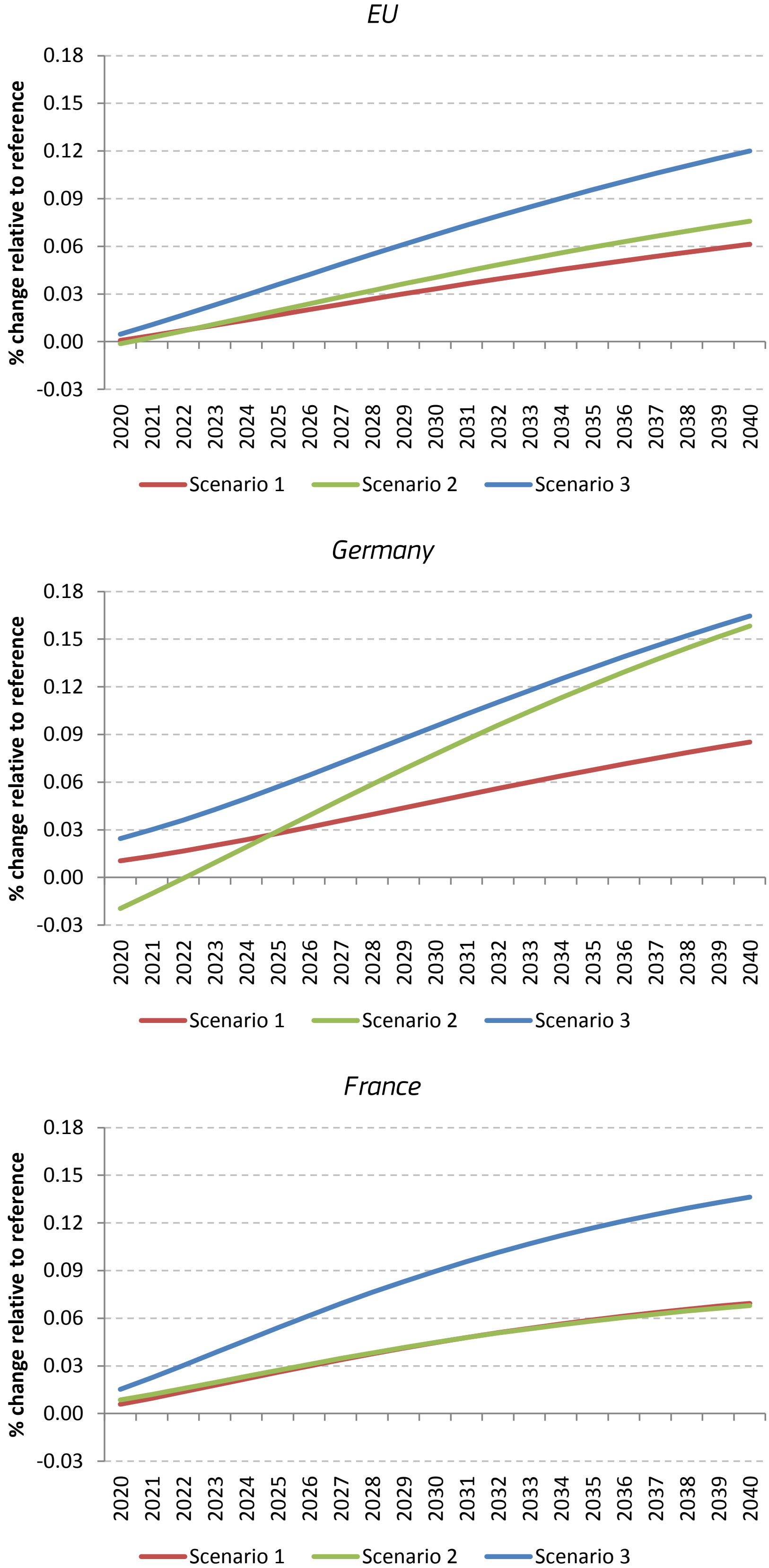
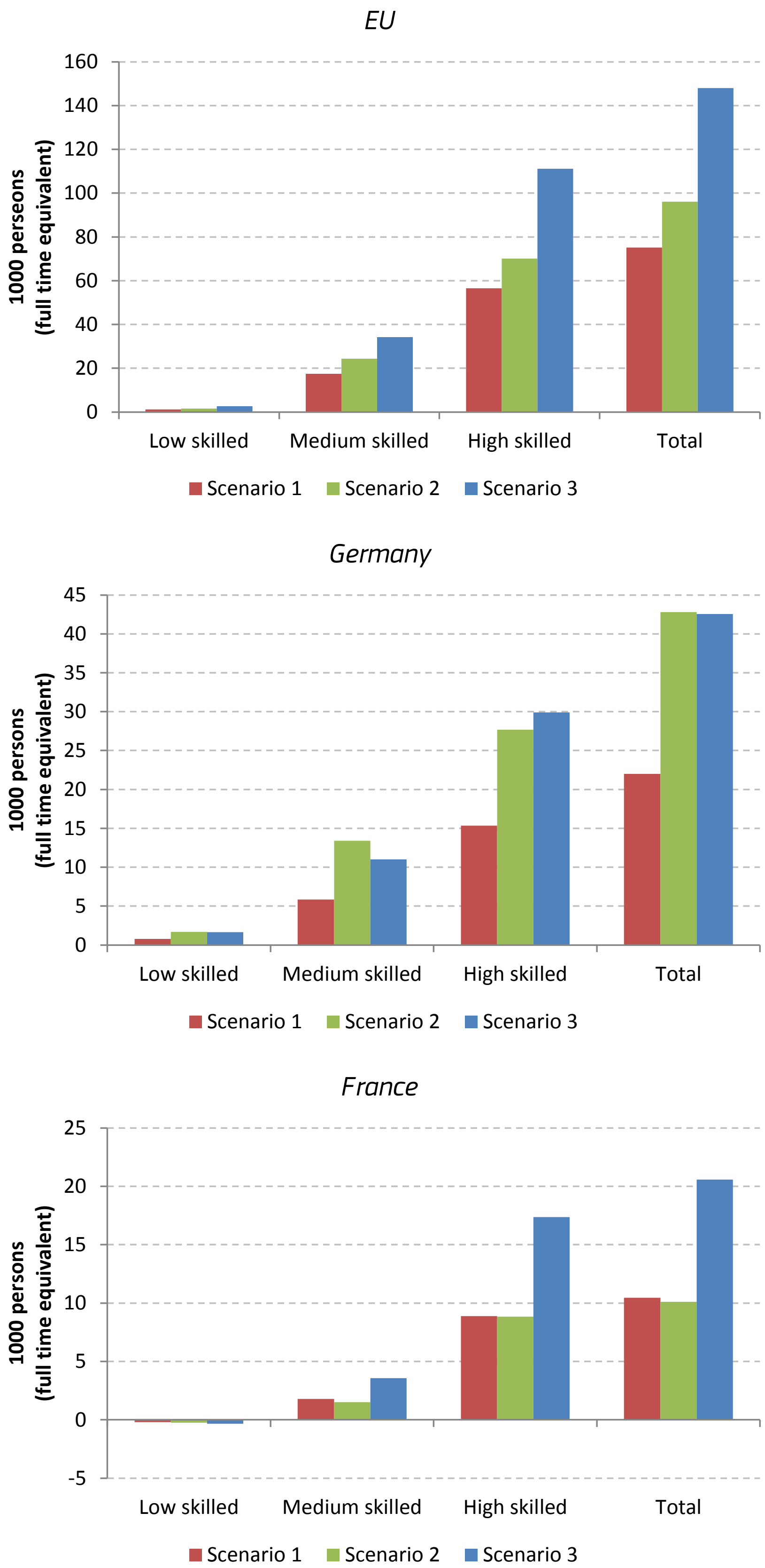


Figure 17: Changes in employment in the long term at varying ICT R&D public expenditure levels



Note: the figure show changes in employment in 2040 relative to the reference scenario

5.2 *Varying the policy instrument: general subsidy vs public procurement*

Amongst policy instruments referred to in DAE, in the previous section we considered ICT R&D subsidies. In this section we will examine public pre commercial procurement targeted at ICT R&D, (group 2 scenarios) comparing its effects to the outcome of ICT R&D subsidies (group 1).

To this end, we assume that public expenditure on ICT R&D is used entirely for ICT R&D procurement, and that this additional ICT R&D purchased by national governments is not sold as blueprints for the development of new commercial ICT technologies, but made freely available for all R&D providers. The accumulated knowledge from ICT R&D procurements hence increases productivity of R&D producers in the ICT sector and spills to R&D producers in the non-ICT sector.[26] This corresponds to the case where the public sector is funding basic research.

Figure 18 shows the development in ICT sector BERD at varying policy instruments when the spending target is reached by all Member States and the policy is funded by an increase in lump sum taxes paid by households. All series in the figure are in 2007 prices and has been de-trended with the model's trend growth rate of 1.64% p.a. to 2007 levels. Hence, a horizontal line in the graphs corresponds to an increase equivalent to the model's long term growth rate.

Comparing the development in ICT sector BERD in the two policy scenarios we find that higher public ICT R&D spending leads to an increase in ICT sector BERD irrespective on which policy instrument is used. However, ICT sector BERD increases much less when ICT R&D public procurement is used as policy instrument (scenario 6) than when ICT R&D subsidies are used (scenario 3): in 2040 each additional Euro spent on ICT R&D public procurements in the EU leads to an increase in the ICT sector BERD of 0.95 €, compared to 1.62 € when ICT R&D subsidies were used as policy instrument.[27] For Germany and France the impact per Euro is 1.02 € (against 1.84 €) and 1.03 € (against 1.76 €) respectively if ICT R&D public procurement is used.

ICT sector BERD includes all business enterprise expenditures on R&D by the ICT sector, no matter whether it is funded commercially or by public procurements. To examine the impact on commercial R&D expenditures in the ICT sector we can construct a variable that only includes ICT sector BERD that is not funded by the increase in public procurement. This is done by subtracting the additional public expenditures on ICT R&D procurements from total ICT sector BERD. We name this variable ICT sector BERD excluding public procurements. Figure 18 also shows the development in ICT sector BERD excluding public procurements in scenario 6. As shown, the slower growth in ICT sector BERD with respect to subsidies is mostly explained by crowding out. The increase in public ICT R&D procurements crowds out commercial R&D provision in the model. The policy instrument stimulates demand for R&D and this additional demand competes for scares resources with the existing R&D production.

In 2020, EU ICT sector BERD in scenario 6 is 3.6 billion € (2007 prices) higher than in the reference scenario, while ICT sector BERD excluding public procurements is 3.0 billion € lower. From 2020 on, we assume that ICT R&D public procurement grow at the model's trend growth rate: ICT sector BERD continues to rise at a higher growth rate as a result of the improved productivity in R&D production driven by knowledge accumulation. By 2040 ICT sector BERD excluding public procurements would be 0.4 billion € lower than in the reference scenario, while ICT sector BERD is 8.7 billion € higher.[28]

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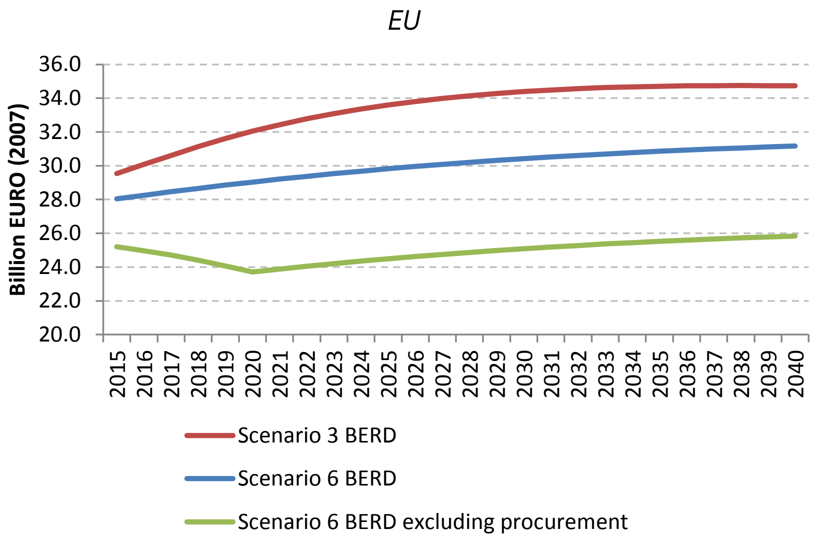
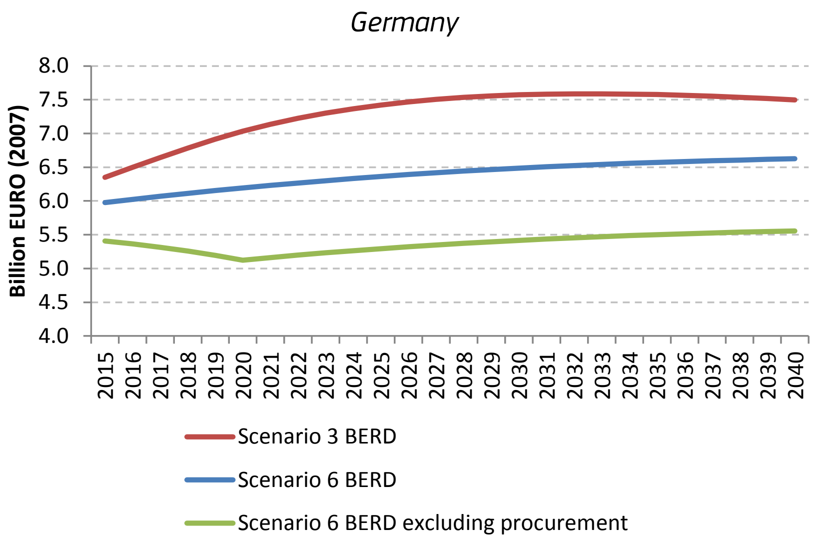
[26] In the scenarios in group 2 we assume that ICT R&D from public procurements affects productivity of R&D producers at the same magnitude as commercial R&D. Further work on the effects of public procurements could modify this assumption.

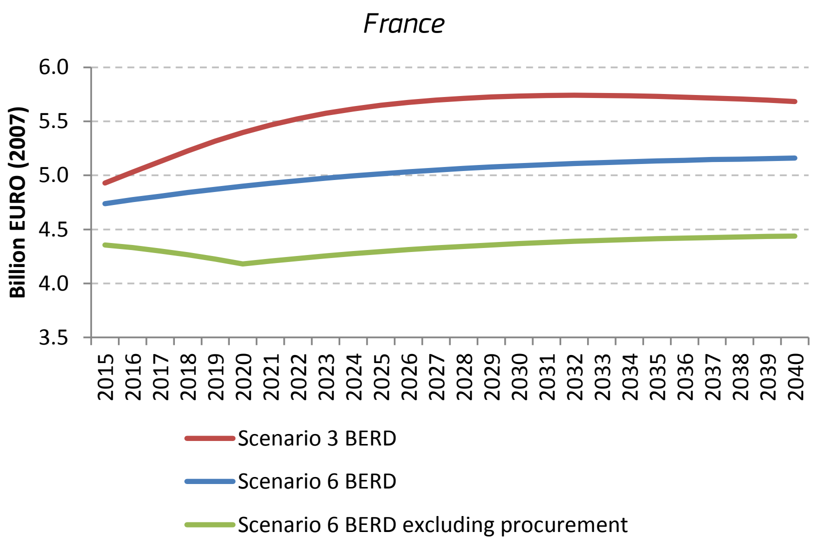
[27] Corresponding to a difference in ICT sector BERD of 6.1 billion € (2007 prices) between scenario 6 and scenario 3.

[28] ICT sector BERD excluding public procurement in the EU continues to grow at a higher rate in scenario 6 and becomes higher than in the reference scenario in 2047.

Figure 18: ICT sector BERD at different policy instruments (2007 prices and levels)







We see a similar development in ICT sector BERD in Germany and France. In 2020 ICT sector BERD excluding public procurement become lower than in the reference scenario as a result of crowding out. In Germany it is 0.5 billion € lower, while it is 0.3 billion € lower in France (2007 prices). In the long run ICT sector BERD excluding public procurements rises. In 2040 ICT sector BERD excluding public procurement become marginally higher than in the reference scenario. In Germany it is 43 million € higher and in France it is 38 million € higher (2007 prices).

Figure 19 compares the change in GDP for polices using ICT R&D subsidies and ICT R&D public procurement.[29] All policies shown in the figure are funded by an increase in lump sum taxes paid by households.

An increase in ICT R&D public procurement leads to higher GDP than in the reference scenario and, up to 2023, also a higher GDP than if ICT R&D subsidies are used. In the longer term, however, ICT R&D subsidies bring progressively higher long term GDP compared to ICT R&D public procurement.[30]

Figure 20 further examines the effects of ICT R&D public procurement by decomposing the changes in GDP in scenario 6 into macroeconomic aggregates. The figure shows that higher GDP in 2020 is mainly driven by an increase in R&D activity in the ICT sector, and by higher non-ICT investments. The crowding out of private ICT sector R&D expenditures leads to a drop in ICT investments. Lower domestic consumption also contribute negative to EU GDP. In scenario 6 we do not observe an initial worsening of the trade balance. In the model ICT R&D public procurement generates a more modest rise in domestic demand than ICT R&D subsidies and hence does not to the same extend drive up domestic prices relative to RoW. Furthermore the structural shift in economic activity is not systematically towards components of the economy with higher import components. Hence, net export initially contributes positive to GDP.

The additional ICT sector BERD caused by ICT R&D public procurements does not directly result in new blueprint that broadens the spectrum of ICT technologies. However, the public purchase of ICT R&D contributes to the accumulation of knowledge. In the long term spill-over effects from ICT R&D public procurement therefore, raise productivity in R&D production, and hence the production of blueprint. Higher ICT R&D activity and the introduction of new production technologies in production gradually improves productivity across manufactoring sectors of the economy and leads to higher GDP. However, in the long term EU GDP increases less than in scenario 3 in which ICT R&D subsidies are used.

Figure 21 compares the effect on value added of doubling public expenditures for ICT R&D using ICT R&D subsidies (scenario 3) and ICT R&D public procurement (scenario 6) respectively. In the short term total value added rises more when ICT R&D procurement is used as policy instrument. In 2020 total value added in the EU is 0.03% higher than in the reference scenario (compared to 0.1% if ICT R&D subsidies are used). However, in the long term value added rises less when ICT R&D procurement is used. In 2040 total value added in the EU is 0.04% higher than in the reference scenario (compared to 0.13% if ICT R&D subsidies are used). The smaller long term impact from ICT R&D procurement arises from crowding out of private ICT R&D expenditures and the introduction of fewer new ICT technologies that leads to a lower increase in ICT sector value added. Furthermore, the introduction of fewer ICT technologies leads to a smaller long term rise in non-ICT sector value added.

[29] Scenarios in which ICT R&D subsidies are used are marked with a full line, while scenarios in which ICT R&D public procurement is used are show with a stippled. Scenarios with identical spending levels are shown in the same colour.

[30] For example, a doubling of public ICT R&D spending leads to a rise in GDP of 0.03 % in 2020 if ICT R&D public procurement is used as policy instrument (scenario 6), but only to a marginal rise in GDP if ICT R&D subsidies is used (scenario 3). GDP in 2040 rises 0.12% if ICT R&D subsidies are used compared to 0.03 % if ICT R&D public procurement is used.

Figure 19: Changes in GDP at different policy instruments

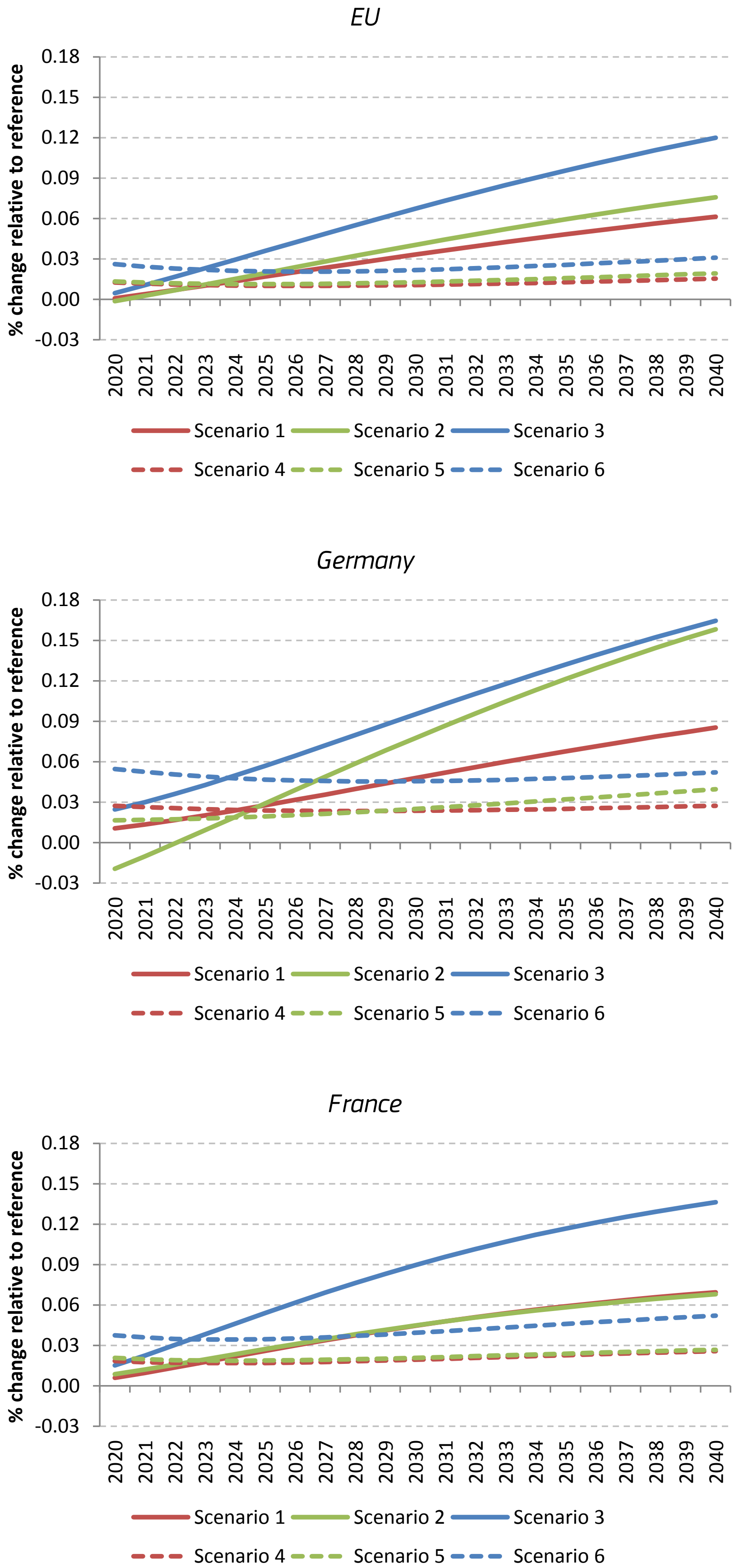


Figure 20: Change in GDP decomposed into macroeconomic aggregates (Scenario 6)

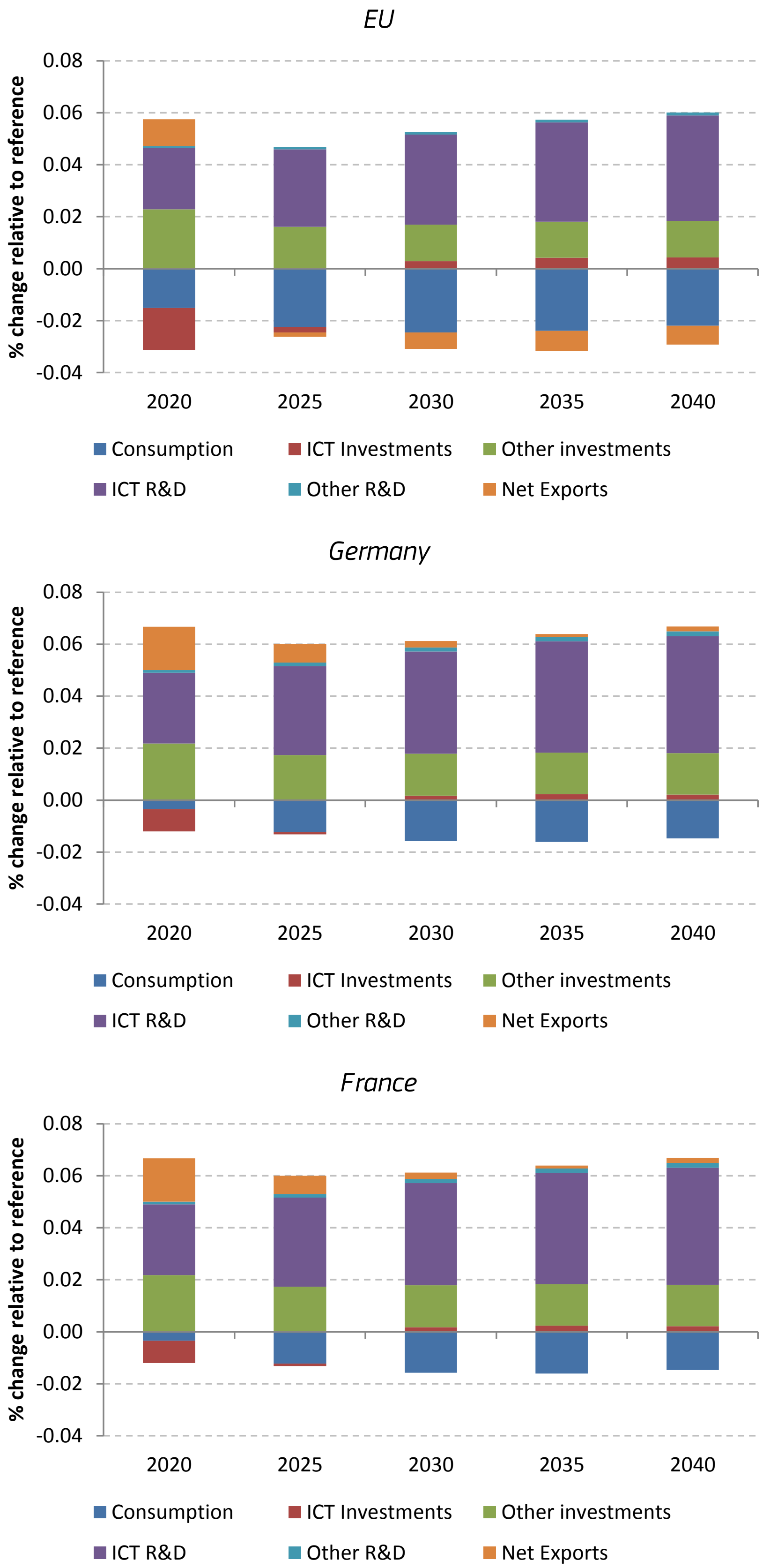
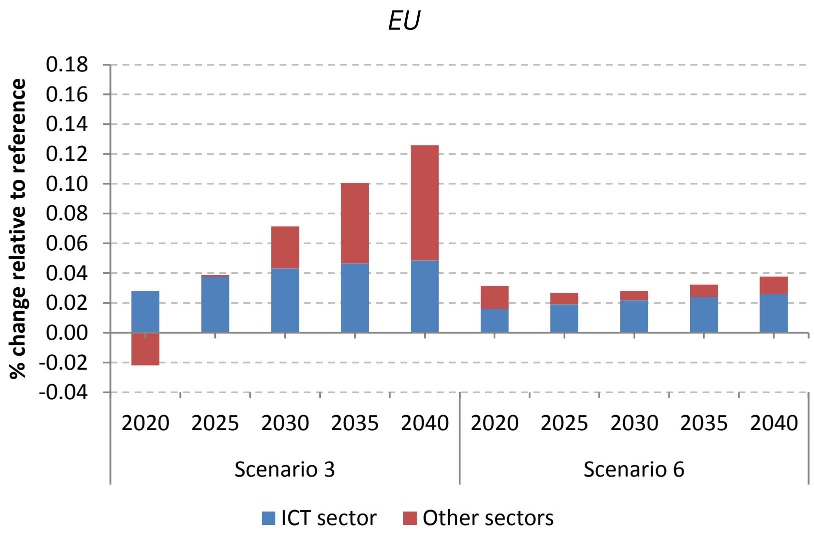
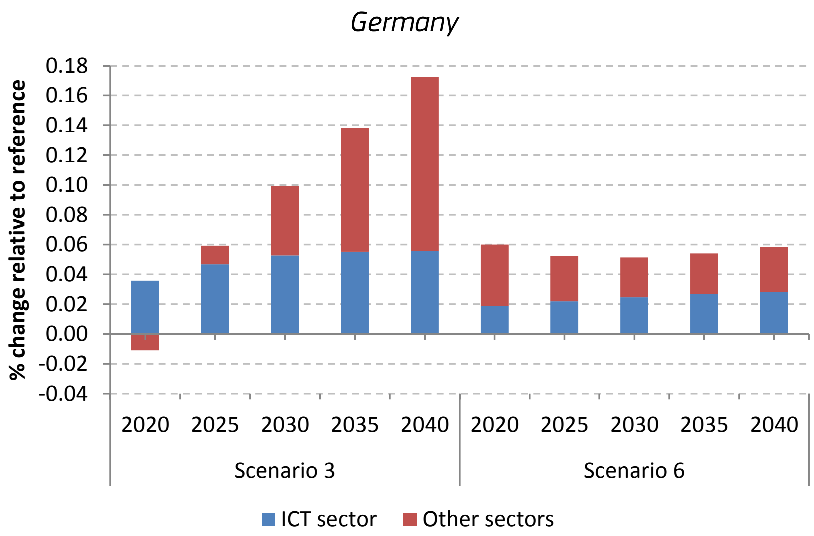
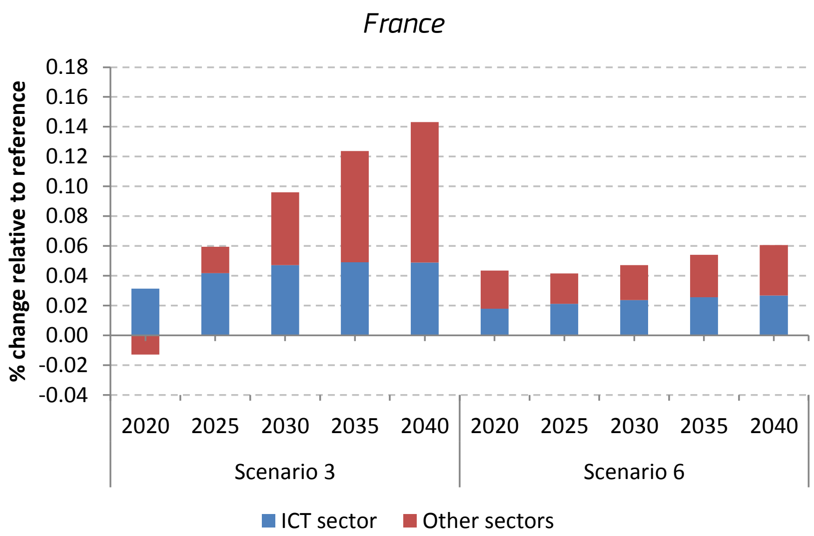


Figure 21: Change in value added at different policy instruments







The higher ICT R&D public procurement also leads to a rise in employment which, however, is about half what was resulting from ICT R&D subsidies and with a less pronounced shift towards high skilled labour. In 2040, EU employment in scenario 6 is 73,400 full-time-equivalent persons higher than in the reference scenario, with medium skilled employment 49,200 full-time-equivalent persons higher, high skilled 24,700 full-time-equivalent persons higher and low skilled 500 full-time-equivalent persons lower than in the reference scenario. This latter effect is due to a shift in the structural composition of the economy: R&D production is lower and growth in production of manufacturing goods is more heavily concentrated in ICT and services if ICT R&D public procurements is used as policy instrument.

5.3 Varying the sources of financing: lump sum taxes vs income tax rates

Above, in our examination of the impact of increased public expenditure on ICT R&D, we have assumed that the policy was financed by an increase in lump sum taxes paid by non-liquidity constrained households. This assumption allows us to examine the impact of increased ICT R&D public expenditures in a nearly neutral context. We now relax this assumption by letting the policy be fully financed by an increase in income taxes. All household types are subject to identical percentage point changes in their income tax rates.

In the model, a rise to the income tax is assumed to reduce the labour supply which, in turn, changes relative prices and households´ disposable income.[31] Such an assumption, although rooted in theoretical and empirical literature, can nonetheless be challenged on the same grounds. This simulation should thus not be considered as a complete representation of the real world implications of policies. Rather, its value lies in portraying a "what if" situation, and in showing how policy outcome changes given different settings and assumptions in the model.

A shift in financing from lump sum taxes to income tax rates only marginally affects ICT sector BERD.[32] On the other hand, as portrayed in Figure 22, the stimulus to GDP growth is much smaller, driven by lower increases in domestic consumption and non-ICT investments, and a worsening of net export. The rise in income taxes also affects employment: assuming that the DAE spending target is fully reached using R&D subsidies, EU employment in the long term (2040) is 110,500 full-time-equivalent persons lower if financed by income taxes (scenario 9) rather than lump sum taxes (scenario 3).

This is explained by a series of interactions, which start from the assumption that financing public ICT R&D expenditures through income taxes reduces labour supply, drive up wages and domestic prices. As a result, net exports worsen, households' real disposable income and consumption rises less than if lump sum taxes is used. Non-ICT investments also rises less as a result of the declining economic activity. As a consequence long term GDP increases less when public funding is financed by income taxes than when the policy is funded by an increase in lump sum taxes paid by households.

[31] In principle, a change in the income tax rate has two effects in opposite directions: a substitution effect and an income effect. An increase in the income tax rate reduces the after-tax income of an hour of labour. This reduces the relative price of leisure. As a consequence the household would substitute from other consumption towards leisure. Hence, the substitution effect makes the household to reduce its supply of labour. On the other hand the income tax rate rise reduces the household's net income from a constant number of hours worked. To maintain the same level of consumption the household would need to work more. The income effect makes the household to increase its labour supply. In the model the substitution effect is assumed to dominate the income effect.

[32] If ICT R&D subsidies are used as policy instrument, then funding by income taxes makes ICT sector BERD in the EU 55 million € lower in 2020 (ICT sector BERD totals 39.6 billion €), and 30 million € lower in 2040 (it totals 59.4 billion €). Aggregate ICT sector BERD in the EU is also slightly lower if ICT R&D public procurement is funded with income taxes. In this case EU ICT sector BERD is 86 million € lower (it totals 35.8 billion €) in 2020 and 121 million € lower (it totals 53.2 billion €) in 2040. Thus, crowding out of commercial ICT sector BERD only marginally increases.

Figure 22: Changes in GDP, ICT R&D subsidies at varying types of funding sources

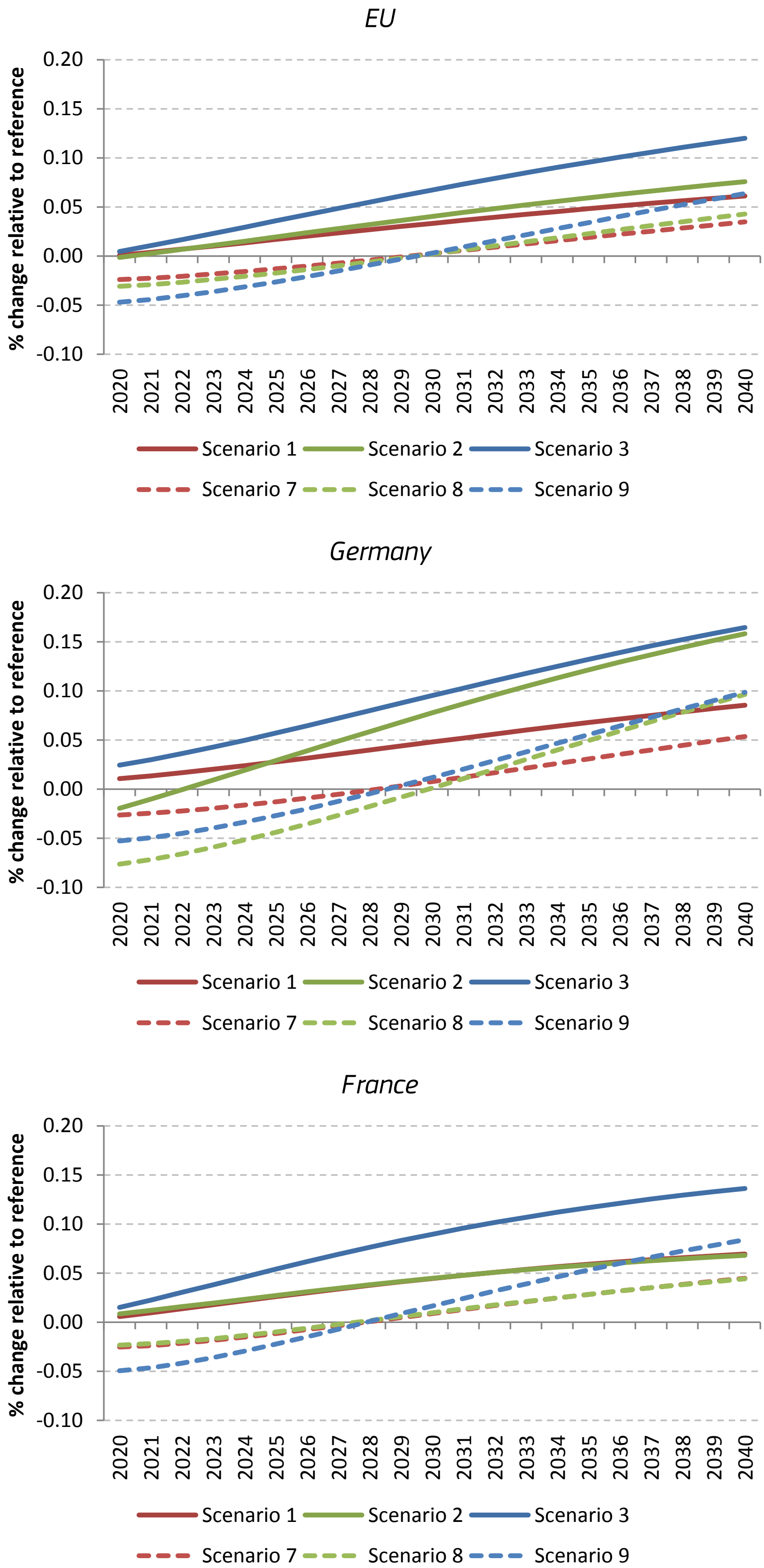


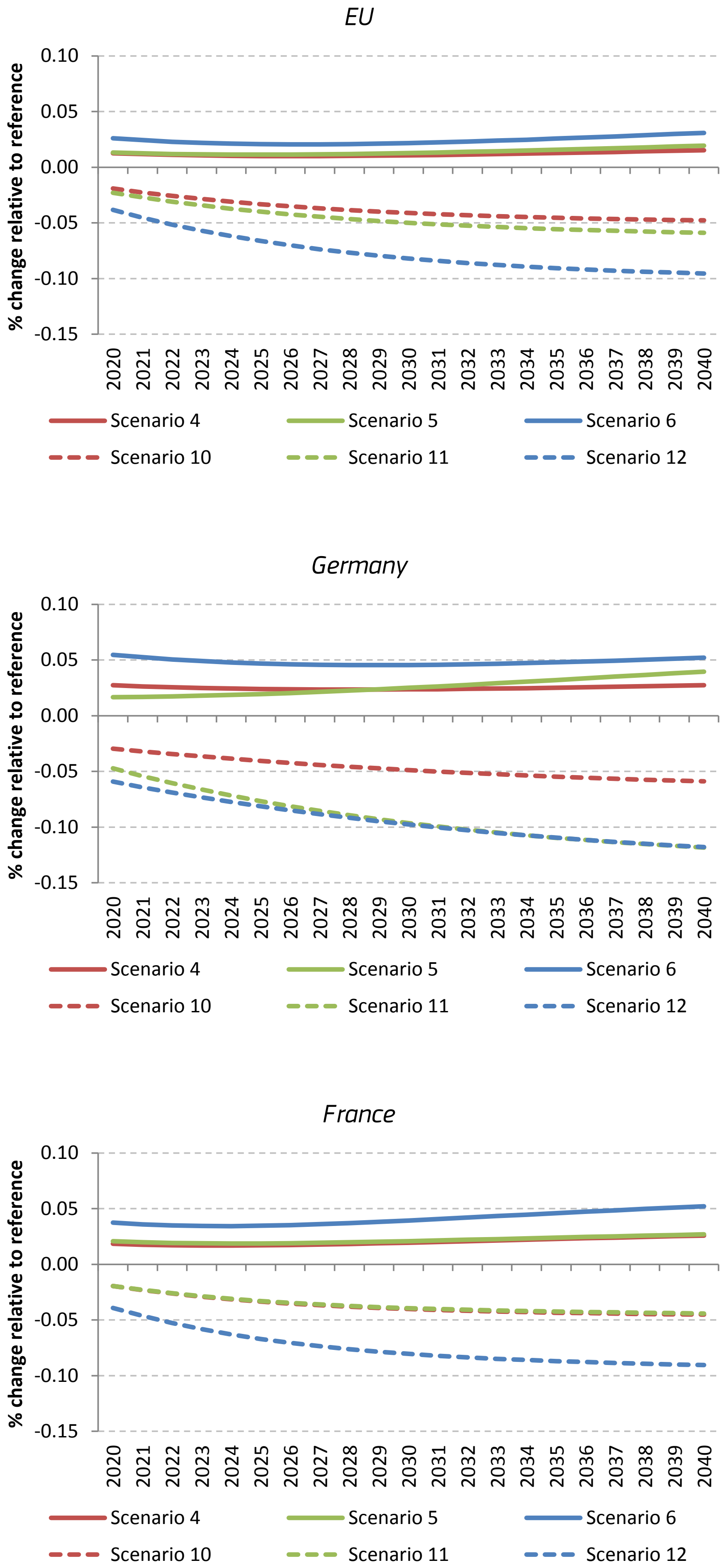
Figure 23 shows the change in GDP under the two alternative sources of financing for the policy scenarios in which ICT R&D public procurement is used as policy instrument. In this case, the distortionary effects from higher income taxes outweigh the positive impacts from ICT R&D public procurement. Hence, GDP becomes lower than in the reference scenario. For example, EU GDP in 2040 is 0.10 percentage points lower than the reference scenario if a doubling of public ICT R&D expenditures is financed by income taxes (scenario 12).[33]

Employment becomes lower than in the reference scenario as a result of the reduced labour supply. For example, in scenario 12 in which ICT R&D public expenditure doubles, EU employment in 2020 is 103,800 full-time-equivalent persons lower than in the reference scenario, and 180,200 full-time-equivalent persons lower in 2040.

Our results suggest that the impact of increased public expenditures on ICT R&D is sensitive to how the policy is financed. For example, the policy outcome of financing by income taxes depends on how strongly labour supply responds to higher income taxes in the model. This depends on assumptions concerning the income and substation effects. The determination of the size of these effects should be done empirically; estimates in the literature of the two effects vary with no clear consensus, although most studies find that the substitution effect tends to dominate the income effect. However, it is worth reminding that at this stage our results should be considered as "what if" outputs only, as changing model assumptions concerning labour supply could affect our conclusions.

[33] That the economic impact of public procurement can change substantially if funded by distortionary taxes has earlier been pointed out by Baxter and King (1993), In a study on a model calibrated to match the US economy, they found that the government multiplier is positive when public purchases is finances by lump sum taxes, but negative when financed by general income taxes.

Figure 23: Changes in GDP, public procurement at varying types of funding sources



6. Summary and conclusions

This report outlines the results of a model-based simulation of the economic impacts of increased public spending on ICT R&D by EU Member States, following the objectives of the *Digital Agenda for Europe* (DAE). The simulation was performed by means of a macroeconomic model belonging to the family of dynamic Computable General Equilibrium Models (CGE) specifically developed for this purpose, with ICT and R&D-driven endogenous growth.[34] The model developed distinguishes R&D by the ICT sector from that performed in other industries. It accommodates a range of policy instruments that may be used to stimulate ICT R&D activity in the economy and captures multiple channels through which R&D activity affects the economy.

The model is used to simulate the economic impact of a set of policies. We consider different spending levels in the form of a full or partial achievement of DAE targets regarding public spending on ICT R&D, i.e. doubling its 2007 level in real terms by 2020. Different policy options are also considered with respect to the instruments used (subsidies vs. procurement) and to the way the additional expenditure is financed (lump sum taxes vs. income tax rates). The combination of the chosen policy specifications leads to the simulation of 12 different policy scenarios, whose outcomes are compared to a reference scenario in which no policy changes are introduced.

In broad terms, the model suggests that increasing public expenditures on ICT R&D leads to an increase of BERD in the ICT sector, stimulates economic growth and raises employment: assuming that all Member States double public expenditures on ICT R&D, each additional euro spent would raise ICT sector BERD in the long term (2040) by as much as 1.6 euros if R&D subsidies are used as policy instruments. Each Euro spent would raise long-term GDP by 2.8 euros.[35] EU employment in the long term (2040) would increase by 148,000 full-time-equivalent persons. A shift in the composition of employment towards high-skilled labour would also occur.

In the model, marginal returns on public spending only slightly diminish (i.e. a partial achievement of the spending targets, say 75 % would result in a marginal impact per euro just above that of full achievement). This indicates that there are still substantial gains to be made from reaching the spending target, even from a position of partial achievement.

The simulation results suggest that the level of expenditures chosen by Member States affects not only domestic growth and employment, but also the economy in other Member States. However, this crossborder effect is found to be small. For example, Germany benefits from a small rise in GDP in both the short term and the long term as a result of higher ICT R&D public spending in the other Member States. This suggests that increasing ICT R&D public expenditure across many EU Member States would generate small positive spill-overs. German employment is also affected by a change in ICT R&D public spending by all other EU Member States, especially with respect to the skills composition of employment. In contrast, a unilateral increase in public expenditures on ICT R&D by Germany would only marginally affect the economy of other EU Member States.

The choice of the policy instrument and the source of financing also affect the policy outcome. In the model, public procurement of ICT R&D leads in the short term to higher GDP and employment than when ICT R&D subsidies are used, while in the long term (2040) these subsidies provide higher growth and a larger increase in employment.[36] Similarly, due to the model's assumptions, financing the policy by increasing income taxation reduces its long term benefits.[37]

[34] R&D output contributes to a common pool of intangible knowledge capital available to firms across sectors and countries. This improves productivity of R&D production. R&D output is also sold as blueprints that provide the purchasing firm with the exclusive right to its use in production. Blueprints allow the production of new technologies and increase productivity.

[35] For Germany and France, each additional euro spent would lead to an increase of ICT sector BERD of 1.8 euros and an increase of GDP by 3.8 euros and 3.7 euros respectively in the long term.

[36] The difference is mainly caused by how the two policy instruments affect the various components of GDP. In the short run, ICT R&D public procurement leads to higher net exports, but also a more modest rise in domestic demand, than ICT R&D subsidies. In the long term, ICT R&D subsidies lead to higher productivity gains from the use of new ICT

These results should not be regarded as the complete representation of real world policy impacts, due to the fact that different assumptions with respect to elasticity of labour supply may lead to different outcomes. Instead, they suggest that the policy instrument chosen and related public finance decisions affect the economy in a complex way. The model provides a tool for examining these complex interactions. In a similar fashion, particular policies may be effective due to features not included in the model analysis. For example, the choice of procurement vs. subsidies may be affected if R&D projects are not provided commercially but are deemed to have positive societal externalities, or when their payoff is very uncertain.[38]

All in all, the basic model deployed for this report represents a first step in the development of a tool for the macroeconomic assessment of public support to ICT R&D. As outlined above, the simulations performed suggest that an increase in public funding of ICT R&D may have a significantly positive impact on ICT sector BERD and on economic growth and employment, but that these effects could vary depending on policy choices.

These preliminary results are promising. However, further work is needed to examine the sensitivity of results to model specifications and assumptions. In this respect, the analysis could be extended in several ways. Firstly, including more individual countries would allow the assessment of policy impacts at Member State level. Second, further work should explore the sensitivity of results to assumptions and parameter settings concerning labour supply, R&D spill-overs and trade elasticities. Finally, the effects of various policy instruments such as tax credits or subsidies targeted at R&D employment could also be usefully modelled.

technologies than ICT R&D public procurements. This because, increased spending on ICT R&D public procurement leads to crowding out of private ICT sector R&D which slows down the introduction of new technologies.

[37] A rise in income tax rates is assumed to slightly reduce labour supply. This drives up wages and domestic prices. As a result the net exports worsen. Households' disposable income becomes lower, and this leads to lower private consumption. The distortionary effects from a rise in income tax, thus, reduce GDP growth and lead to a lower rise in employment.

[38] Also, public procurement of ICT R&D may provide results from basic research that are widely applicable. In this case, spill-over to other R&D projects may be larger than those for commercial ICT R&D. In our model analysis, we assumed that the spill-overs from publicly procured ICT R&D are of the same magnitude as those for commercial ICT R&D. Further work on the effects of public procurement could modify this assumption.

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