# Social Impact Policy Analysis of Technological Innovation Challenges (SIMPATIC)

## *A Compilation of Main Results for Policy Makers*

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# 1 INTRODUCTION

SIMPATIC represents a unique project, bringing together micro and macro researchers with expertise in evidence-based policy analysis and impact assessment of research and innovation policies. Insights from micro-analysis and micro-evidence, including SIMPATIC's own frontier pushing ex-post policy impact analysis of R&D subsidies and tax credits, is used as input in SIMPATIC's sectoral EU macro models, NEMESIS and GEM-G3. These models have already regularly served in the assessment of innovation and environmental policies in Europe. In this project, these models are further developed to include the latest insights from micro models. Thus, SIMPATIC develops and uses the best possible evidence and methodologies, both micro and macro, to simulate the impact of research and innovation policy on European growth and jobs. As such SIMPATIC contributes to advancing impact assessment and evidence based innovation policy design in Europe, allowing research policies to better respond to the growth challenge it faces but also to other grand challenges, including environment and social inclusion.

The aim of this paper is to summarize the main results and policy messages from SIMPATIC. Several studies in this project are highly technical and aimed at developing theoretical and empirical methodologies to draw conclusions and policy recommendations that are exposed in subsequent SIMPATIC papers. However, with the purpose of being a guideline for policy makers, this document will focus on compiling those insights with direct policy implications. The full set of SIMPATIC studies can be found on the SIMPATIC website: www.simpatic.eu.

This compilation is organized as follows. Section 1 first describes the aim and structure of the SIMPATIC project. Section 2 introduces the contribution of SIMPATIC micro-analysis to evidence based innovation policies in Europe, specifically, in evaluating the impact of R&D subsidies and tax credits, and in assessing green innovation policies. Section 3 focuses on the evidence based macro-analysis of innovation policies in Europe. In this section, a coherent quantitative macro perspective is implemented to better understand the impact of research policies on overall economic growth and jobs, with a special emphasis on leverage effects of public incentives on green R&D decisions and investment in green technologies, and for a broad social impact assessment of R&D policies. Section 4 provides the micro-macro link, with a special emphasis given to knowledge spillovers and the impact of innovation in employment and growth, including non-technological innovation as service and social innovations.

## 1.1 Outlining the Contribution of SIMPATIC to Evidence Based Innovation Policies

The objective of SIMPATIC is to present new evidence based perspectives to support research and innovation policies that can enhance the new EU 2020 strategy. To do so, evidence is collected, analysed and the results presented on the success and failure of innovation policies in a number of European countries, as well as at the EU level.

When evaluating innovation policies, we take the new EU2020 perspective of smart, inclusive and sustainable growth as the objective. To this end we go beyond the traditional economic performance dimensions of growth and competitiveness, to also include the impact on environmental and social dimensions. Particular emphasis is given to those broad areas, which appear instrumental for Europe today in response to so-called "*grand*" societal challenges. In particular the climate change challenge is addressed, evaluating policies to support innovations for a sustainable growth path. On the social dimensions, a wider range of indicators is considered for feasibility to be included in the impact assessment, ranging from employment over human capital formation to include social cohesion. As SIMPATIC allows generating country and sectoral specific effects, it can also analyse the dimensions of social and economic cohesion across countries and sectors. For the sectoral dimension, special attention is devoted to include the specifics of ICT sectors as well as service sector innovations.

The uniqueness of SIMPATIC is that micro and macro approaches are combined in such a way that the impact of innovation policies can be assessed quantitatively and qualitatively with a broader and deeper perspective.

### 1.1.1 The Contribution of SIMPATIC Micro-Analysis to Evidence Based Innovation Policies

R&D subsidies are typically considered to be the main policy tool for RTD policies. They are one of the largest and fastest growing forms of industrial aid in developed countries. Innovation policy in industrialized as well as developing countries has also seen a rise in the use of R&D tax credits. Another significant development has been the changing uses of existing policy tools, with more targeted approaches in a 'grand challenges' perspective. There is very little, if any research, on how the effectiveness of innovation policy has changed during the last decade, how different tools worked or should have worked, how the same tools of innovation policy work in different countries. SIMPATIC address these questions using micro-evidence and analysis.

**(i) Evaluating R&D subsidies and tax credits**

The majority of existing economic research related to innovation policy follows either qualitative or reduced form quantitative methods that have been introduced in innovation policy research elsewhere. The popularity of these traditional methods stems from their relative simplicity and swiftness, and they have produced and continue to provide numerous useful insights. However, the methods have limitations in terms of policy advice, e.g., due to their inability to provide counterfactual analysis. Therefore, as a complement to traditional methods, we pursue a new research agenda of developing theoretical and structural econometric models for evaluation of innovation policy while also including reduced form analysis where appropriate. A key feature of our approach is that it combines economic theory and advanced econometrics into a so-called structural model. The advantage of structural modelling is that it allows for the modelling of the preferences of firms as well as of public agencies. The latter is particularly important for the more targeted type of innovation policy interventions in the grand-challenges perspective. As this structural model allows to explicitly take into account the participation decision of institutes and the granting decisions of agencies, it is an ideal framework for including the modeling of behavioral effects from and drivers for policy designs. Finally, structural modelling allows to conduct counterfactual policy analyses and tackle the causality issue that has plagued previous impact assessment analyses.

Secondly, the data available in SIMPATIC allows, for the first time, large cross-country comparisons. SIMPATIC has secured access to exceptionally high quality and comparable data across a number of Member States.

**(ii) Evaluating green innovation policies**

The evidence provided by climate change scientists clearly signals the size of the Climate Change challenge– probably one of the most pressing policy challenges we face today, requiring a large scale and speedy reaction. To keep the costs of mitigating and adapting to climate change “manageable”, a sufficiently wide portfolio of technologies in action in needed. Although we can go a long way with the diffusion of existing technologies, we also need new technologies to come on stream. These new technologies are not yet available or still far from large scale commercialization.

Facing a combination of environmental and knowledge externalities, the private “green innovation machine” cannot be expected to be effective on its own. It needs government intervention. R&D support is a necessary but not sufficient condition for government intervention. A portfolio of instruments is needed. This portfolio includes carbon pricing, established either through carbon taxes or cap-and trade systems.

SIMPATIC research identifies whether and how various instruments have succeeded in their goal of driving investment and innovation in low-carbon technologies.

### 1.1.2 The Contribution of SIMPATIC Macro-Analysis to Evidence Based Innovation Policies

Macro-quantitative modelling is a commonly used tool for the assessment of economic policies. These models have the advantage of providing a coherent quantitative perspective on competitiveness, growth and employment, resulting from a macroeconomic approach that traces global interactions in the whole economic system.

For the assessment of R&D policies or all other policies that are based on R&D or knowledge, for example green (including carbon pricing) and social policies, the minimum requirement for these models is to have an endogenous technical change module, and to describe precisely the knowledge externalities (spillovers) between firms, sectors and countries. The first requirement is necessary for describing how the policies will change R&D and human capital decisions, and the impact on economic performance. In addition, spillovers allow the macroeconomic productivity to go beyond the effects evaluated at the individual units.

The two models used in SIMPATIC, an Econometric one, NEMESIS, and a General Equilibrium one, GEM-E3, include already the modelling of endogenous technical change and knowledge spillovers. Within SIMPATIC, the two quantitative models NEMESIS and GEM-E3 are further developed by adapting these tools in order to address a number of specific questions linked to R&D, Green and Social policies, by including the results of micro-analysis.

For the assessment of RTD policies, an important issue is the impact of incentives (such as subsidies and tax credits) on private R&D decisions. For the subsidies for instance, in the former assessments, the leverage (or crowding-in) effect was based on econometric works and on calibration. But these inputs are too coarse to give precise answers to finely defined policies. It is for instance important to distinguish possible differences in leverage effects across countries and sectors and for different types of R&D (Green, Energy, I.C.T., etc.). The R&D decision module of the macro-models takes on board the inputs from SIMPATIC's micro works to provide up to date calibrations.

A second important issue is the modelling of knowledge spillovers between activities and between countries. Here again, micro works provides new insights for assessing intersectoral and international knowledge spillovers. Also these results are implemented in the NEMESIS and in the GEM-E3 models.

By now, it is well recognized that R&D drives growth, but that the evolution of demand may induce R&D. The case of "demand-led innovations" is further developed in NEMESIS for I.C.T. and services, through the interactions between investment in I.C.T. and R&D by service sectors, investment in R&D led by demand from services to I.C.T. producers, and innovation and productivity in both set of sectors.

***(i) Evaluating Green innovation policies***

As already discussed supra, climate change may be the most pressing policy challenge today. Macro sectoral modelling allows taking into account all the required interactions and to deliver results at macroeconomic and sectoral levels of green innovation policies in terms of competitiveness, growth, and employment. The minimum requisite for such macro-evaluations is an endogenous technical change but also a biased technical change that describes the direction of technical change that is induced by a change in production factor prices: most environmental policies are based on instruments that change these prices. NEMESIS and GEM-E3 have such a biased technical change approach.

A first important improvement developed in SIMPATIC is on the leverage effects of public incentives on green R&D decision and investment in green technologies. A second important improvement is on the possible crowding-out effect of green R&D on more general R&D. The results of micro econometric works are included in the decision module of NEMESIS and GEM-E3. These updated models are used for making an assessment of the European Climate-Energy package and the commitment of all European countries for the post-Kyoto period.

***(ii) Social Impact of R&D Policies, Social Innovation***

An important issue for social impact assessment of R&D is the definition of relevant indicators. New indicators are introduced in the NEMESIS model to incorporate socio-economic indicators such as GDP per head, unemployment rates and GDP inequalities between countries and EU regions (NUTS 2). The results of the RTD policy simulations on these various indicators are derived, showing which are the countries, sectors and workers that most benefit from the policies. It thus allows analyzing the impact on social and economic cohesion in the EU, through assessing effects on inequalities or convergence between EU countries, or between skill categories. One particularly scenario studied is the extension to the whole of Europe of flex-security policies.

### 1.1.3 The Contribution of SIMPATIC through its Micro-Macro Link

The **sectoral EU macro models** which SIMPATIC uses, allow the assessment of the impact of various innovation policy instruments at the aggregate national and EU level. Insights from the state of knowledge on the economics of innovation, including SIMPATIC's own analysis on ex-post policy impact analysis of R&D subsidies and tax credits, is used as input in these models, thereby drastically improving the model design and the quality of parameters used for simulating at the aggregate national and EU level, the ex-ante impact of a number of national and European research and innovation policy alternatives.

Applied macro-models are particularly looking for inputs in the following areas: (i) to which extent can public instruments leverage private innovative investments ("additionality"); (ii) how important are the drivers and barriers in the markets for innovation for incentivizing investments; (iii) how does innovation affect social dimensions; (iv) how different are new green technologies compared to other technologies; and (v) how strong are the mechanisms of technology diffusion across sectors and across countries and regions.

These inputs are provided from (i) the project's own micro work and (ii) drawing on a review of existing state-of-the-art scientific work and empirical evidence on the socio-economic and environmental analysis of innovation.

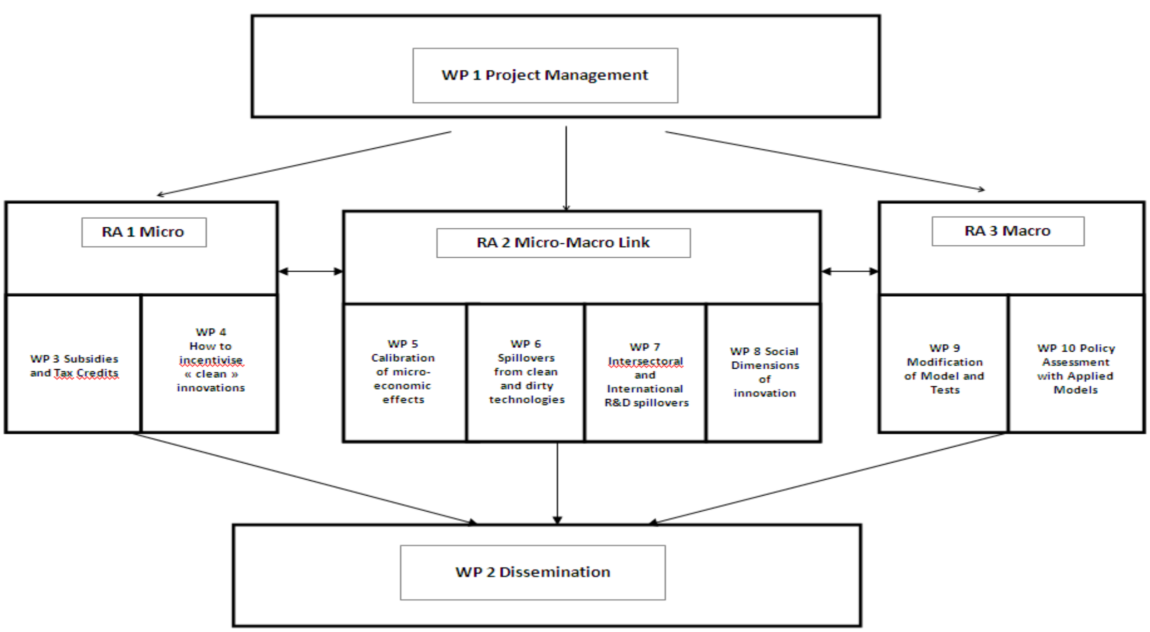
## 1.2 SIMPATIC Work Plan

SIMPATIC scientific work is structured around three main Research Areas (RA), with a number of Work Packages (WPs) linked to each RA.

The **micro** work is done in RA 1. This is subdivided into two major WP's: WP3 on subsidies and tax credits and WP4 studying ETS and green innovations.

The **macro** work is done in RA 3 corresponding to WP 9"Modification of Macro-Models and Tests" and WP10"Policy Assessment with Macro Models". WP9 and WP10 further detail the work on (i) adapting the macro models to the new challenges for innovation policy and (ii) using these adapted models for policy assessment exercises at aggregate national and EU level.

The **micro-macro link is** worked out in RA 2. The input to the macro-modelling comes from (i) own micro work developed within the SIMPATIC project and (ii) expertise in the team on state-of-the-art scientific micro work available outside SIMPATIC. WP 5 "Calibration of micro-economic effects" processes the SIMPATIC micro-work done in WP3 "Subsidies and Tax Credits" & 4 "How to incentivize "Clean" innovations" for input into macro-modelling. In addition, there are three other topics for macro-inputs covered: international spillovers, the specifics of spillovers from clean technologies and the social dimensions of innovations in separate WPs (respectively WP 6 "Spillovers from Clean versus Dirty Technologies", WP 7 "Intersectoral and international spillovers" and WP8 "Social dimensions of innovation").



# 2 MICRO ANALYSIS

## 2.1 Evaluating R&D Subsidies and Tax Credits

SIMPATIC (2013) offers the first systematic cross-country view on R&D subsidy (and/or tax credit) programs in different EU countries. The countries that are studied are Belgium (Flanders), Finland, Germany, The Netherlands, and Spain. Of these countries, Finland and Germany rely – during the period(s) studied – only on R&D subsidies, while the other three offer also R&D tax incentives of various forms.

### 2.1.1 R&D Subsidy Applications: Observed Patterns and Evidences

**Firm application behavior**

What characteristics explain whether a given firm applies for R&D subsidies from the national agency in question? The analysis finds that firm age has a negative impact on the probability of a firm to apply for R&D subsidies in all five countries. Firm size has a negative (nonlinear) impact on the probability of applying in Finland, Germany and Spain, and a positive impact in Flanders and Germany. Exporters are more likely to apply for R&D subsidies. With respect to SMEs, one could have expected that SMEs are more likely to apply given that they are often given favorable treatment (e.g. by allowing higher maximum subsidies). This turns out not to be universally the case. The only country for which there is any sign of a positive effect of SME status on the probability of application is Belgium, and even there the evidence is weak. For all other countries the effect is either clearly negative (Spain, The Netherlands), or zero or weakly negative (Germany, Finland).

**Agency decision-making**

The first systematic cross-country view on how government agencies behave when to decide on R&D subsidies is also introduced in the context of SIMPATIC. The decision variable explained is the subsidy rate, i.e., the percentage of the applicant firm's R&D cost that the government promises to cover.

The set of explanatory variables is largely the same as in the studies on firms' application behavior. In addition to these, information on how the agency graded an application is also obtained. Projects rated with a high market risk have a lower subsidy rate in both Spain and Finland. The technical challenge of the project has a strong positive impact on the subsidy rate in both Spain and Finland. The only country in which firm age has an impact on the subsidy rate is Finland where the effect is negative. Firm size has no effect on the subsidy rate in any of the five countries. The export status of the firm has no effect in any of the four countries (The Netherlands is the one country where this variable is not used) where it is used to explain the subsidy rate decisions.

The SME status was expected to have an impact on the subsidy rate as in all countries, SMEs get favorable treatment in the form of a higher maximum subsidy rate. It turned out that this prediction only seems to hold in Finland, Germany and The Netherlands, where an SME gets a subsidy rate that is somewhat higher. SMEs don't get higher subsidies in Belgium and Spain.

Also of high importance for evaluation is whether public R&D spending is "additional" to private R&D spending, or whether it substitutes for and tends to "crowd out" private R&D. Reviewing the macro and industry level literature, Capron and Van Pottelsberghe de la Potterie (1997) conclude that "despite the heterogeneity of the empirical models referred to in the literature, which makes any comparison exercise hazardous, the balance seems to tilt towards the recognition of a complementary effect between the two sources of funds. In Czarnitzki et al. (2014a) the results at firm level are highly mixed, suggesting a large heterogeneity in how firms respond to R&D support. In the most robust specification the authors found a crowding-in effect for Belgium and Spain, and the opposite for the rest of the countries. Beyer et al. (2013) claim that this heterogeneity manifests itself across firms/applications, across countries, and to some extent also across time. According to them, one source of heterogeneity are differences in institutions across countries and time.

### 2.1.2 R&D Subsidy Applications: Structural Modelling

In order to consubstantiate the previous analysis a structural model was estimated in Czarnitzki et al. (2014b). The benefit of a structural model is that one can uncover effects which would otherwise be unknown. This model builds on estimating firms' decisions to 1) apply for subsidies; 2) to invest or not in R&D; and 3) how much to invest in R&D if they invest. This is complemented by the analysis of the government's decision as to how much to subsidize a given R&D project. In this context, there are three dimensions of particular interest that can be traced with the structural model: the quality of the R&D ideas from the point of view of firm profits, the fixed cost of R&D, and the cost of applying for subsidies.

The following stylized facts emerged that are of key importance to policy:

- A large number of firms do not have R&D projects that are worth executing;

- A large fraction of those firms who end up pursuing R&D have very high perceived costs of applying for subsidies. This limits the benefits of such a policy, although admittedly at the same time keeps the budgetary implications at a more modest level;
- A comparison across countries suggest large differences in all key numbers related to R&D: the quality of ideas, the fixed costs of R&D, and the costs of applying for government support. In result, policies need to be adapted to local circumstances.

### 2.1.3 R&D Subsidy Applications: Counterfactual Analysis

When deciding on how to support private sector R&D, policy makers need to compare different policies against each other. For the purposes of fostering such an analysis, Czarnitzki et al. (2014c) performed a counterfactual empirical analysis, providing insights into how different policies perform. Following the same systematic cross-country comparison of the previous studies, the main analyzed policies were the following:

- Laissez-faire: no government support to private sector R&D;
- Optimal tax credit: a simple tax credit based on the R&D payroll. This policy seeks to mimic policies in several countries such as the Netherlands and Norway where the R&D tax credit is not on corporate tax, but on the R&D payroll taxes. The great benefit of a tax credit of this type is that it offers immediate support also to firms with no taxable profits;
- The current policy: in the case of the countries under analysis, this always includes R&D subsidies, but may – as in the case of Belgium, Netherlands and Spain – also include other forms of support.

Three main findings were achieved. Firstly, activist policies yield large gains in R&D among firms who would pursue R&D anyways, and next to no gains in terms of enticing new firms to start R&D. It seems to be hard to raise the fraction of firms engaging in R&D. This finding was very robust and holds across all countries and across all the implemented robustness tests.

Secondly, optimal R&D tax credits are high and activist policies yield large budgetary costs. It is important to have in mind that any costs have to be put in perspective by comparing them to the corresponding gains. However, it is a fact that all European governments struggle with budgetary balance issues and therefore the direct budgetary costs have some implications of their own, independently of the benefits they confer. Therefore, it is hard to see how governments could expand these policies greatly. Nevertheless, the estimated optimal tax credit or subsidy rates suggest that large expansions would be needed to ensure the socially optimal investment levels.

Thirdly, activist policies yield modest welfare gains and the gap between these and laissez-faire policy scenarios is very small. In this case, it is worth noting that while the increases in the level of R&D investment would need to very large to reach socially optimal level, this does not translate into equally large welfare gains. This happens because firms that would invest in R&D even without activist policies already spend so much that the marginal returns to R&D are quite low. Thus, pushing them to invest more has only a modest impact on their profits (while still generating sizeable spillovers). Furthermore, the policies fail miserably in enticing new firms to start investing in R&D. This is crucial for the above observation as the returns to the first invested R&D euros are very high in all countries (but are thereafter subject to decreasing returns to scale).

Thus the main policy implication of the last remark is that the most obvious but in no way simple way to improve welfare through R&D is to help firms come up with better R&D projects, thereby enticing more firms to invest in R&D. This certainly calls for other policies than R&D support, such as policies targeting education, regulation, market conduct and intellectual property.

### 2.1.4 R&D Support Programs: National versus International Schemes

Huergo and Moreno (2014) compare the effects of different public R&D funding programmes on firms' technological performance. Using data on 2,319 Spanish firms during the period 2002-2005, three different programs were analysed: i) the low-interest loans provided by the main national agency which finances firms' R&D projects; ii) the national scheme of R&D subsidies, and iii) and the European system of R&D grants. This allowed the authors to analyse the relative relevance of two features of public programmes: the national or supranational character of the financing agency and the magnitude of reimbursement implied in the design of public support.

The authors found that the participation in national subsidy programs and in European subsidy programs are positively linked to each other. The same happens with the soft loans and national subsidies schemes, indicating the presence of common unobserved factors that affect the probability of participating in both programs. Besides, being awarded a soft loan or a national subsidy clearly increases the probability of conducting R&D activities. However, participation in European subsidy programs does not seem to affect the decision to undertake these activities.

Additionally, once a firm has decided to invest in R&D, the intensity of the investment may also differ. Therefore, the three types of public aid stimulate the intensity of R&D investment differently, with soft loans presenting the highest impact. It appears that national subsidies have a higher impact on internal R&D intensity than EU grants, but the opposite relation is found in regard to total R&D intensity. This suggests that international funding is more effective for fostering external R&D activities.

As for innovation outputs, public support has an indirect effect by stimulating R&D intensity, which has a positive impact on innovations and patent applications. In addition, participation in the loan system and in the European subsidy program has direct positive effects on the probability of obtaining product innovations and applying for patents. However, this direct effect is absent with regard to process innovations.

### 2.1.5 Key Policy Implications

- Governments should attract more applications by redesigning subsidy schemes in order for R&D grants to have a larger effect on the economy. As it was shown, only a very small fraction of firms actually applies for subsidies, even within firms that do invest in R&D;
- Governments should define ex-ante what are the objectives to be achieved with R&D subsidies and predict what type of firms are most likely to engage with the defined target and check how likely it is that such firms apply for the subsidies. Activation campaigns can be targeted towards firms that are likely to produce the type of R&D the government would want to subsidize if research shows that they are not likely to apply on their own;
- The same process should be implemented in order to define the subsidy rate, in such a way that the firms whose R&D produce the highest social benefits get the highest subsidies. With this exercise, the grading process can be adjusted towards the direction of the initial goal;
- Given that social returns to R&D are subject to decreasing returns to scale, the most effective way of improving welfare through R&D is to help firms come up with better R&D projects. This calls for policies other than R&D support, namely policies targeting education, regulation, market conduct and intellectual property;
- With the large regional differences in the quality of ideas, fixed costs of R&D, and costs of applying for government support, policies need to be adapted to local circumstances;
- Participating in national subsidy programs and in European subsidy schemes are positively linked to each other.

- Within the firms that do conduct R&D, different instruments may affect differently the intensity of these research activities.

## 2.2 Evaluating Green Innovation Policies

This section identifies whether and how the various policy instruments have succeeded in their goal of driving investment and innovation in low-carbon technologies. From micro-econometric evidence and analysis conclusions are drawn on whether the various instruments incentivized a specialization of companies into carbon saving innovations.

### 2.2.1 When and How to Support Renewables? Letting the Data Speak

Low-carbon energy technologies are pivotal for decarbonizing our economies up to 2050 while ensuring secure and affordable energy. Consequently, innovation that reduces the cost of low-carbon energy would play an important role in reducing transition costs. Zachmann, Serwaah and Peruzzi (2014) focus on the balance and timing of two main policy areas to drive innovation:

- Public research, development and demonstration (RD&D) subsidies;
- Public deployment policies.

The current literature on this topic provides some evidence of (i) decreasing returns to both, deployment and RD&D and (ii) a potential positive interaction of the two policy measures. In addition, the price of the competing technologies matters. This would indicate that innovation is best driven by a combination of RD&D and deployment.

However, as it is argued, numerous countries introduced deployment support and RD&D spending but no one applies an analytic approach for determining an optimal policy mix. This resembles a “shot in the dark” approach, and its persistence is astonishing given the magnitude of the corresponding public spending.

In order to find evidence of how to better encourage innovation in energy technologies in terms of specific timing and balance of deployment policies and RD&D spending, a panel of 28 OECD countries was explored, covering the time period from 1990 to 2010. By focusing on wind and solar energy, the main variables of interest are patent count (as output of innovation), R&D expenditure and deployment. Revealed comparative advantage (RCA) rankings are also used in order to access the impact of these policies in countries’ competitive advantage in wind and solar.

It was found that increasing RD&D support by one standard deviation over a period of time has a substantial impact on patenting in this technology. Solar deployment has a strong effect on solar patenting, while the effect of wind- deployment on patenting is modest. Nevertheless, the combination of both policies appears to be more than the sum of its parts. In fact, for wind the additional benefit in terms of patents when joining policies is up to 25 percent (for solar 1 percent). Technology spillovers were also found, by considering the impact of patenting and deployment in a given technology on the other technologies. Furthermore, the deployment and RD&D spending in one country seems to have an effect on patenting in neighboring countries.

In regard to countries' competitiveness in these areas the results suggest that a key driver of export specialization in renewables is the innovative power of a country. Indeed, deployment is positively associated with competitiveness of the corresponding technology. A sustained increase in domestic deployment of wind turbines increases the RCA ranking in wind turbines by about one position in the case of Germany. For solar panels there is also a clearly positive impact, as countries which deploy more solar panels also appear to export more of them in future. The results for the impact of RD&D on competitiveness seem all not very meaningful.

In conclusion, these results indicate that timing, cross-border spillovers and technology spillovers matter for the success of support policies. With respect to timing, the data suggests that a certain sequence of RD&D support and deployment is most strongly linked to patenting. In particular, deployment based on earlier RD&D expenditures seems to strongly coincide with wind innovation. Also, cross-border spillovers play a positive role for wind deployment. Finally, there is slight evidence that technology spillovers might matter for patenting.

### 2.2.2 Key Policy Implications

- Deployment and RD&D support are effective in advancing technology development;
- Certain combinations of deployment and RD&D support are more efficient than others; This calls for a strategic approach towards renewable energy technology support;
- The existence of substantial cross-border spillovers from deployment implies that international coordination might make renewable energy technology support more efficient;
- Investing more in ex-ante and ex-post evaluation of renewable energy technology support schemes to avoid the uncoordinated "shot-in-the-dark" is clearly worthwhile.

# 3 MACRO ANALYSIS

## 3.1 Evaluating Green Innovation Policies

Assuming that the EU adopts early action towards virtual decarburization of its energy system without waiting for an overall agreement involving other major polluters in the world, it is of particular interest to understand whether there are any economic consequences that could accrue from the so-called "first-mover advantages" in energy technologies. Indeed, in the eventuality that other major polluters join in the effort at a later stage, it is possible that the EU has established a lead in key technologies and sectors involved in GHG abatement sufficient to benefit from the rapidly expanding world markets, thus being able to offset at least in part the economic costs associated with early and drastic decarburization.

General Equilibrium models have been extensively used to evaluate the macro-economic impacts of alternative energy and climate policies and to quantify the overall costs of climate change mitigation action. However, they usually lack technological details for the representation of the energy system. In order to overcome this limitation, the multi-sectoral, multi-regional global computable general equilibrium (CGE) model GEM-E3 was enhanced in the context of SIMPATIC with a bottom-up representation of the energy system and emissions reduction options[1]. Particular attention was given to power generation technologies, energy efficiency improvements, representation of the transport sector (including mobility electrification), and energy demand for households and biofuels. The enhanced model separates the representation of clean energy producing sectors combined with endogenous technology dynamics, which allows for the quantification of possible "first-mover advantages" in case that the EU adopts strong climate policies earlier than other parts of the world. However, the model assumes that the technological learning initiated by the EU leads to productivity improvements in other regions due to knowledge spillovers, which diminish the "first-mover advantages" over time.

### 3.1.1 Assessment of the EU "First-Mover Advantages" in Energy Technologies: Projections from the GEM-E3 Model

As shown in SEURECO and ICCS (2014), the weak climate policy reference scenario assumes a continuous regional fragmentation of climate policies and a stalling in international climate policy negotiations. This is the baseline scenario of the GEM-E3 model. The EU has established an internal target to reduce

[1] The modifications, simulations and reference scenario building of GEM-E3 can be found in ICCS (2014a), ICCS (2014b), SEURECO, FPB and ICCS (2013) and SEURECO, FPB and ICCS (2014).

total GHG emissions by 20% from their 1990 levels and to increase RES share in gross final energy demand to 20% by 2020. The baseline scenario for the SIMPATIC project reflects these policies up to 2020. Beyond 2020, the reference scenario assumes an annual reduction of the ETS cap (equivalent to an average reduction of 1.74% p.a.), no additional policies for energy efficiency and RES penetration, limited electrification of the transport sector and that non-ETS GHG emissions will remain below the cap specified for 2020.

With these assumptions, GEM-E3 delivers the following projections concerning **energy technologies.**

In the market for **wind equipment**, the baseline implies for Europe an increase in the market for wind equipment to the middle of the current decade. The world market for wind turbines is expected to grow vigorously until 2035. The share of the EU in world cumulative sales between 2010 and 2035 is projected to be a substantial 30%, but China will also account for 25% and North America for 17%. In general the baseline implies some erosion of the competitive position of the EU in the wind generator market. This is reflected both in a loss of domestic market share after 2025 and a reduction in the share of EU exports in the Rest of the World market from 2020 onwards with the emergence of new producers in the developing world.

For **photovoltaics**, there is a rapid growth in the EU in the market between 2010 and 2030, a hiatus between 2030 and 2040 and a resumption at the end of the forecast period, albeit at a more modest pace. The baseline projects a dramatic erosion of EU competitive advantage with regard to PV production. EU producers are effectively eliminated from international markets by the end of the forecast period. At the same time, imports of photovoltaics will end up accounting for more than half of domestic demand.

Unlike wind and photovoltaics, **CCS technologies** cannot be considered to be a properly available option for power generation currently. Existing **CCS** plants are effectively demonstration prototypes. The requirements of high carbon values and the fact that the technology is not readily available mean that its prospects before 2030 are almost non-existent. Although given baseline climate policy assumptions the importance of CCS in economic terms is very limited, its potential must not be underestimated. Under different conditions to be examined in alternative scenarios within the SIMPATIC project, CCS can play a major role because it allows the utilization of abundant fossil fuel resources like coal in a carbon constrained world. Under such conditions, an early start by the EU could provide a competitive advantage in a potentially vast market.

The GEM-E3-RD model distinguishes between **plug-in hybrid vehicles** and **pure electric ones**. Both categories depend crucially on the development of cost-effective advanced batteries with a high power density allowing for a reasonable range. The baseline takes an optimistic view that both will start becoming available in the EU and in the Rest of the World already by 2020. Beyond that date, the evolution of the market is projected to be rapid. Apart from the EU, high penetration rates are achieved mostly in highly developed economies, like the USA and Japan. The low penetration rates notwithstanding the potential market for non-conventional vehicles is huge especially if (and this is the case in the table below) the whole cost of the vehicle and not just the parts that render it unconventional are considered. This is clearly another case where an early advantage could confer major benefits that are worth exploring in subsequent scenarios within the SIMPATIC project.

**Biofuels** constitute another category of alternatives to $CO_2$emitting conventional liquid fuels in transport. They are already widely use. As the baseline assumes a continuation of this situation and even some further increases in oil prices beyond 2030, the incentive to switch into biofuels is likely to persist. In terms of EU biofuel production, in what concerns ethanol the baseline suggests an increase in penetration of imports. This is not true of biodiesel where the assumption is that promotion of biodiesel production constitutes part of the Common Agricultural Policy. The EU exports no biofuels whatsoever on grounds of lack of competitiveness.

In terms of the main macroeconomic consequences of this policy, it is important to stress that the changes induced by carbon pricing are costly and energy services become more expensive. Thus, this leads to an overall decline of the EU economic activity compared to the scenario without the reduction of GHG emissions, despite the increased investments in R&D. The loss of competitiveness of the EU economy due to higher energy costs is offset by increased EU exports of clean energy technologies. With regard to the impact on employment, this is projected to be minimal, as additional jobs in clean energy sectors counterbalance the reduction in employment in other production sectors. In terms of sectoral impacts, production losses are higher in industrial sectors, mainly in energy intensive and trade-exposed industries (basic metals, chemicals and cement), and in the energy sectors compared to services.

### 3.1.2 Key Policy Implications

- R&D efforts on clean energy technologies combined with economies of scale and other learning by doing effects, lead to reductions in costs that can be appropriated by EU industries;

- The EU production of clean energy technologies is projected to increase significantly by 2050, with most of this driven by higher domestic demand, but also by increased exports to non-EU regions due to competitive advantage;
- The most important technological option appears to be electric vehicles, due to their particularly high value added and the competitive advantage in global trade already enjoyed by the EU in the vehicle manufacturing sector;
- The changes induced by carbon pricing are costly and energy services become more expensive, leading to an overall decline of the EU economic activity compared to the situation without this environmental policy. The loss of competitiveness of the EU economy due to higher energy costs is offset by increased EU exports of clean energy technologies, and the impact on employment is projected to be minimal, as additional jobs in clean energy sectors counterbalance the reduction in employment in other production sectors.

## 3.2 Social Impact of R&D Policies

This section sums up the results of two policy scenarios analyzed with the enhanced NEMESIS model[2]. The two policy scenarios are i) the ex-ante assessment of the impacts on GDP and employment of the FP7 2013 budget of € 8 billion; and ii) the ex-ante assessment of the economic and social impacts of the 2014 call for proposals of Horizon 2020. Some properties of the NEMESIS model on the leverage effect of R&D incentives and on the economic performance of R&D were enhanced in SIMPATIC, namely with the incorporation of the role of Information and Communication Technologies as General Purpose Technologies, as well as of other intangible assets.

The main mechanisms involved in the assessment of R&D policies in the enhanced NEMESIS model are:

- The crowding in or leverage effect that allows calculating how much R&D expenditures will allow a one euro subsidy;
- The knowledge spillovers that describe all the positive externalities induced by R&D increase;
- The economic performance resulting for each productive sector;
- The intersectoral and macroeconomic feedbacks that allows to calculate the competitiveness, growth and employment consequences of the policy.

[2] The modifications and reference scenario building of NEMESIS can be found in SEURECO (2014), Sessa (2013), Melon and Bossier (2014), SEURECO, FPB and ICCS (2013) and SEURECO, FPB and ICCS (2014).

### 3.2.1 Economic Impact of the FP7 2013 Budget of €8 billion – NEMESIS Model

The crowding in or leverage effect allows calculating how much R&D expenditures will allow a one euro subsidy. Taking into account recent literature results, SEURECO and ICCS (2014) adopted for the present simulation of the 2013 call the following leverage effect: 0.5 for public R&D investments (40% of the €8 billion funding) and 0.9 for the private sector. Averaging, these assumptions give a leverage effect of about 0.74, which means that €1 EU investment from the 2013 FP7 budget is calibrated to generate €1.74 of research and innovation expenditure. Hence, the €8 billion FP 2013 funding will generate € 13.9 billion R&D and innovation expenditure.

Four phases of economic impact are distinguished:

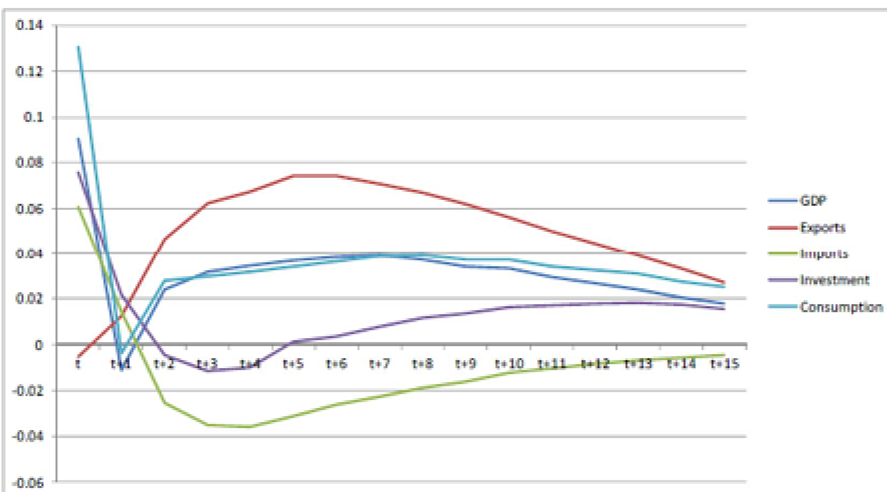
1. The first one is the expenditures phase when R&D expenditures increase demand for research equipment goods and for researchers. It is only a "demand driven phase" in the sense that the R&D increase has not yet given innovation during the maturation of R&D (no supply effects). The simulation assumes that the extra €8 billion is handed over in the first year in a one-off shock. Figure 1 shows that GDP grows from year one on a scale slightly lower than the shock effect. In fact, R&D investment consists mainly in physical investment (research hardware) and in jobs, which result in higher pay and consumption. During the first three years, there are only demand effects, because the additional R&D has not yet achieved its full impact. This translates into higher prices and imports, which affects the external balance somewhat and causes the multiplier to "leak". If the instant multiplier is smaller than one, the sum of the effects on the first three years is greater than unity, which is consistent with what is expected. 210,000 jobs are created in the first year; the number then falls back almost completely, as does the GDP, since the shock is one-off;
2. During the second phase, extra innovations progressively arrive. Total factor productivity increases and unitary cost decreases; the quality is also enhanced; these two factors will increase the demand. But this takes time: consumers do not immediately react to a lower price and they need time in order to adapt. For equipment goods, the adoption of new technologies pass by a diffusion process that takes time. The result of an increase in productivity without instantaneous demand expansion is job destruction. During this phase employment falls below its business as usual level (see Figure 2);
3. The third phase is the diffusion of innovation. During this phase, lower prices and improvement in quality will increase domestic demand (consumption and investment) and improve

competitiveness and the external balance. The GDP is above its business as usual level and grows up to year t+10 (with t is the year of the shock). It is then about 0.04%. Employment is then around +0.02% which is small compared to GDP growth, but this is explained by an increase in productivity resulting from innovation. Spending on research and innovation results in higher competitiveness that contributes to increase the global surplus of European external balance or to reduce the deficit of some Members States;

4. The last phase is the obsolescence of the previous new knowledge induced by new R&D increase and new innovations.

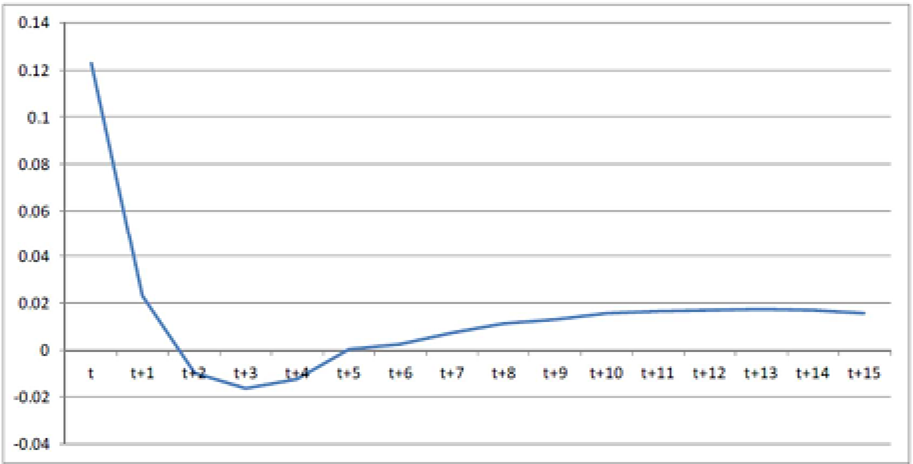
With the depreciation of knowledge, the effects of given innovations (those which results from the R&D policy analyzed) will decrease over time and so its effect on GDP and its components. In t+5, the level of GDP is only 0.02% above its business as usual level. Nevertheless, the employment is decreasing slower.

*Fig. 1 One-off shock across all sectors (% gap from central account).*




SOURCE: SEURECO, FPB AND ICCS (2013).

*Fig. 2 Employment trends (% gap from central account).*




SOURCE: SEURECO, FPB AND ICCS (2013).

The cumulative jobs created from the policy shock is reflected in the area between the employment curves and the time axis. Cumulative job creation in 2027 (t+15) is 569,000 persons-year. Over the 15 years period, this represents, on average, **38,000 jobs** more than in a situation without the FP7 2013 call.

The cumulative GDP represents all the wealth created by the initial FP funding. It is interesting to calculate the multiplier effect of this expenditure, to see what value €1 of FP can create. After 15 years, the wealth created amounts €75 billion; after 20 years this is €86 billion. This implies that after 20 years, the multiplier effect of R&D expenditures is about 6.2.

### 3.2.2 Comparing NEMESIS Model Forecasts with "Europe 2020" Targets

SEURECO and ICCS (2014) also compare the NEMESIS model forecasts with "Europe 2020" targets.

| | | | | Nemesis | |
|---|---|---|---|---|---|
| | 2005 | 2010 | "Europe 2020" target | 2020 | 2030 |
| Employment rate | 68.0% | 68.6% | **75.0%** | 72.3% | 79.1% |
| Gross domestic expenditures on R&D | 1.82% | 2.01% | **3.00%** | 2.01% | 2.01% |
| Greehouse gas emissions (index 100 in 1990) | 92 | 85 | **80** | 74 | 68 |
| Share of renewable energy in gross final energy consumption | 8.5% | 12.5% | **20.0%** | 16.0% | 19.6% |
| Primary energy consumption (Gtoe) | 1.95 | 1.89 | **1.56** | 1.66 | 1.59 |

SOURCE: SEURECO, FPB AND ICCS (2013).

The table above displays the NEMESIS forecasts for the “Europe 2020” targets. The first indicator, the European employment rate, is targeted at 75% in 2020. The baseline scenario displays an employment rate of only 72.3 % in 2020, and it is only in 2025 that the 75% objective is reached. The employment rate continues to rise after and reaches 79.1% in 2030. For the second target, the R&D to GDP ratio, set to 3% for 2020, the NEMESIS forecasts shows a ratio of about 2%, stable over time. This is a conservative assumption, and any policy designed to rise this intensity and stimulate innovation and growth. The other targets concern energy and environment. The -GHG emissions reduction in 2020 compared to 1990 is reached, but the energy efficiency and renewable targets are not. Here again, along with resources efficiency policies (energy-saving investment support, re-enforcement of environmental standards, reduction of emissions caps in ETS), policies aiming to reinforce R&D and innovation may help to improve resource efficiency and accelerate the development of renewable energy sources.

### 3.2.3 Key Policy Implications

- EU research programs can be expected to generate an increase of productivity, creation of employment and reinforcement of the external trade balances, in a period where low productivity is one of the main challenges that Europe faces.

# 4 MICRO-MICRO LINK

## 4.1 Spillovers at Inter-sectoral and International Level

It has been well established in the literature that there are intra- and inter-sectoral knowledge spillovers, national as well as cross-border, that make the social rate of return to R&D exceed the private rate of return. These effects can accrue, for example, from the use by a firm of public knowledge generated by other organizations, use of enhanced intermediate inputs, international trade in final goods, foreign direct investment, and migration of scientists, engineers, or educated people in general.

This section aims at exploring how to take such spillovers into account, as these are essential to examine the impact of R&D policies and R&D multipliers into country and European-wide productivity and growth effects.

### 4.1.1 Intersectoral and International R&D Spillovers

In the context of SIMPATIC, Belderbos and Mohnen (2013) summarize the main insights generated by the literature on spillovers, drawing conclusions on the crucial link between the micro and macro analyses.

An important theoretical distinction was discussed regarding knowledge spillovers. Pure knowledge spillovers arise if firms learn from ideas, technologies, blueprints, etc. from other firms and utilize this knowledge in their own R&D and production process. They arise through the non-rival and public good nature of knowledge. In the other hand, pecuniary spillovers, arise if firms get access to the fruits of ideas and R&D of other firms through economic transactions, i.e. with trade, direct investment, hiring of workers, research collaborations, and mergers and acquisitions. The most widespread form of such spillovers is when firms purchase (capital) goods that embody ideas and technological knowledge developed by other firms. These two types of spillover are hard to dissociate because knowledge flows are often concomitant. Taking this into consideration, an inclusive approach to spillovers is preferred, focusing in economy wide effects on output, productivity and employment.

Spillovers depend on the proximity between the firms or industries. Two industries with a higher degree of closeness will benefit more from spillovers. However, the role of distance can be reduced by intensifying the use of transfer mechanisms such as trade, migration, foreign direct investment, etc…

These effects are also moderated by the absorptive capacity of the beneficiary. Improving this capacity should also be a focus of policy attention.

In general, studies have suggested that both technological distance and geographic distance attenuate the productivity effects of R&D spillovers, while proximity appears less crucial for the most proximate technologies. Technological knowledge developed by leading industries at the technology frontier also seems to diffuse more broadly. Furthermore, spillovers from competitors and suppliers appear to contribute to TFP growth, in addition to intra-firm technology transfers.

However, R&D spillovers may in some cases also be negative. When new products and technologies developed by a firm makes a competitor's existing products and technologies obsolete, these become less productive and do not generate the same demand. Similarly the social rate of return to R&D is reduced when R&D is used as a mere strategy to preempt competition or when patent races lead to duplicative R&D. Potential negative R&D spillovers, if these occur, are most likely to occur for horizontal spillovers within narrowly defined industries.

## 4.2 Spillovers from Clean versus Dirty Technologies

Spillovers are also relevant to understand the likely impact of climate policies on short and medium term economic growth. Indeed, if spillovers in clean technologies are higher than for dirty technologies there might be positive growth effects that need to be taken in consideration by policy makers. The optimal level of subsidies for clean R&D might need to be different from those for dirty technologies they replace.

### 4.2.1 Effect of Energy Prices on Clean and Dirty Innovation

Aghion et al. (2012) examine the link between energy prices (e.g. fuel prices) and innovation using firm level data for the global automotive industry. Importantly, price effects on radical clean transport technologies areas – e.g. electric or hydrogen propulsion – are distinguished from those from internal combustion engines ("dirty").

The results suggest that there is a short run price elasticity of clean innovation of 0.97 and a short run price elasticity of dirty innovation of - 0.57. Clean innovation increases and dirty innovation reduces in response to a uniform global increase in fuel prices.

When using the tax component of fuel prices as an explanatory variable instead of tax-inclusive fuel prices, slightly smaller values are obtained, consistent with the idea that only part of a cost increase will be imposed on consumers. With this framework, a short run tax elasticity of clean innovation of 0.40 and a short run tax elasticity of dirty innovation of - 0.23 were found.

They also find evidence for two different dynamic channels which determine the long run response at the firm level. Firstly there is a strong path dependency whereby firms are more likely to engage in the same type of innovation that they have been conducting in the past.  In addition, Dechezleprête and Martin (2013) find evidence for stronger innovation spillovers within innovation types. Both these effects give clean innovation a disadvantage when starting from a state of the world where dirty innovation is historically more dominant. However, these feedback effects also create a multiplier effect leading to a stronger long run response of a given policy intervention.

### 4.2.2 Effect of ETS on Clean Innovation

As it is explained in Dechezleprête and Martin (2013), policies that primarily target the environmental externalities such as carbon emission pricing – through carbon taxing or a trading system – might not only reduce GHG emissions. By putting a price on carbon, they also provide incentives for companies to direct their R&D investments more to clean technology areas.

The European Emissions Trading System (EUETS) is arguably the largest climate policy initiative to date which has now been operating for 8 years. Calel and Dechezlepretre (2012) examine its impact on innovation.   Nearly 3,500 companies are compared that, by virtue of operating at least one sufficiently large installation, came under EU ETS regulations in 2005, with over 4,000 comparable companies that were exempted. Before 2005, these two groups were similar in size, in patenting activities, and operated in the same countries and economic sectors. Both groups would have faced similar macroeconomic conditions but from 2005 they faced different regulatory obligations for their emissions.

The firms look similar over the period 2000-2004, but since the EU ETS launched in 2005, EU ETS regulated firms have started filing more patents for low-carbon technologies. EU ETS firms have increased their low-carbon patenting by about 10% compared to the control group of firms not exposed to EU ETS.

### 4.2.3 Knowledge Spillovers from Clean and Dirty Technologies

A new dataset is used in Dechezleprêtre, Martin and Mohnen (2013) including over one million patented inventions, clearly distinguishing between clean and dirty inventions in the areas of energy production, automobiles, fuel and lighting, and three million citations to these patents. This allows to compare the magnitude of the knowledge spillovers for both types of technologies and the potential drivers behind the observed differences in these externalities.

The authors find consistent evidence that clean patents generate 20 to 30 percent higher knowledge spillovers than their dirty counterparts. All other things being equal, clean patented inventions receive 43% more citations (between 23% and 160%, depending on the technology) than dirty inventions. Furthermore, there are also innovations that make dirty technology less dirty by improving their efficiency – the grey technologies. It was found that clean technologies exhibit significantly higher levels of spillovers than grey technologies, which themselves outperform truly dirty technologies. These results hold for all four technological fields and are robust to a large number of sensitivity tests. Interestingly, the gap between clean and dirty technologies has been constantly increasing during the past 50 years. Moreover, clean patents are not only cited more often, they are also cited by patents that are themselves cited more often (irrespectively of their technological area).

Dechezleprêtre, Martin and Mohnen (2014) explain that these findings support the claim that climate policies that induce clean innovations while displacing dirty innovation could have a short to medium run positive impact on economic growth - in addition to avoiding dramatic reductions of GDP and damage because of climate change in the long run. Furthermore, the presence of localized spillover effects undermines the concern that unilateral climate policies led to negative competitiveness effects.

### 4.2.4 Key Policy Implications

- Policy interventions such as an increase in fuel taxes lead to strong long-run responses given the multiplier effects that accrue from the feedback mechanisms related with technological path dependence;
- Clean innovations are in disadvantage when starting from a state of the world where dirty innovations are historically more dominant. Radically new clean technologies should receive higher public support than research activities targeted at improving the efficiency of existing dirty technologies;
- Spillovers from clean technologies are about 20 to 30 percent higher than spillovers from dirty technologies. In result, fuel taxes should be complemented with specific support for clean innovation—e.g. through additional R&D subsidies—that goes beyond standard policies in place to internalize knowledge externalities;

- Carbon pricing, like the EU ETS induces firms to invest more in developing low-carbon technologies.
- Innovation from dirty to clean technologies reduces the net cost of environmental policies and can also lead to higher economic growth in the short run, if the benefits from higher spillovers exceed these costs. Indeed, independently of the environmental problem, if the under-provision of knowledge is more severe for clean technologies, then environmental policies could generate growth by simply correcting the market failure that has been hampering the economy. Moreover, these technologies will also eventually increase productivity.

## 4.3 Social Dimensions of Innovation

This section aims at analyzing how innovation impacts employment and growth. Moreover, most of the research on innovation typically focuses on technological innovations and on manufacturing sectors that pursue R&D. However, other types of non-technological innovations are also of key importance, not only for technological advancement and growth, but also, more broadly, to improve the quality of life of individuals and communities. These types of innovations are more typical for non-manufacturing services sectors, including non-market based services. In addition, increasing interlinkages of services with manufacturing opens additional channels through which innovation in services influences growth and employment. Manufacturing firms introduce services, new business models and other forms of non-technological innovations related to their major offerings in order to complement and upgrade their value chains. Knowledge intensive business services (KIBS) play a critical role in these processes as the catalysts of innovation in the whole economy, acting, for example, as agents for innovation, productivity and export performance of manufacturing firms.

### 4.3.1 Employment and Innovation

Economic theory suggests there is a dual effect of innovation on employment. Innovation may lead to the creation of new/additional jobs for the new products or processes it is offering. At the same time, innovation may lead to a reduction in employment due to destruction of existing jobs, which the innovation is replacing. The complexity of the relationship between successful innovation and employment growth is further enhanced at the macro-level by the existence of many transmission mechanisms, feedback loops and institutional factors, which play a role in the determination of the end effect on employment. Even at the firm level, the overall effects on the labour demand of an innovation firm are not straightforward for product and process innovations. Product innovation may increase turnover and thus employment, but if the innovation leads to a market monopoly or displaces older, more labour intensive products it might lead to a reduction in employment. Similarly, process innovation, may have a negative direct effect on employment as improved production processes reduce the need for labour, but may also ultimately lead to an increase in employment if lower production costs are passed to consumers, which, in turn, increase demand.

In the context of SIMPATIC, Damijan et al. (2013) investigate the dual effect of innovation on employment. They also look at the impact on skill upgrading. They distinguish between technological (product and process) and non-technological innovation (organizational and marketing). They also distinguish between manufacturing and services sectors.

Using four waves of the Community Innovation Survey data for the period 2004-2010 for 28 EU countries, they find, in line with the literature, that product innovation, as reflected in differential output growth of the new products, has a consistent positive effect on employment growth. This effect is larger for manufacturing industries than for services. Process innovations are found to exhibit no labour-displacement effects neither in manufacturing nor in service industries. On the other hand, organizational and marketing innovations reveal a consistent positive impact on employment.

Process, organizational and marketing innovations were also found to have substantial positive impacts on skill demand in manufacturing sector. For instance, results suggest that increasing the share of firms engaged in process innovation by 10 per cent will lead to an increase in share of high skilled labour by 2 per cent, while increasing the share of firms engaged in organizational and marketing innovation by 10 per cent will lead to an increase in share of high skilled labour by 4 per cent and an increase in share of scientific workers by 2 per cent. These effects of innovation on demand for skilled labour are, however, limited mainly to manufacturing sector. In service industries, these effects are significantly lower. What is more, when studying both issues the authors also control for the impact of Chinese import penetration. Chinese import competition presented no impact on employment growth in manufacturing industries, but showed a strong positive impact on skill upgrading. The results indicate that increasing the share of Chinese imports in total imports by 10 per cent leads to an increase in share of high skilled labour by 2 per cent.

### 4.3.2 Service Innovation

Notwithstanding the fact that knowledge on service innovation has improved significantly in the last two decades, this knowledge has not been adopted more broadly in public policy shaping and integrated into the design of innovation support measures. The attention of policy makers to service innovation and the amount of public funds spent to support service innovations is still disproportionate with the economic importance of services and services related innovations. A number of misunderstandings and myths remain concerning the benefits and impacts of service innovation due to deficiencies in measuring non-technological innovation that is particularly relevant in services. It is of paramount importance to better understand service innovation (in all its varieties) and the ways and means we have of assessing and fostering it. Finally, one cannot ignore the dominant role of services in value added and employment in advanced economies, as well as the facilitating role of service activities in promoting innovation and competitiveness throughout the economy. These facts put innovation in the service sector and in service activities high on the agenda of business strategy and of innovation policy.

Stare (2013a, 2013b) considers "service innovation" as any innovation activity with service-like attributes, which can occur in any sector of the economy, apart from the service sector. Innovation in the service sector is being increasingly acknowledged, but the effects of service innovations on other sectors of the economy, most notably on the manufacturing sector, are studied less. Service innovation is more than innovation in services and it is not synonymous with non-technological innovation.

Public policy design needs to take account of the peculiar features of service innovation. Service innovation has a lower R&D intensity in the traditional perspective of technological innovations. In addition, it is usually less formalized and rarely carried out in research and development departments; it is often more incremental, implicit and often less visible. Moreover, service innovation is largely a distributed phenomenon that depends on cooperation and interactions among stakeholders (including the suppliers, research and university, intermediate and final customers) to a greater extent than in technological innovation. Finally, service innovation is mainly demand driven and emerges as a response to user needs (intermediate and final users) that provide critical incentives.

Given the still scarce empirical research in the field of service innovation, Stare and Damijan (2013) study the impact of this type of innovation on employment and skills composition. To account for this, a general framework is employed that accounts for the impact of firms' own innovation as well as innovation spillovers from vertically linked services sector on individual firm's employment growth and changes in skill composition. The impact of firms' own technology and non-technology innovations on employment and skills composition is studied in manufacturing and in services firms. In addition, it is studied how innovation in manufacturing and services industries affects employment and skill composition in vertically linked manufacturing and services firms via spillover effects.

The analysis uses unique representative samples of micro data for Spain and Slovenia for the period 1996-2008. The analysis shows mixed results. In Spain, there are positive effects of firms' own innovation both on future employment growth and on high-skilled labor shares. In Slovenia no such effects were found. In terms of innovation spillover effects on employment, the research finds on the sample of Spanish firms that product innovation in vertically linked industries is positively affecting firms' future employment growth, while process innovation is shown to have a negative impact. The opposite results were found on the sample of Slovenian firms. In terms of the effects of innovation spillovers on skill composition of labor, in both countries only manufacturing firms experience some significant innovation spillover effects. Positive effects of vertical spillovers are found from product and marketing and organizational innovations and negative spillovers effects from process innovations. In Spain these significant innovation spillovers stem from service industries, while in Slovenia they originate in manufacturing industries.

These results hence show a substantial heterogeneity of innovation effects on employment and skill composition of labor for both countries. Any effects on employment depend a lot on the specific structure of each economy. And even within countries, results can vary substantially across industries that generate spillovers and across firms that are potential beneficiaries of the spillovers. When comparing services sectors with manufacturing sectors, the results do not seem to reveal any significant difference in the spillover effects on employment and skill structure.

### 4.3.3 Social Innovation and Economic Growth

While technological innovation typically results in more production and is therefore implicitly aimed at increasing gross domestic product, social innovation aims at improvements of the quality of life of individuals and communities. It increases the flow of information among members of the society, thus lowering transaction costs and the need for formal institutions. Given its relation with social capital, Konings and Marcolin (2014) show how social innovations may impact the economy through several channels:

- Social capital reduces monitoring cost over the action of financial brokers, increasing savings and investment possibilities, which in turn increases economic growth. It also increases the propensity of venture capitalists to finance risky projects, since it lowers monitoring costs over the firms they decide to finance;

- It impacts positively innovation and decreases the probability of cheating by scientists, who care more about their reputation when social capital is more present. Social capital is hence found to relevantly impact patenting activities;
- Public policies in countries which are endowed with more social capital are more credible and effective and education policies develop better human capital;
- Social capital also delivers better politicians by reducing corruption and raising the return of reputation. Thus, it is found to have a positive impact on bureaucratic efficiency, property rights security, contract enforceability and confidence in the government.

Konings and Marcolin (2013) consider social capital as an asset embedded in inter-individual relations that enhances the achievement of individual and social goals. Social innovations can then be seen as the process and outcome of changes in social capital, as a new response to pressing social needs, which affect the process of social interactions (i.e. social capital). Crowdfunding is one example that could be considered a social innovation. Crowdfunding is a new form of securing financing for specific projects through the internet, where entrepreneurs and financers meet and cooperate over projects of diverse nature. Crowdfunding may be seen as a new type of social interaction providing an interesting alternative form of financing for start-ups, especially in a period of credit retrenchment. What is more, crowdfunding permits to connect individuals with specific causes they may want to support, especially in the social field;

The advantage of the proposed definition is that it makes it possible to proxy a country's level of social innovation exploiting indicators for social capital. The following dimensions of social capital stated by the OECD (Healy, 2002) were considered:

- Trust;
- Community participation through membership and volunteer work in civil society organizations (associations, unions, religious communities, sport clubs, etc…);
- Informal networks (family and friends, neighbors);
- Political participation (voting, personal involvement in politics, trust in political institutions).

13 proxy measures for social capital were proposed, using information from the European Value Survey. Although the authors used different proxies for social capital, country rankings seem to be mostly coherent with the one derived using the variable Trust, which has been extensively used in the

economic literature so far. It is therefore possible to approximate social innovation with changes in levels of trust in the population.

### 4.3.4 Key Policy Implications

- Innovation tends to increase employment and upgrade the level of skills, but this effect depends crucially on the type of innovation and the overall macroeconomic situation;
- Public policy design needs to take account the peculiar features of service innovation. This type of innovation has a lower R&D intensity in the traditional meaning of the term. Moreover, service innovation is largely a distributed phenomenon that depends on cooperation and interactions among stakeholders, to a greater extent than in technological innovation;
- Innovation in service industries does not seem to have a different spillover effect on employment and skills structure when compared to innovation in manufacturing industries;
- Policy makers also have to consider the particularities of social innovation that distinguishes it from technological innovation.
- Seeing social innovation as a flow mechanism contributing to the stock of social capital, it correlates positively with trust in institutions and thus contribute to the growth potential of a country.

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