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Harmonization of R&D Tax Credits across the European Union: Nonsense or common sense?

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Harmonization of R&D Tax Credits across the European Union: Nonsense or common sense?

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Abstract

We examine the relevance of R&D tax credits as incentives to spur investment in R&D throughout the European Union (EU) and discuss the relevance and feasibility of harmonizing these tax-based policy instruments across Member States. Based on a thorough investigation of the instruments implemented in five selected European countries (Belgium, France, Italy, the Netherlands and the UK), we argue that the main obstacle to harmonization lies in the great diversity of instruments and eligibility conditions that currently prevail across the EU. We conduct a subsidiarity test, which suggests that, if the EU decides to move towards a harmonized R&D tax credit framework, it should at least impose a minimal level of tax rebate at the EU level, possibly complemented by additional country-level incentives. We highlight that the recent proposal of a Common Consolidated Corporate Tax Base (CCCTB) goes further than this minimal EU-level tax credit, by suggesting to implement a "super-deduction" that would allow EU-based firms to deduce more than 100% of their R&D expenditures from their tax base. We also discuss, as far as the harmonization of R&D tax credits is concerned, possible implications of Brexit both for the UK and for the EU.

To complement our reflection and discussion, we develop an econometric analysis on our five selected countries. The super-deduction proposed by the European Commission (EC) has its roots in the conviction that economic growth in Europe can only be knowledge-based, and that the current level of R&D investment in the EU is too low. The EC hopes that the super-deduction will boost R&D investment across Europe, which is assumed to be conducive to more innovation and, ultimately, more growth. Our econometric analysis allows us to test whether this hope is empirically grounded, by examining whether the R&D tax credits implemented in the five aforementioned EU countries have spurred R&D and innovation (measured by patenting intensity) between 1980 and 2007. We find that the R&D conducted when a tax credit is available is associated with more R&D in the future in all five countries, and with more innovation in three countries out of five. In addition, we identify a causal effect of the R&D tax credit on future R&D intensity in three countries out of five. However, we do not find any causal effect of the tax credit on innovation.

Keywords: European Policy, Tax Harmonization, R&D Tax Credit, Innovation Policy

JEL codes: H25, H54, H77, H87, F36, O31, O38

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Set-up in 2000, the Lisbon Agenda for the economy of the European Union (EU) was aiming, in the words of the EU Parliament[3], to make the EU "the most competitive and dynamic knowledge-based economy in the world" by 2010. This strategy involved, among others, to increase investments in R&D up to 3% of the EU Gross Domestic Product (GDP). This objective has not been met in 2010, and it remains one of the objectives of the Europe 2020 strategy, which has superseded the Lisbon Agenda. There are several reasons why EU Member States would like to sustain firms' R&D effort, including (*i*) expected positive social returns on investment in R&D (e.g., in terms of innovation, growth and welfare) and (*ii*) the existence of "externalities" or "market failures" that would require and justify State intervention. One of the main policy tools to foster an increase in R&D spending is the R&D tax credit or, more generally, R&D tax incentives.

In this paper, we examine two complementary research issues pertaining to R&D tax credits. In a first part of the paper, we discuss the relevance, in view of the principle of subsidiarity, of harmonizing R&D tax credit schemes across EU Member States. Tax harmonization remains a hotly debated topic in the EU. The recent proposal (in October, 2016) of a Common Consolidated Corporate Tax Base (CCCTB) has reignited the debate, extending it to R&D tax credits in the process. We illustrate our discussion by contrasting the tax credit schemes that exist in five selected EU Member States, including the UK (which incidentally leads us to consider the implications of Brexit). These examples highlight the great diversity of instruments and eligibility conditions that currently prevail across the EU. We argue that this diversity may constitute a serious obstacle to harmonization. A subsidiarity test suggests that, if the EU decides to move towards a harmonized R&D tax credit framework, it should at least impose a minimal level of tax rebate at the EU level, possibly complemented by additional country-level incentives. The recent proposal of a Common Consolidated Corporate Tax Base (CCCTB) goes much further, by suggesting to implement a "super-deduction" that would allow EU-based firms to deduce more than 100% of their R&D expenditures from their tax base.

The proposal of a "super-deduction" of R&D expenditures at the EU level is grounded in the aforementioned beliefs that economic growth in Europe can only be knowledge-based, and that the current level of R&D investment in the EU is too low. In the second part of this paper, we examine these beliefs by estimating the effect of R&D tax incentives on both R&D expenditures and the outcome of the innovation process. We conduct econometric analyses on a panel of industries that spans our five selected EU countries and that provides us with measures of R&D and of innovation outcome. After estimating Instrumental Variables (IV) models within each country, we use a Differences-in-Differences (DID) approach to determine whether the implementation of R&D tax incentives has had any causal effect on R&D and on innovation outcome. We identify a causal effect on future R&D intensity in three countries out of five (including in the UK, which raises issues regarding the consequences of Brexit). We do not find, though, any causal effect of R&D tax credits on innovation (as measured by patenting).

The remainder of the paper is organized as follows: In a first section, we present some justifications as to why R&D tax credit schemes should exist at all and a rationale for their harmonization across EU countries. In a second section, we illustrate, using five selected EU countries, how the complexity and sheer diversity of R&D tax credits schemes could make such a harmonization difficult, should it be acted at the EU level.

[3] http://www.europarl.europa.eu/summits/lis1_en.htm, Part I, Point 5.

The third section is dedicated to the presentation of our data and to the econometric analysis we implement on this data, trying to address two major shortcomings of the evaluation literature. We summarize our findings in a fourth section, and conclude in a final section.

1. R&D tax credit schemes: Why should they exist and why should they be harmonized across EU member States?

1.1. Justification

R&D tax incentives and related R&D policies are rooted in the belief that, in modern economies, innovation is the main source of growth, a belief largely grounded in endogenous growth theory (e.g., Romer, 1990). This belief has led to the widespread conviction, in EU policy circles, that innovation may be the only option to get the EU economy out of stagnation and back on the path of growth. The rationale is that innovation-induced economic growth will result in increased wealth, employment and well-being. EU policy makers are therefore searching for the conditions that are more likely to make firms increase their innovation effort. A widespread recommendation consists in creating the conditions of increased competition between firms (or in "letting the market decide"), as the increased competitive pressure would supposedly lead firms to innovate in order to survive or to gain advantages over their competitors.

A potential problem with this recommendation is that markets left to their own devices are likely to generate less innovation than expected, i.e. less innovation than it would be desirable for the society as a whole. Among economists, this is known as a "market failure". As far as innovation is concerned, there are at least two reasons for such a failure.

One reason is that innovation relies on knowledge creation, and that knowledge is a very particular type of economic good: it is largely immaterial and presents some characteristics of what economists call a "public good", i.e. it cannot be completely appropriated by the entity (individual or firm) who generated it. For instance, ideas or inventions can generally be copied and used by others than those who originated them. This imitation process will take more time if an invention is complex, but it is likely to occur anyway if the invention generates revenue. In the case of firms trying to innovate, ideas are generally created through R&D, so R&D can be seen as a crucial input into the innovation process, or as an investment that will yield returns once the innovation is marketed. However, because knowledge created through R&D cannot be completely appropriated by the firm that created it, the returns on investment in R&D will not entirely accrue to this firm. Firms are therefore likely to invest less in R&D than it would be socially optimal, or at least desirable (Arrow, 1962). Intellectual property rights (e.g., patents) may alleviate this problem, but do not completely solve it (e.g., a patent is effective only for a limited period of time and over specific geographical areas, where the patent has been applied for and granted).

The second reason for market failure is that innovation is a very risky and uncertain endeavour, and that investment in R&D is thus a risky business. Firms may therefore face serious difficulties in finding financial support for their R&D projects, as banks and investors may be unwilling to lend money to projects that they cannot easily monitor (or the outcomes of which they cannot clearly see). This may result in a lack of private funding for R&D projects, and in the abandonment of projects that firms would be eager to pursue had they the required funds.

If the assumption that innovation is conducive to economic growth and to social well-being is correct, then the two above-mentioned reasons call for public intervention in order to spur firms' R&D effort. This type of public intervention will generally take the form of R&D subsidies or of R&D tax incentives such as R&D tax credits. The latter form is more widespread, because it does not imply spending money directly. It simply results in less tax revenue, which is expected to be compensated by more wealth creation at the level of the economy.

1.2. Harmonization

So far, we have examined justification for the existence of R&D tax credits in EU Member States. However, these tax credits can take a multiplicity of forms, and may vary hugely across States. Until lately, at one end of the spectrum, there were States where no tax credit existed (e.g., Germany) and, at the other, States where R&D tax credits had been implemented for a long time (e.g., France), possibly experiencing changes along the way. The question of whether this variety should be harmonized at the EU level remains opens, and is a very though one to answer. The proposal, in October 2016, of a CCCTB has reignited the debate, by suggesting to implement a "super-deduction" on R&D expenditures.[4] Here is how the proposal for this super-deduction is worded:

"*To support innovation in the economy, this re-launch initiative will introduce a super-deduction for R&D costs into the already generous R&D regime of the proposal of 2011. The baseline rule of that proposal on the deduction of R&D costs will thus continue to apply; so, R&D costs will be fully expensed in the year incurred (with the exception of immovable property). In addition, taxpayers will be entitled, for R&D expenditure up to EUR 20 000 000, to a yearly extra super-deduction of 50%. To the extent that R&D expenditure reaches beyond EUR 20 000 000, taxpayers may deduct 25% of the exceeding amount*" (European Commission, 2016, pp. 9-10)

This super-deduction is, in effect, a very generous R&D tax credit scheme, as is clearly stated in the associated press release:[5]

"The CCCTB will support innovation in Europe by allowing the costs of R&D investment to be tax deductible. All companies that invest in R&D will be allowed to deduct the full cost of this investment plus an additional percentage of the costs, depending on how much they spend. The full cost of R&D will be 100% deductible, while an additional 50% deduction will be offered for R&D expenses of up to EUR 20 million. An additional 25% deduction will be allowed for R&D spending over EUR 20 million".

The press release illustrates this scheme with the following example. An EU-based company that spends EUR 30 million on R&D in a given fiscal year will be allowed to deduct: (*i*) the full amount of its R&D expenditures (i.e., EUR 30 million) from its taxable income, *plus* (*ii*) an additional 50% of the first EUR 20 million (i.e., EUR 10 million) *plus* (*iii*) an additional 25% of the remaining R&D expenditures above the EUR 20 million threshold (i.e., EUR 2.5 million as 25% of the remaining EUR 10 million). In

[4] The October 2016 CCCTB proposal is actually an initiative to re-launch a 2011 proposal, which already included a specific regime for R&D-conducting firms. The R&D regime in the 2016 proposal is more generous and constitutes a somewhat more radical proposition.

[5] http://europa.eu/rapid/press-release_MEMO-16-3488_en.htm

total, this hypothetical company will be able to deduct EUR 42.5 million from its CCCTB, which only goes to show that the "super-deduction" term is rather appropriate for this R&D tax credit scheme.[6]

The 2016 CCCTB has yet to be implemented, and may yet meet the ill fate of its 2011 predecessor. In the current state of affairs, national R&D tax credit schemes prevail. R&D tax credits are essentially negative corporate taxes, and corporate taxes are the prerogative of Member States. EU institutions themselves do not collect taxes, but with the 2016 CCCTB proposal, the EU is trying to take a first step towards tax harmonization. Tax harmonization refers to "an equalization of tax bases and/or tax rates" (Benassy-Quéré *et al.*, 2014), a variant of which consists in imposing minimum bases or rates, as was done in the case of the Value Added Tax (VAT).[7] The 2016 CCCTB proposal strictly focuses on a common tax base, work on tax consolidation (i.e., on common tax rates) being "*postponed until agreement is first secured on a mandatory set of rules for the (…) common corporate tax base*" (European Commission, 2016, p. 3). The rationale for tax harmonization at the EU level is that, in the absence of harmonization, tax competition between Member States prevails. While tax competition may have positive effect on government efficiency, it may also distort public and private choices.

In the case of R&D tax credits, tax competition could result in uneven increases in R&D investments across EU regions (with R&D expenditures rising in some States and stagnating in others), which could go against the Europe 2020 objective. Some degree of tax harmonization in R&D tax credits may therefore make sense (hence the proposal for a "super-deduction" at the EU level). This harmonization is however more complicated than in the above-mentioned case of VAT because it does not concern just the tax rate and because the tax base can be determined through a very large number of eligibility conditions. In theory, there are thus several dimensions along which harmonization could occur. These dimensions will be examined in Section 2 using the examples of five EU Member States. Before moving on to this section, it is useful to examine how a subsidiarity test of the type proposed by Pelkmans (2006) applies to the harmonization of R&D tax credits across EU Member States, and to compare the conclusion of this test to the "super-deduction" included in the 2016 CCCTB proposal.

The subsidiarity test is a five-step procedure. The **first step** consists in identifying whether a measure falls within the area of shared competencies. This could be the case for the R&D tax credit, which is as much an element of science and innovation policy as it is a tax measure. The **second step** is the "need to act in common" test, which consists in demonstrating the need for EU-level intervention due to either economies of scale or cross-border externalities. In the case of the R&D tax credit, as mentioned above, a lack of harmonization could result in an uneven expansion of the R&D effort across EU Member States (e.g., with innovative firms concentrated in areas with higher R&D tax credits) to the detriment of the Europe 2020 objective. The **third step** is to verify whether credible cooperation (without EU intervention) is feasible, which is unlikely in the case of R&D tax credits.

The **fourth step** then consists in checking whether Step 1 and Step 2 are confirmed, whereas Step 3 is not – which is the case here. In this case, EU-level public

[6] The scheme is even more generous for "small starting companies" (i.e., start-ups, primarily), which will be allowed to deduct a further 100% of their R&D expenditures, within the limit of EUR 20 million. Thus, a start-up that invests EUR 5 million in R&D will be allowed to deduct EUR 10 million from its CCCTB.

[7] Actually, the harmonization of the VAT in the EU concerns both the tax base and the tax rate. Two directives (from 1977 and 2006) impose a minimum rate of 15% and a restricted list of goods on which a reduced rate may apply (thus harmonizing the tax base as well as it rate).

intervention is justified. In the **fifth and final step**, EU authorities must make sure that the action is proportional to the desired objective, and determine the extent of their intervention. This fifth step actually tests whether the principle of proportionality (according to which EU action, when it is required, should be minimal) applies to the case at hand. In the case of R&D tax credits, this would mean ensuring that each Member State is able to attract R&D-doing firms and spur its national R&D effort, but without interfering so much as to reduce incentives for firms to invest in R&D. This delicate balancing act could be achieved, by harmonising the tax credit base (or key elements of it) and imposing a minimum common tax rebate, as was done for the European VAT (Pelkmans, 2006; de Mooij, 2004). This would allow for a degree of (mostly harmless) tax competition.

In practice, EU member States would first have to agree on how to harmonize the R&D tax credit base, which implies deciding, among e.g., whether it should apply only to small and medium entreprises (SME) or to all firms, whether it should concern all R&D costs or only parts of these costs such as R&D wages, etc. Once a base has been agreed upon (e.g., a tax credit for SME), the EU could make the R&D tax credit a requirement in all member States, with a minimal tax credit rate (e.g., 75% of R&D costs). Since an agreement would have been reached on the tax base, it would be easier to make a mandatory R&D tax credit acceptable in all member States.

As can be seen in the description given at the beginning of this section, the "super-deduction" associated with the CCCTB is a radical move, that goes way beyond the above-mentioned institutional arrangement and leaves practically no room for tax competition. First, the proposed tax credit is extremely large, being at the very least equal to 100% of R&D expenditures. Second, since it is designed to apply throughout the EU, it leaves little room for tax competition, as companies will be able to benefit from the same deduction regardless of the Member State in which they operate. In addition, although the super-deduction in itself is not mandatory, it is automatically granted to all firms that fall under the CCCTB.

Formally, one could consider that the "super-deduction" passes the core of the subsidiarity test, but may fail to pass the proportionality test (i.e. the fifth step of the subsidiarity test), insofar as it is anything but a minimal intervention. In addition, it may be too ambitious to be easily accepted by all Member States – all the more since it is only a secondary feature of the CCCTB (which is primarily presented as a way to facilitate business and tax clearing across the EU). The super-deduction on R&D may then be rejected not only in itself, but as part of an unpopular CCCTB package. Indeed, the notion of a consolidated tax base is unpopular among Member States that rely on low taxes to attract foreign business.[8] To make it more acceptable, the EU has declared that the proposed CCCTB will be mandatory only for large multinational firms (defined in the proposal as groups with a global turnover of over EUR 750 million per year). Other firms that operate in at least two Member States may choose to opt for the CCCTB or not.

As far as national R&D incentives are concerned, this implies that the rule stated in the 2011 CCCTB proposal would prevail: "*A company which does not qualify or does not opt for the system provided for by the CCCTB Directive remains subject to the national corporate tax rules which may include specific tax incentive schemes in favour of Research & Development.*" (European Commission, 2011, p. 6) Thus, even if the 2016 CCCTB proposal were accepted, the implementation of the super-deduction would not make a

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[8] Prominent among these Member States is Ireland, and reactions against the 2016 CCCTB proposal have flourished in the Irish press from the autumn of 2016 onwards (see for instance the following article: http://www.irishtimes.com/business/economy/why-brussels-latest-tax-plan-is-a-threat-to-ireland-1.2842579).

clean slate – at least in the short run – of all the tax credits that currently exist within EU Member States. Given that R&D tax credits are defined using eligibility conditions which vary widely across EU Member States, it might be hard for companies to decide which system works best for them, despite the generosity of the proposed super-deduction. To illustrate this point, we examine in the next section the variety of R&D tax credit schemes in the case of five EU Member States.

2. The complexity of R&D tax credits: An illustration for five EU Member States

We now turn to the examination of the R&D tax credit schemes in five EU Member States: Belgium, France, Italy, The Netherlands and the United Kingdom. We do not aim at an exhaustive comparison of existing R&D tax incentives[9], but rather at highlighting how current R&D tax credit schemes differ along multiples dimensions. The description of R&D tax incentives given in this section will thus illustrate the scope for harmonization that exists across the EU, as well as the difficulties that may arise should the 2016 CCCTB proposal be agreed upon. Our choice of countries was largely dictated by our desire to have quantitative data that would allow us to go beyond a simple description of the schemes and to venture into probing the potential effect of R&D tax credits on R&D expenditures and on the outcome of the innovation process.[10] Since the UK decided to leave the EU in June 2016, we also evoke the consequences of the so-called 'Brexit' in terms of R&D tax credit competition.

FIGURE 1 ABOUT HERE

Before comparing R&D tax credits scheme per se, it is useful to have a look at the state of investment in R&D in the selected countries. Figure 1 shows gross R&D expenditures in percentage of GDP for the period 1981-2014. For reference, we also display this figure for Germany (a country that did not implement any R&D tax credit over the period) as well as its average for OECD countries and for EU 28 (the latter being available only from 1995 to 2014). A first striking feature is that, across the whole period, R&D expenditures in Germany remain consistently above both the OECD average and the EU 28 average. They are also higher than in any other selected country, with the exception of France between 1989 and 1998. This (and the fact that Germany had almost reached the Europe 2020 objective of "3% of GDP" in 2014) may explain why this country never relied on an R&D tax credit[11].

By contrast, R&D expenditures in Italy have remained consistently below both the OECD average and the EU 28 average throughout the period, slowly rising from about 0.8% of GDP in 1981 to about 1.3% of GDP in 2014. In the other four selected countries, R&D expenditures follow the OECD trend, remaining below the OECD average of 2% to 2.5% throughout (over 1995-2014, we can observe that they remain between the EU 28 average, which steadily raised from 1.5% to 2%, and the OECD average). Among these four countries, France is the one where R&D expenditures are the highest,

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[9] For exhaustive comparisons, see Straathof *et al.* (2014), Deloitte (2014) or E&Y (2014). OECD (2010) also provides, for the year 2009, a useful comparative table that encompasses our five selected countries.

[10] We were able to gather a complete industry-level panel dataset spanning the years 1980 to 2007 for these five countries. This dataset will be described in Section 3.

[11] A system of R&D grants and R&D loans do exist in Germany, but that is also the case in some other EU countries where they come in addition to R&D tax credits (e.g., in Belgium, innovative firms can benefit from regional R&D grants, which are not subject to corporate taxation).

going above the OECD average (and even above German R&D expenditures) during the 1990s. Overall, Figure 1 suggests that the selected countries (Belgium, France, Italy, the Netherlands and the UK) all have an interest (in the light of the Lisbon Agenda and subsequent Europe 2020 objectives) in raising their R&D expenditures. This may explain the reliance on R&D tax credits, as policy instruments to achieve this objective. Nevertheless, while all five countries have implemented R&D tax credit schemes, these differ widely in their timeline, tax rate and tax base.

2.1. Difference in R&D tax credit schemes

Regarding **timeline**, France was the first of the five selected countries to introduce an R&D tax credit. This was done in 1983[12]. The credit was incremental, based on the yearly variation (increase) in R&D expenditures, and remained so until 1998, with various changes in rates and ceiling across the period, as well as a brief attempt at a co-existing volume-based tax credit from 1987 to 1990. In 1999, the R&D tax credit was renewed for a period of five years, and it was made permanent in 2004, with a change in rate in 2008. Comparatively, the remaining four countries are latecomers: Belgium and the Netherlands introduced R&D tax credits in 1998, and Italy and the UK did so in 2000. In Italy, the R&D tax credit was regional at first, with a tax rebate varying across regions; it only became a national scheme in 2006.

As mentioned earlier, eligibility conditions for an R&D tax credit may vary widely across countries, which results in tax bases (or, in the case of tax credit, the base for a tax rebate) varying along multiple dimensions. First, tax credits can be **incremental** (i.e., based on the yearly variation in R&D expenditures) or **volume-based** (i.e., based on the yearly volume of R&D expenditures, possibly with respect to a year of reference). The latter form of tax credit make it easier for firms to obtain tax rebates, but whether it gives them a strong incentive to increase R&D expenditures remains doubtful. Nonetheless, R&D tax credits are currently volume-based (or primarily volume-based) in all selected countries except in Italy, where an incremental tax credit prevails. The French R&D tax credit that existed between 1983 and 1999 was also primarily incremental[13] (it coexisted with a volume-based tax credit between 1987 and 1990). Overall, the current prevalence of volume-based tax credits would likely facilitate a possible harmonization, and indeed the super-deduction that is part of the 2016 CCCTB proposal is volume-based.

The tax base can also vary with **firm size** and with the **industry** in which a firm operates. Thus, the rate of the R&D tax credit in Italy during 2000-2014 was of 20 to 30% for SMEs (depending on regions), versus 15 to 25% for medium-sized firms and 10 to 20% for large ones. In the UK[14], the R&D tax credit introduced in 2000 was originally available to SMEs only, and a different regime for larger companies was introduced in parallel in 2002. The former could deduce 50% of their R&D personnel expenses from their taxable profit, whereas the latter could deduce 25% of their R&D personnel expenses. In 2008, these amounts could be as high as 75% of R&D personnel expenses for SMEs and 30% for large firms. In the Netherlands, the amount of the 1998 tax credit

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[12] Giraud *et al.* (2014) present a detailed timeline of the French R&D tax credit in their report to the French Ministry of Higher Education and Research.

[13] For instance, from 1985 onwards, the tax rebate was equal to 50% of the variation of a firm's R&D expenditures between year t and t-1.

[14] See for instance https://forrestbrown.co.uk/rd-tax-credits-explained/ for a business-oriented presentation of the British R&D tax credit scheme.

was of 40% of "knowledge workers" wages in SMEs versus 17% in large firms. In 2004, it was raised to 42% for SMEs and reduced to 14% for large firms.

By contrast, in France, the current version of the R&D tax credit does not formally distinguish between SMEs and large firms, but the amount of the tax credit varies with respect to the investment in R&D. It is equal to 30% for investments lower than EUR 100 millions and 4% for investments above this threshold. In effect, since SMEs typically invest lower amounts in R&D, they will benefit from the higher tax credit – but this scheme also let large firms benefit from the same rate (provided their investment remains below the threshold), which is not the case in the UK or in the Netherlands. Not only may this feature of the French tax credit give large firms an incentive to under-invest, it may also make harmonization more difficult.

R&D tax credit regimes may also be industry-specific, either targeting certain industries or excluding some industries. For instance, prior to 1992, agricultural and textile firms could not benefit from the French R&D tax credit. In the UK, since 2008, pharmaceutical firms doing vaccine research can deduce about 40 to 50% of their R&D personnel expenses from their taxable profit – this is, in effect, a specific regime, distinct from both the SME regime and the large company regime. If the 2016 CCCTB proposal and the associated super-deduction were adopted, a specific regime for newly-created small firms would apply, as stated in Footnote 3.

Another dimension in which tax bases vary is the existence of a **ceiling** to the R&D tax credit. For instance, the tax credit introduced in France in 1983 had a ceiling of FF 3 millions (approximately 900 000 euros[15]), which was raised up to 5 millions (about EUR 1.3 millions) in 1985 and 10 millions (about EUR 2.5 millions) in 1987. A ceiling still existed in the early 2000's, but was finally suppressed in 2008, probably because it kept on rising (from EUR 8 millions in 2004 to EUR 10 millions in 2006 and EUR 16 millions in 2007). There is no ceiling to the R&D tax credit in Belgium or the United Kingdom either, but a ceiling of EUR 14 millions (on R&D wages) exists in the Netherlands and a ceiling of EUR 50 millions (on all eligible R&D) prevails in Italy. The super-deduction included in the 2016 CCCTB proposal does not impose a ceiling: R&D expenditures are fully deductible from the consolidated corporate tax. A threshold of EUR 20 million exists, however, for additional deductions: an additional 50% deduction is available under the threshold, whereas the additional deduction is of "only" 25% beyond the threshold.

Last but not least, the **contents** of R&D expenditures that entitle firms to a tax rebate vary hugely across country. In the Netherlands, the expense base for the R&D tax credit is restricted to R&D wages (and social contributions). In Belgium, it primarily consisted in R&D wages as well, but has been extended to include capital assets. Investments in R&D are eligible to the tax credit provided they have no harmful effect on the environment (a condition which does not exist in the other four countries). In France, Italy and the UK, the expense base includes all R&D expenditures (reported as such in a firm's accounts). Of all three countries, France may be the one where the definition of R&D expenditures is the broadest. For instance, they include external R&D conducted in any European Economic Area (EEA) country. The expense base may also include items that are beyond the actual expenses. Thus, 200% of the wages (and overheads) of young Ph.D. graduates are tax deductible, provided that the graduates are hired on a long-term contract. In the 2016 CCCTB proposal, the super-deduction is

[15] We did all conversions of French francs to euros using the online tool of the French National Statistical Institute (INSEE), http://www.insee.fr/fr/service/reviser/calcul-pouvoir-achat.asp?, which takes long-term inflation into account.

supposed to bear on all R&D costs incurred in a given year, with the exception of immovable property.

2.2. Implications of Brexit

One of the five EU countries on which this study focuses is the United Kingdom, which has opted in 2016 for leaving the EU in the near future. At the time of this writing, there is much uncertainty about the specifics of the Brexit process. On February 1st, 2017, the UK House of Commons has voted in favour of the bill that gives Prime Minister Theresa May the authority to invoke Article 50 of the Lisbon Treaty, thus effectively triggering the process of leaving the EU. The UK and the EU have now entered a two-year discussion process that may lead to an agreement on the terms of UK exit and on the future relationships between both parties. Only time will tell whether such an agreement is reached or not.

This has important consequences for the harmonization of R&D tax credits discussed in the present study. Let us consider that the EU agrees on the 2016 CCCTB proposal. If an agreement between the EU and the UK is reached within the next two years, it might include the possibility for British companies with subsidiaries or parent firms in the EU to opt for the CCCTB (and thus to benefit from the associated super-deduction of R&D expenditures). In the current state of affairs, this seems most unlikely. If the discussion process fails to lead to an agreement, or if the agreement fails to include the possibility to opt for the CCCTB, one can expect the consequences to be negative, both for the UK and for the EU.

First, well before the June 2016 referendum on Brexit, a panel of 150 leading academic economists[16] (including 12 Nobel laureates) has warned that leaving the EU was likely to result in a drop of investment in the UK, harming both innovation and job growth. The answer proposed by supporters of Brexit primarily consists in drastically lowering tariffs and corporate taxes. But keeping tariffs low might be harmful for the UK in the long run, as it will drastically reduce the country's negotiating power, allowing other countries to raise their own tariffs and thus impeding UK's exports. The reduction of corporate taxes might be harmful for the EU as well, as it would implies severe tax competition: foreign investors – and even EU companies – might choose to relocate in the UK, if corporate taxes there suit their purpose better than the CCCTB. This could be the case especially for large multinational companies, for which the CCCTB would be mandatory in the EU.

Those investors, however, might not be the most innovation-oriented companies, as it is unlikely that the UK would be able to propose better R&D tax incentives than the super-deduction included in the CCCTB proposal. And it seems that after Brexit, the environment for research and innovation in the EU will be head and shoulders above the one that the UK may offer – unless a specific agreement in that domain is reached during the oncoming negotiations. In an article[17] published in *The Guardian,* Prof. Mazzucato, a UK-based leading expert in the economics of innovation[18], states that *"[c]ollaboration*

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[16] "Economists for remain", see: https://economistsforremain.org/

[17] "Austerity is the cause of our economic woes. It's nothing to do with the EU", available at: https://www.theguardian.com/commentisfree/2016/jun/27/austerity-economic-woes-eu-referendum-brexit

[18] Prof. Mazzucato has been called one of the "three most important thinkers about innovation" in the *New Republic* in 2013 (https://newrepublic.com/article/114395/three-most-important-thinkers-about-innovation-you-dont-know), and has won the 2014 *New Statesman* SPERI Prize in Political Economy (http://www.newstatesman.com/economics/2014/10/mariana-mazzucato-wins-new-statesman-speri-

across the continent has made Europe a powerhouse for science. Britain gained disproportionately from EU research funding. The loss of this funding will create a real gap, making our low productivity even harder to resolve". While some could argue that this opinion may be biased by the fact that Prof. Mazzucato has herself largely benefitted from EU research grants[19], it is widely shared by UK researchers, as reported in House of Lords (2016). Regarding the harmonization of science and research regulatory framework across the EU, this document states:

"*(...) the majority of evidence suggested that the regulatory harmonisation brought about by the EU was of benefit to the UK. Such harmonisation can provide a strong platform for collaboration and commercialisation in science and research. The Academy of Medical Sciences (AMS) corroborated this perspective and suggested that the collaborative potential brought about by harmonisation warrants the "burden" of engaging with regulatory processes*". (House of Lords, 2016, p. 12).

Based on this evidence, we can expect that Brexit will lead to increased corporate tax competition between the UK and the EU. Since it may attract more multinational firms to the former than to the latter, this tax competition is likely to be detrimental to the EU, at least in the short run. In the long run, though, it may prove more detrimental to the UK than to the EU, because (1) there is a limit to the gains the UK may derive from tax competition and (2) innovative firms are more likely to be attracted by the favourable research environment the EU offers, and innovative firms are supposedly those that contribute more to (skilled) job creation and growth.

3. Empirical analysis

Having discussed the rationale for (and feasibility of) harmonization of R&D tax credits across EU Member States, one question remains open: That of the effectiveness of these policy instruments. Since they are in effect the most widespread policy instruments used to promote innovation (Straathof *et al.*, 2014), one should expect them to have a positive impact at the very least on R&D expenditures. If so, they would contribute to the Europe 2020 objective of having R&D expenditures reach 3% of the EU GDP, and the super-deduction included in the 2016 CCCTB proposal would appear as grounded on sound empirical facts. If R&D tax credit failed to spur R&D expenditures, they would be unlikely to have any effect on innovation, and let alone economic growth.

There exists a large literature on the evaluation of R&D tax credits, the bulk of which is dedicated to the effect of specific tax credit schemes on R&D expenditures within countries. In their report to the European Commission, Straathof *et al.* (2014) point out to several gaps and limitations to this abundant literature and identify two major challenges. The first is that evaluation studies almost never rely on natural and social experiments, or on quasi-experimental methods like differences-in-differences (DID), to identify the impact of tax policies. The second is precisely that most studies

prize-political-economy). Her book *The Entrepreneurial State: Debunking public versus private sector myths* was included in the 2013 "Books of the Year" list of the *Financial Times* (https://www.ft.com/content/f60b681e-529f-11e3-8586-00144feabdc0).

[19] She has been awarded two grants from the Horizon 2020 programme, DOLFINS (Distributed Global Financial Systems for Society) and ISIGrowth (Innovation-fuelled, Sustainable, Inclusive Growth).

focus on the impact of R&D tax credits on R&D expenditures, and not on innovation, let alone productivity.

In the present paper, we try to address these two challenges using a panel of industries observed over 1980-2007 across the five EU countries discussed in Section 2. The rationale for using this level of analysis is that it is well suited to international comparisons and that it is more likely to capture nation-wide effects. An obvious shortcoming, compared to more micro-level analyses, is that we cannot use precise information on the specifics of a given tax credit scheme. Nevertheless, we have precise information on the timeline of R&D tax credits in each selected country, and we can use this information for econometric identification and statistical inference. This is detailed in the presentation of our methodology.

We first conduct by-country analyses to assess the effect of R&D tax credits on both R&D expenditures and innovation (measured by patenting intensity). We then rely on DID analyses to try and estimate the causal impact of R&D tax credits in each country of interest, using Germany (a country that did not implement any R&D tax credit during 1980-2007) as the control group. In both types of analyses, we identify the effect of R&D tax credits by comparing periods without tax credits to periods with tax credits. We describe our data in Sub-Section 3.1 and sketch our methodology in Sub-Section 3.2.

3.1. Data and variables

To build our industry-level panel, we primarily rely on the EU-KLEMS database constructed by the Groningen Growth and Development Centre (GGDC), completed with information from linked databases from OECD and from EUROSTAT. Our key variables are R&D intensity and patenting intensity. The former is built from R&D stock measures[20] divided by the number of hours worked in each industry at each time period. The latter is built, in a similar way, as the number of patents divided by hours worked. The "number of patents" is the number of patent applications to the European Patent Office (EPO) by sector of economic activity (EUROSTAT, Sciences & Technology database). A concordance matrix between the International Patent Classification (IPC) and the NACE industry classification then allows patent applications to be distributed across industries for a given country (Schmoch *et al.*, 2003). The division by hours worked yields a continuous aggregate indicator of innovation intensity.

As explained earlier, we will measure the effect of R&D tax credits by comparing periods without tax credits to periods that saw the implementation of an R&D tax credit. Control variables include a measure of the World Technology Frontier (WTF), identified as the highest Total Factor Productivity (TFP) level observed in the sample for a given industry (across 17 OECD countries) in a given year. TFP levels were obtained by combining TFP growth measures provided by EU-KLEMS with the Productivity Levels (PL) database, also provided by the GGDC. Using both databases allows researchers to reproduce TFP series in levels for the period 1980-2007, using the "constant Purchasing Power Parity (PPP)" approach (Inklaar and Timmer, 2008). While we focus on only five EU countries for which R&D tax credits schemes were well identified, we build (for obvious reasons) our measure of WTF using the largest number of OECD countries available. This will allow us to see how distance to the WTF in a given industry in a given country affects R&D and innovation in this industry-country. The other control variable is an indicator of the export share of production in a given industry-country and in a

[20] Provided by the EU-KLEMS linked database, derived from OECD ANBERD.

given year, provided by the linked OECD-STAN database. This variable helps us control for international demand-pull channels of technical progress and for economies of scale driven by foreign markets.

We further describe our sample in the Appendix. There, we present the list of industries in Table A1. We also present our two key innovation variables (R&D intensity and patenting intensity) by industry for each of our five selected countries in Figure A1 and Figure A2, respectively. In all five countries, we observe an overall increasing trend in R&D intensity in all industries. At the end of the observation period, R&D intensity is the highest in France, followed by the Netherlands and the UK, Belgium and Italy. In addition, we notice that, in each selected country, a couple of industries are more R&D-intensive than the rest. In all five countries, these are primarily "Chemicals and Chemical products" and "Electric, Electronic and Optical Equipment", followed by "Transport equipment" in France and Italy and by "Coke, Petroleum and Nuclear fuel" in France and the UK. Rather reassuringly for the supposed R&D-innovation relationship, we observe that patenting intensity follows the same increasing trend as R&D intensity. At the end of the period, though, patenting intensity is the highest in the Netherlands, followed by France, Belgium, the UK and Italy. We also notice that, in each country, the most R&D-intensive industries are also the most patent-intensive ones, which, again, is reassuring for the R&D-innovation relationship that is at the heart of the Europe 2020 strategy.

3.2. Methodology

3.2.1. By-country IV regressions

The first analyses we conduct on our panel of industries consist in estimating, within each selected country, an econometric model that relates patenting intensity to past R&D intensity, and past R&D intensity to its own lag. Assuming that the later has a direct effect on R&D but not on patenting, the model can be specified as an IV model. We introduce R&D in interaction with an indicator of the time period in which the R&D tax credit was implemented. This allows us to measure the effects of conducting R&D in a period of tax credit on both R&D intensity and patenting intensity. Formally, using i and t as the respective indices of industry and year, this model can be written as:

$$\text{(1)}\quad \begin{cases} \ln PI_{it} = \beta_1 \ln WTF_{it\text{-}1} + \beta_2 \ln EX_{it\text{-}1} + \beta_3 \ln RD_{it\text{-}1} \times TC_{t\text{-}1} + u_{1i} + v_{1t} + w_{1it} \\ \ln RD_{it\text{-}1} \times TC_{t\text{-}1} = \alpha_1 \ln WTF_{it\text{-}1} + \alpha_2 \ln EX_{it\text{-}1} + \alpha_3 \ln RD_{it\text{-}2} \times TC_{t\text{-}2} + u_{2i} + v_{2t} + w_{2it} \end{cases}$$

where PI denotes patenting intensity, RD denotes R&D intensity and TC_t is an indicator variable equal to 1 if an R&D tax credit exists in year t and to 0 otherwise. Control variables include our measures of the World Technology Frontier WTF and of the export share of production EX (see Sub-Section 3.1). Last but not least, each equation includes an industry fixed effect u_i, a time fixed effect v_t and a random error w_{it}.

In Model (1), coefficient α_3 measures the effect on current R&D intensity of past R&D conducted in the presence of a tax credit, *relative to* R&D conducted in the absence of a tax credit. Similarly, coefficient β_3 measures the effect on patenting intensity of past R&D conducted in the presence of a tax credit *relative to* R&D conducted in the absence of a tax credit. In other words, α_3 and β_3 measure the potential increases in R&D intensity and patenting associated, at the industry level, with past R&D conducted in the presence of a tax credit. These parameters are therefore measures of the variations induced by an R&D tax credit in a "baseline effect" of R&D that is not explicitly modelled.[21] In the first-stage equation, the estimate of α_3 corresponds to what is known in the literature as "*"input additionality"*, i.e. as the share of R&D expenditures attributed to the R&D tax credit, with respect to the size of the tax credit itself (Straathof *et al.* 2014, p. 27). Our estimation strategy falls within what Straathof *et al.* (2014) call the "direct approach", because it is not based on an explicit economic model. In the second-stage equation, β_3 is simply the elasticity of patenting with respect to R&D intensity.

We define the TC indicator(s) in each country according to the actual timeline of R&D tax credit introduction in this country. This means that, in Belgium and in the Netherlands, we have a single indicator equal to 1 from 1998 onwards and to 0 prior to 1998. In Italy and in the UK, we have a single indicator equal to 1 from 2000 onwards and to 0 prior to 2000. In all four countries, using this indicator is equivalent to splitting the sample into two periods: "Before" the introduction of the R&D tax credit, and "after" its introduction. Since the introduction of the tax credit in these countries is comparatively recent, we stick to one-year lags between patenting and R&D on the one hand and between current and past R&D on the other, as shown in Model (1).

Matters are more complicated in France, where the R&D tax credit was originally introduced in 1983 (i.e., almost at the beginning of our period of observation). To account for this, we distinguish a short period of non-implementation (1980-1982) and three periods of implementation, which correspond to major changes in the tax credit: (*i*) 1983-1998 is the period of the original, primarily incremental, tax credit, (*ii*) 1999-2003 is its final five-year renewal period and (*iii*) 2004-2007 is the period in which the tax credit was made permanent.[22] We adapt Model (1) accordingly.

3.2.2. DID estimations

Even though Model (1) relies on an instrumental variables approach, it would not be wise to interpret α_3 and β_3 as causal effects. Identifying the causal effect on innovation of introducing an R&D tax credit requires a quasi-experimental approach. Since, for each country, we are able to observe a period "before" the tax credit and a period "after" the tax credit, we were able to implement DID estimations. To implement our DID approach, we need a control group of industries. Since Germany did not introduce any R&D tax credit over the period of observation, German industries make a natural control group. We conduct the analysis five times, using five distinct samples that pair the country of interest (the "treated" group of industries in which a tax credit was implemented during the period) with Germany (the "control" group in which no tax credit was implemented).

For each sample, we define a pre-tax credit period and a post-tax credit period.[23] We make the pre-tax period end on the year before the introduction of the tax credit and the post-tax one start in the year after its introduction. This allows us to measure the

[21] We have also estimated an alternative model in which the baseline effect of R&D is explicitly modelled. The results of this model, which involves 3-equations and has to be estimated using Three-Stages Least Squares (3SLS), is available upon request. In this paper, we prefer relying on Model (1), which is more parsimonious and focuses on the parameters of interest (i.e., measures of the potential gains in R&D and patenting intensities associated with an R&D tax credit).

[22] As more EU-KLEMS data becomes available from the GGDC, we hope to be able to measure the post-2007 period, in which a major reform of the French R&D tax credit made it volume-based.

[23] In France, we distinguish between three periods of implementation of the tax credit, as we did when we estimated Model (1).

effect of the tax credit net of any "anticipation" effect that would prevail shortly before its introduction and net of any "learning" effect that would immediately follow its introduction. Then, for each country, we estimate the following model, which is a direct adaptation of the IV model described by Equations (1):

$$\ln PI_{it} = \beta_1 \ln WTF_{it\text{-}1} + \beta_2 \ln EX_{it\text{-}1} + \beta_3 \ln RD_{it\text{-}1} + \beta_4\, T_{it} + \sum_{j=1}^{\tau} \beta_{4+j}\, Y_{jit} + \sum_{k=1}^{\tau} \beta_{4+\tau+k}\, Y_{kit} \times T_{it} + u_{1i} + w_{1it}$$

(2)

$$\ln RD_{it\text{-}1} = \alpha_1 \ln WTF_{it\text{-}1} + \alpha_2 \ln EX_{it\text{-}1} + \alpha_3 \ln \mathrm{RD}_{it\text{-}2} + \alpha_4\, T_{it} + \sum_{j=1}^{\tau} \alpha_{4+j}\, Y_{jit} + \sum_{k=1}^{\tau} \alpha_{4+\tau+k}\, Y_{kit} \times T_{it} + u_{2i} + w_{2it}$$

where T is the "treatment" indicator (equal to 1 for all industries in a country that has introduced a tax credit and to 0 in Germany) and where Y_j is an indicator equal to 1 in each year j after the introduction of the R&D tax credit (and to 0 for any other year). Their interactions, $Y_k \times T$, are indicators equal to 1 for observations that are in the treatment group in year k (and to 0 for all other observations).

The treatment indicator T captures possible differences between the treated and control groups before the introduction of the tax credit, whereas the year indicator Y_j captures time-specific factors that may affect both groups in the same way. The coefficients of interest are those associated with the interaction terms $Y_k \times T$, which measure the effect of the R&D tax credit net of time-specific factors and net of systematic unmeasured differences between the treated and control groups. It is this effect that can be interpreted as a causal impact. It is captured by $\alpha_{4+\tau+k}$ in the first-stage equation and by $\beta_{4+\tau+k}$ in the second-stage equation. The $\alpha_{4+\tau+k}$ parameters measure the impact of the R&D tax credit on R&D intensity, while the $\beta_{4+\tau+k}$ parameters measure its impact on patenting intensity. Our specification makes it easy not only to observe the effect of a tax credit in any given year, but also to test its cumulated effect overall several years and/or its average effect over a period of time.

To end this section on a caveat, let us clearly state that in any application such as ours (with small samples and a small number of control variables), one has to be cautious with this interpretation. Our aim here is primarily to identify effects that would deserve further investigation with larger samples, and see which light our findings can cast on the "harmonized R&D tax credit" (or "super-deduction") proposed along with the 2016 CCCTB.

4. Findings

4.1. By-country IV regressions

Table 1 displays the results we obtained for Belgium, Italy, the Netherlands and the UK when we estimated Model (1) using Fixed Effect Two Stages Least Squares (FE-2SLS).[24] The first-stage equation estimates (reported in the upper panel of Table 1) reveal that the parameter for R&D intensity conducted during a period of R&D tax credit is always significantly different from zero and positive. This means that conducting R&D when a tax credit is available is associated with a higher R&D intensity in the near

[24] We also implemented the two-step efficient Generalized Method of Moment (GMM). Since it yielded the same estimates for the key parameters of the model, we do not display its results here but make them available upon request.

future, *more so* than if a tax credit had not been implemented. The estimated parameter (which can be interpreted as "input additionality", as defined in Section 3.2.1) is slightly above 0.90 in Italy, Netherlands and the UK, and close to 0.75 in Belgium.

Overall, we thus find an estimate of input additionality that is very close to 1, which is consistent with the literature.[25] For instance, in Italy, Caiumi (2011) finds, using firm-level data, that a tax cut of EUR 1 leads to an additional investment in R&D of EUR 0.86 "over and above the investment level that otherwise would have been undertaken" (p. 27). This leads her to conclude that "there is no additionality" (*Ibid.*). In the Netherlands, Lokshin and Mohnen (2012), using simulations on firm-level data, find an estimate of input additionality roughly equal to 1 in the short run (i.e., in the first four years of the tax credit), which goes down to 0.5 in the long run (i.e., after fifteen years). In Belgium, Dumont (2013), using a panel of firms, finds estimates of input additionality equal to 0.79 for an R&D tax credit targeting young innovative companies and to 0.82 for an R&D tax credit granted to firms that hire R&D personnel with a Master's degree.[26]

TABLE 1 ABOUT HERE

The second-stage equation estimates (reported in the lower panel of Table 1) lead to more contrasted results. The parameter for R&D intensity conducted during a period of R&D tax credit is significantly different from zero (and positive) in Belgium and in the Netherlands, but not so in Italy nor in the UK. Conducting R&D when a tax credit is available may thus be associated with more innovation (as measured by patenting), but in some countries only. Since we control for time-invariant industry characteristics as well as for time trends, our finding is likely due to the specific features of the tax credit schemes (described in Section 2). Identifying the precise features that make an R&D tax credit spur innovation more than another is beyond the scope of the present econometric analysis, however. Interestingly, even when significant, the estimated parameters have a much lower magnitude than their first-stage counterpart: The elasticity of patenting with respect to R&D intensity is estimated at 0.05 in Belgium and at 0.14 in Netherlands (compared to 0.75 and 0.94, respectively, for input additionality). This suggests that R&D tax credits are likely to elicit a larger response in terms of future investment in R&D than in terms of innovation output.

This finding is somewhat less optimistic than those reviewed in Straathof *et al.* (2014), who consider that "[o]verall, studies on the effectiveness of R&D tax incentives tend to find a positive impact on innovation." (p. 38). Indeed, Ernst and Spengel (2011) find that R&D tax incentives have a positive effect on patenting in Europe. However, this study does not use cross-country comparisons *per se*, but relies on a database pooling patents applied for at the EPO, from various European countries. Similarly, Westmore (2013), using a panel of OECD countries (with the country as the relevant unit of analysis) finds that R&D incentives are positively associated with patenting at the OECD level. But, again, the nature of the data is such that the author can only derive global estimates and cannot conduct cross-country comparisons.

TABLE 2 ABOUT HERE

[25] The lower value of 0.75 obtained in Belgium may be due to missing years in the Belgian sample, which is thus smaller than the other three. In any case, with a standard error of 0.10, the estimate lies within a 95% confidence interval of [0.55, 0.95].

[26] We have not found any study providing similar estimates for the UK.

As explained earlier, France has a much longer experience of R&D tax credits than the four other EU countries presented in Table 1. It therefore deserves to be treated with an econometric model that takes this specificity into account. To analyse the French sample, we adapt Model (1) by including three periods of tax credit ($TC1$, $TC2$ and $TC3$) rather than one, instrumenting each interacted term ($\ln RD \times TC1$, $\ln RD \times TC2$ and $\ln RD \times TC3$) with its own lags. Since implementation took place earlier in France, we are able to assume a 3-year lag between patenting and R&D, and lags of up to 3 years between current and past R&D. Period TC1 is the longest and corresponds to 1983-1998, while periods RTC2 and RTC3 correspond to 1999-2003 and 2004-2007, respectively. The estimates of this adapted model are presented in Table 2.

In all first-stage equations (displayed in the first three columns of estimates), there is at least one significantly positive parameter among those measuring the effects of the lags of R&D intensity. We therefore find, as we did in our other four EU countries, that conducting R&D in a context of tax credit is associated with more R&D in the future than if the tax credit had not been available. It is also noteworthy that the estimated input additionality is very close to those previously found in Italy, the Netherlands and the UK (which were always above 0.90). It is indeed equal to 0.89 (parameter estimate for $\ln RD_{it\text{-}4} \times TC1_{t\text{-}4}$) in the first column of Table 2, and to 0.91[27] (with a standard error of 0.08) in the second column. The much lower value of 0.24 found in the third column of Table 2 can be explained by the much shorter length of time available in our data to observe the third period of R&D tax credit in France. The first two estimates are, again, quite consistent with the literature. In particular, Duguet (2012), using Propensity Score Matching on firm-level data, finds an estimate of input additionality equal to 1. Mulkay and Mairesse (2013), using a more structural approach combined with simulations, find an estimate of about 0.7 in the long run.

In the second-stage equation (fourth column of Table 2), we observe significantly positive effects of R&D intensity on patenting in all three periods of R&D tax credit. The estimates of these effects are very similar, however: 0.26 for RTC1, 0.25 for RTC2 and 0.24 for RTC3. These results suggest that the successive waves of R&D tax credit conducted in France have been associated not only with an increase in R&D but also with an increase in the output of innovation (as measured by patenting). This makes France, together with Belgium and the Netherlands, one of the EU countries in which the R&D tax credit schemes may have proven effective (to some extent at least) in spurring innovation. As was already the case in Belgium and Netherlands, the effect of the tax credit on patenting is much lower than its effect on R&D. In addition, the fact that the estimates for all three periods in France are very close suggests that changes in the tax credit schemes were somewhat secondary (as far as innovation is concerned) compared to the existence of the tax credit itself. It could well be that these changes were adjustments due to trial-and-error more than to long-term planning.

To put it in a nutshell, the IV regressions presented here reveal a positive association between R&D conducted during a period of R&D tax credit and future investments in R&D in all of the five EU countries we consider in this study. In addition, we find a positive association between R&D conducting in the context of tax credit and patenting in three countries out of five. While these associations suggest that the existence of a tax credit is favourable to R&D and innovation, they may not be interpreted as causal effects of the R&D tax credit. To investigate the possible existence

[27] This value is the rounded sum of the parameter estimates for $\ln RD_{it\text{-}5} \times TC1_{t\text{-}5}$ and for $\ln RD_{it\text{-}4} \times TC2_{t\text{-}4}$, which are approximately 0.15 and 0.77 in the second column of estimates in Table 2.

of causal effects, we relied on a DID approach, the results of which are presented in the next sub-section.

4.2. DID analyses

The results of our DID estimations are presented in Table 3 for all five countries. We present the estimates of the first-stage equation (dedicated to the effect of the tax credit on R&D intensity) in the upper panel of Table 3 and those of the second-stage equation (dedicated to the effect of the tax credit on patenting) in the lower panel. We are primarily interested in the parameters estimates for the interaction terms Y_t x T, which are supposed to capture the causal effect of the R&D tax credit.

There are many year indicators Y_t in each country: nine in Belgium and the Netherlands, where the tax credit was introduced in 1998 (and where the observed treatment period in our data is therefore 1999-2007, i.e. nine years); seven in Italy and the UK, where the tax credit was introduced in 2000 (which leads to an observed treatment period of seven years, i.e. 2001-2007); and, last but not least, twenty-two in France, where the tax credit was introduced in 1983. To make the interpretation of the effect of the tax credit easier, we perform in each country a Fisher test of nullity of all interactions (H_0 "Y_1 x T = … = $Y_\mathcal{T}$ x T = 0" versus H_1 "There exists at least one Y_t x $T \neq 0$").

TABLE 3 ABOUT HERE

The results of these tests (in the form of their p-values) are presented for each country at the bottom of each panel of Table 3. In the case of France, we display three *p*-values because we conducted three tests, to account for the existence of three distinct phases in the tax credit: 1984-1998 (test of H_0 "Y_1 x T = … = Y_{15} x T = 0"), 2000-2003 (test of H_0 "Y_{16} x T = … = Y_{19} x T = 0" and 2005-2007 (test of H_0 "Y_{20} x T = … = Y_{22} x T = 0"). If a test is significant (i.e. with a p-value lower than the conventional thresholds of 0.10, 0.05 or 0.01), we conclude that there was an effect of the R&D tax credit on the relevant dependent variable during the period. Whenever a test is significant, we then compute the cumulated effect of the tax credit over the period, as well as its average effect (i.e., its estimated effect in an "average year"). These two effects are displayed at the bottom of each panel of Table 3, right after the p-values of the tests. We do not compute these effects when the tests are not significant.

One can see in Table 3 that the DID estimations allowed us to identify a significantly effect of the R&D tax credit on R&D intensity in three countries out of five: the Netherlands, the UK and France. In the former two countries, the cumulated effect is estimated is estimated at 44% and 37%, respectively. This means that nine years of tax credit have led to an overall increase of 44% in the log-R&D intensity in the Netherlands, and that seven years of tax credit have led to an increase of 37% in the log-R&D intensity in the UK. These effects correspond to an average yearly increase in the log-R&D intensity of 5% in the Netherlands and of 4% in the UK.

In France, the cumulated effect is estimated at 71% after the first 15 years (end of the first phase of the tax credit), then at 30% at the end of the second phase of the tax credit (i.e. after 4 years) and at 31% after 3 years of the tax credit in its third phase. These figures correspond to an average yearly effect of 5% in the first phase of the tax credit, 7% in the second phase, and 10% in the third phase.

All in all, these findings lead us to conclude to R&D tax credits are liable to increase investment in R&D in at least some EU countries. The findings displayed in the second panel of Table 3 are less encouraging, though: the test fails to reject the null hypothesis of no effect of the tax credit on innovation (as measured by patenting) in all five countries. As a whole, our findings suggest that the harmonized "super-deduction" for R&D proposed with the 2016 CCCTB may be effective in achieving the Horizon 2020 objective of increased R&D spending (although nothing guarantees that this increase will lead to R&D expenditures equal to at least 3% of the GDP by 2020). However, the super-deduction is unlikely to lead to more innovation and let alone to more innovation-based economic growth.

5. Conclusion

In this paper, we have discussed the relevance and feasibility of harmonizing R&D tax credits across the EU, as suggested as part of the 2016 CCCTB proposal. After detailing the tax credit schemes implemented in five selected European countries (Belgium, France, Italy, the Netherlands and the UK), we have argued that the main obstacle to harmonization lies in the great diversity of instruments and eligibility conditions that currently prevail across the EU.

We have conducted a subsidiarity test which suggests that, if the EU decides to move towards a harmonized R&D tax credit framework, it should at least impose a minimal level of tax rebate at the EU level, possibly complemented by additional country-level incentives. We highlight that the "super-deduction" included in the 2016 CCCTB proposal goes much further than this minimal EU-level tax credit. First, it would allow EU-based firms that choose this option to deduce more than 100% of their R&D expenditures from their tax base (which has no equivalent among current tax credit schemes). Second, it would be mandatory for large multinational firms. We have also discussed the possible implications of Brexit, both for the UK and for the EU.

To complement these reflections, we have conducted an econometric analysis on our five selected countries. The super-deduction proposed by the European Commission (EC) has its roots in the conviction that economic growth in Europe can only be knowledge-based, and that the current level of R&D investment in the EU is too low. The EC hopes that the super-deduction will boost R&D investment across Europe, which is assumed to be conducive to more innovation and, ultimately, more growth. Our econometric analysis has let us test whether this hope is empirically grounded, by examining whether the R&D tax credits implemented in the five aforementioned EU countries have spurred R&D intensity and patenting intensity between 1980 and 2007. We have found that the R&D conducted when a tax credit is available is associated with more R&D in the future in all five countries, and with more innovation in three countries out of five. In addition, we have identified a causal effect of the R&D tax credit on future R&D intensity in three countries out of five. However, we have not found any causal effect of the tax credit on innovation.

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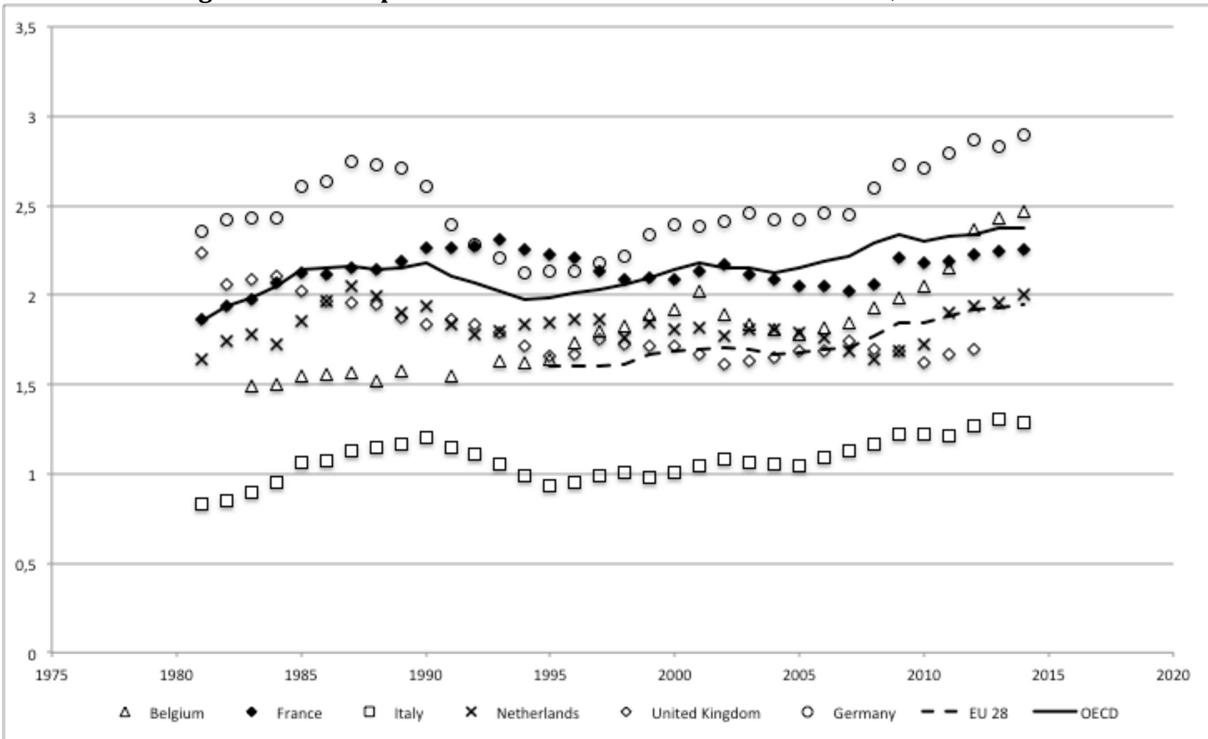
Figure 1: R&D expenditures in % of GDP for 6 EU countries, 1980-2014



Source: OECD (https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm), authors' own representation

Table 1: IV regression estimates for countries with a single RTC period

	First stage – dependent variable: R&D intensity (ln $RD_{it-1} \times TC_{t-1}$)			
	Belgium	**Italy**	**Netherlands**	**UK**
ln WTF_{it-1}	0.41	0.08	0.08	0.12
	(0.52)	(0.10)	(0.15)	(0.13)
ln EX_{it-1}	-1.55	-0.04	0.27^{*}	-0.14^{***}
	(1.20)	(0.07)	(0.15)	(0.06)
ln $RD_{it-2} \times TC_{t-2}$	0.75^{***}	0.92^{***}	0.94^{***}	0.95^{***}
	(0.10)	(0.02)	(0.02)	(0.03)
P-value of F test	0.000	0.000	0.000	0.000
	Second stage – dependent variable: Patenting intensity (ln PI_{it})			
	Belgium	**Italy**	**Netherlands**	**UK**
ln $RD_{it-1} \times TC_{t-1}$	0.05^{***}	0.03	0.14^{***}	0.03
	(0.02)	(0.03)	(0.02)	(0.02)
ln WTF_{it-1}	-0.09	0.13	-0.05	0.12^{*}
	(0.07)	(0.11)	(0.08)	(0.07)
ln EX_{it-1}	0.02	-0.12	0.97^{***}	-0.05
	(0.34)	(0.13)	(0.15)	(0.10)
P-value of F test	0.000	0.000	0.000	0.000
Observations	156	338	338	332

Note: Standard errors in parentheses. * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.
All estimations include a constant term, an industry fixed effect and a year fixed effect.
Statistics are robust to arbitrary heteroskedasticity and to arbitrary autocorrelation through kernel-based estimations. In addition, all estimations pass the usual under-identification and weak identification tests.

Table 2: IV regression estimates for France (three RTC periods)

	First stage – R&D intensity			2nd stage - Patenting intensity
	ln $RD_{it\text{-}3} \times TC1_{t\text{-}3}$	**ln $RD_{it\text{-}3} \times TC2_{t\text{-}3}$**	**ln $RD_{it\text{-}3} \times TC3_{t\text{-}3}$**	
ln $WTF_{it\text{-}3}$	0.02 (0.11)	-0.03 (0.11)	-0.03 (0.07)	-0.003 (0.04)
ln $EX_{it\text{-}3}$	0.56 (0.42)	0.09 (0.41)	-0.11 (0.26)	0.12 (0.13)
ln $RD_{it\text{-}3} \times TC1_{t\text{-}3}$	—	—	—	0.26^{***} (0.02)
ln $RD_{it\text{-}3} \times TC2_{t\text{-}3}$	—	—	—	0.25^{***} (0.04)
ln $RD_{it\text{-}3} \times TC3_{t\text{-}3}$	—	—	—	0.24^{**} (0.12)
ln $RD_{it\text{-}4} \times TC1_{t\text{-}4}$	0.89^{**} (0.06)	-0.08 (0.08)	—	—
ln $RD_{it\text{-}5} \times TC1_{t\text{-}5}$	-0.10 (0.06)	0.15^{**} (0.06)	—	—
ln $RD_{it\text{-}4} \times TC2_{t\text{-}4}$	—	0.77^{**} (0.07)	0.001 (0.05)	—
ln $RD_{it\text{-}5} \times TC2_{t\text{-}5}$	—	—	0.24^{***} (0.06)	—
P-value of F test	0.000	0.000	0.000	0.000
Observations			299	

Note: Standard errors in parentheses. * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.
The model includes a constant term, an industry fixed effect and a year fixed effect. It passes the usual under-identification and weak identification tests, as well as the Hansen over-identification test.

Table 3: DID IV estimates (dependent variables are ln R&D$_{it-1}$ in 1st stage and ln Patenting$_{it}$ in 2nd stage)

1st stage eq.	Belgium		Netherlands		Italy		UK		France	
ln WTF_{it-3}	0.03	(0.01)	0.03***	(0.01)	0.04***	(0.01)	0.02***	(0.01)	0.01**	(0.01)
ln EX_{it-3}	0.02***	(0.00)	0.01***	(0.00)	0.01**	(0.00)	0.02***	(0.00)	0.02***	(0.00)
ln RD_{it-2}	0.97***	(0.01)	0.99***	(0.00)	0.95***	(0.00)	0.96***	(0.00)	0.98***	(0.01)
T	0.02	(0.01)	-0.05***	(0.01)	-0.07***	(0.01)	-0.05***	(0.01)	-0.06***	(0.02)
Y_1	-0.05***	(0.14)	-0.05	(0.02)	-0.01	(0.02)	-0.02	(0.02)	0.0002	(0.02)
Y_2	-0.03**	(0.14)	-0.03**	(0.02)	-0.01	(0.02)	-0.02	(0.02)	-0.04**	(0.02)
Y_3	-0.04***	(0.14)	-0.04**	(0.02)	0.004	(0.02)	-0.01	(0.02)	-0.03*	(0.02)
Y_4	-0.03**	(0.14)	-0.03	(0.02)	0.02	(0.02)	0.01	(0.02)	-0.05***	(0.02)
Y_5	-0.02*	(0.14)	-0.03**	(0.02)	-0.02	(0.03)	-0.03	(0.02)	-0.06***	(0.02)
Y_6	-0.01	(0.14)	-0.01	(0.02)	0.01	(0.03)	-0.003	(0.02)	-0.07***	(0.02)
Y_7	-0.05***	(0.16)	-0.05***	(0.02)	-0.01	(0.03)	-0.02	(0.02)	-0.07***	(0.02)
Y_8	-0.02	(0.16)	-0.02*	(0.02)	—		—		-0.10***	(0.02)
Y_9	-0.04**	(0.16)	-0.04*	(0.02)	—		—		-0.10***	(0.02)
Y_{10}	—		—		—		—		-0.06***	(0.02)
Y_{11}	—		—		—		—		-0.03***	(0.02)
Y_{12}	—		—		—		—		-0.06***	(0.02)
Y_{13}	—		—		—		—		-0.05***	(0.02)
Y_{14}	—		—		—		—		-0.05***	(0.02)
Y_{15}	—		—		—		—		-0.08***	(0.02)
Y_{16}	—		—		—		—		-0.08***	(0.02)
Y_{17}	—		—		—		—		-0.09***	(0.02)
Y_{18}	—		—		—		—		-0.08***	(0.02)
Y_{19}	—		—		—		—		-0.07***	(0.02)
Y_{20}	—		—		—		—		-0.09***	(0.02)
Y_{21}	—		—		—		—		-0.07***	(0.02)
Y_{22}	—		—		—		—		-0.09***	(0.02)
$Y_1 \times T$	0.02	(0.02)	0.03	(0.02)	0.01	(0.03)	0.03	(0.02)	-0.02	(0.02)
$Y_2 \times T$	0.01	(0.02)	0.06**	(0.02)	0.04	(0.03)	0.02	(0.02)	0.03	(0.02)
$Y_3 \times T$	0.001	(0.02)	0.05**	(0.02)	0.02	(0.03)	0.04*	(0.02)	0.03	(0.02)
$Y_4 \times T$	0.004	(0.02)	0.04	(0.02)	-0.01	(0.03)	0.04	(0.02)	0.04	(0.02)
$Y_5 \times T$	-0.01	(0.02)	0.05**	(0.02)	0.02	(0.03)	0.09***	(0.03)	0.05	(0.02)
$Y_6 \times T$	-0.02	(0.02)	0.02	(0.02)	0.01	(0.03)	0.07***	(0.03)	0.05	(0.02)
$Y_7 \times T$	0.01	(0.02)	0.09**	(0.02)	0.05	(0.03)	0.07***	(0.03)	0.05	(0.02)
$Y_8 \times T$	-0.01	(0.02)	0.05*	(0.02)	—		—		0.09	(0.02)
$Y_9 \times T$	-0.02	(0.02)	0.05*	(0.02)	—		—		0.11	(0.02)
$Y_{10} \times T$	—		—		—		—		0.06	(0.02)
$Y_{11} \times T$	—		—		—		—		0.07	(0.02)
$Y_{12} \times T$	—		—		—		—		0.06	(0.02)
$Y_{13} \times T$	—		—		—		—		0.04*	(0.02)
$Y_{14} \times T$	—		—		—		—		0.03*	(0.02)
$Y_{15} \times T$	—		—		—		—		0.07	(0.02)
$Y_{16} \times T$	—		—		—		—		0.08	(0.02)
$Y_{17} \times T$	—		—		—		—		0.09	(0.02)
$Y_{18} \times T$	—		—		—		—		0.06	(0.02)
$Y_{19} \times T$	—		—		—		—		0.08	(0.02)
$Y_{20} \times T$	—		—		—		—		0.10	(0.03)
$Y_{21} \times T$	—		—		—		—		0.08	(0.03)
$Y_{22} \times T$	—		—		—		—		0.13	(0.03)
P-value - F test	0.000		0.000		0.000		0.000		0.000	
P-value - *"all interactions equal to 0"*	0.734		0.000		0.622		0.000		RTC { 1: 0.000 2: 0.048 3: 0.000	
Cumulated effect	—		0.44*** (0.08)		—		0.37*** (0.06)		{ 0.71** (0.36) 0.30*** (0.10) 0.31*** (0.08)	
Average effect	—		0.05*** (0.01)		—		0.04*** (0.01)		{ 0.05** (0.02) 0.07*** (0.02) 0.10*** (0.03)	

(TABLE 3 CONTINUES ON NEXT PAGE)

2nd stage eq.	Belgium		Netherlands		Italy		UK		France	
ln $WTF_{it\text{-}3}$	0.001	(0.07)	-0.15***	(0.04)	-0.11**	(0.05)	-0.10*	(0.05)	-0.06	(0.04)
ln $EX_{it\text{-}3}$	-0.33***	(0.02)	-0.42***	(0.01)	-0.39***	(0.01)	-0.38***	(0.01)	-0.51***	(0.01)
ln $RD_{it\text{-}1}$	0.21***	(0.03)	0.36***	(0.02)	0.34***	(0.02)	0.36***	(0.03)	0.07**	(0.03)
T	-0.23***	(0.07)	0.003	(0.03)	-0.74***	(0.04)	-0.99***	(0.03)	-0.40***	(0.09)
Y_1	0.37***	(0.06)	0.62***	(0.05)	0.57***	(0.08)	0.57***	(0.07)	0.12***	(0.10)
Y_2	0.42***	(0.06)	0.66***	(0.05)	0.61***	(0.08)	0.61***	(0.07)	0.21***	(0.10)
Y_3	0.40***	(0.06)	0.65***	(0.05)	0.70***	(0.08)	0.70***	(0.09)	0.30***	(0.10)
Y_4	0.43***	(0.07)	0.69***	(0.05)	0.73***	(0.09)	0.73***	(0.09)	0.43***	(0.09)
Y_5	0.53***	(0.07)	0.78***	(0.06)	0.87***	(0.09)	0.76***	(0.11)	0.49***	(0.09)
Y_6	0.57***	(0.07)	0.81***	(0.06)	0.87***	(0.09)	0.76***	(0.11)	0.52***	(0.08)
Y_7	0.65***	(0.09)	0.84***	(0.08)	0.86***	(0.09)	0.75***	(0.11)	0.44***	(0.08)
Y_8	0.66***	(0.09)	0.84***	(0.08)	—		—		0.38***	(0.08)
Y_9	0.65***	(0.09)	0.83***	(0.09)	—		—		0.40***	(0.08)
Y_{10}	—		—		—		—		0.51***	(0.08)
Y_{11}	—		—		—		—		0.64***	(0.09)
Y_{12}	—		—		—		—		0.67***	(0.10)
Y_{13}	—		—		—		—		0.89***	(0.10)
Y_{14}	—		—		—		—		1.04***	(0.10)
Y_{15}	—		—		—		—		1.14***	(0.10)
Y_{16}	—		—		—		—		1.26***	(0.10)
Y_{17}	—		—		—		—		1.26***	(0.10)
Y_{18}	—		—		—		—		1.31***	(0.10)
Y_{19}	—		—		—		—		1.42***	(0.11)
Y_{20}	—		—		—		—		1.56***	(0.14)
Y_{21}	—		—		—		—		1.56***	(0.14)
Y_{22}	—		—		—		—		1.56***	(0.14)
$Y_1 \times T$	-0.23**	(0.11)	-0.11	(0.09)	0.04	(0.09)	-0.13	(0.09)	0.04	(0.13)
$Y_2 \times T$	-0.22**	(0.10)	-0.06	(0.09)	0.01	(0.09)	-0.11	(0.10)	0.11	(0.13)
$Y_3 \times T$	-0.33***	(0.09)	-0.05	(0.10)	-0.05	(0.09)	-0.16	(0.11)	0.07	(0.13)
$Y_4 \times T$	-0.27**	(0.11)	-0.05	(0.09)	-0.07	(0.10)	-0.18	(0.11)	0.07	(0.12)
$Y_5 \times T$	-0.24**	(0.12)	-0.11	(0.10)	-0.11	(0.10)	-0.22	(0.13)	0.04	(0.12)
$Y_6 \times T$	-0.24**	(0.11)	-0.01	(0.10)	-0.12	(0.10)	-0.17	(0.13)	0.07	(0.11)
$Y_7 \times T$	-0.33***	(0.12)	-0.06	(0.11)	-0.17	(0.11)	-0.16	(0.14)	0.11	(0.11)
$Y_8 \times T$	-0.26**	(0.13)	0.04	(0.11)	—		—		0.20*	(0.11)
$Y_9 \times T$	-0.24*	(0.12)	-0.06	(0.11)	—		—		0.14	(0.11)
$Y_{10} \times T$	—		—		—		—		0.12	(0.11)
$Y_{11} \times T$	—		—		—		—		0.08	(0.11)
$Y_{12} \times T$	—		—		—		—		0.09	(0.12)
$Y_{13} \times T$	—		—		—		—		-0.002	(0.12)
$Y_{14} \times T$	—		—		—		—		-0.08	(0.12)
$Y_{15} \times T$	—		—		—		—		-0.08	(0.12)
$Y_{16} \times T$	—		—		—		—		-0.17	(0.12)
$Y_{17} \times T$	—		—		—		—		-0.17	(0.12)
$Y_{18} \times T$	—		—		—		—		-0.17	(0.13)
$Y_{19} \times T$	—		—		—		—		-0.24*	(0.13)
$Y_{20} \times T$	—		—		—		—		-0.29*	(0.16)
$Y_{21} \times T$	—		—		—		—		-0.27	(0.17)
$Y_{22} \times T$	—		—		—		—		-0.23	(0.17)
P-value, F test	0.000		0.000		0.000		0.000		0.000	
P-value, "all interactions equal to 0"	0.107		0.940		0.560		0.254		RTC 1: 0.448 RTC 2: 0.439 RTC 3: 0.166	
Cumulated effect	—		—		—		—		—	
Mean effect	—		—		—		—		—	
Observations	303		641		641		635		589	

Note: Robust standard errors in parentheses. * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01.
All estimations include an individual fixed-effect.

Appendix

Table A1 – List of industries (NACE, 2 digits)

Code	Description
15t16	Food, Beverages and Tobacco
17t19	Textiles, Textile products, Leather and footwear
20	Wood and Products of wood and cork
21t22	Pulp, Paper, Paper products, Printing and publishing
23	Coke, Refined petroleum and Nuclear fuel
24	Chemicals and Chemical products
25	Rubber and plastic
26	Other non-metallic mineral
27t28	Basic metals and Fabricated metal
29	Machinery, Other Machinery
30t33	Electrical equipment, Electronics and Optical equipment
34t35	Transport equipment
36t37	Other manufacturing, Recycling

Figure A1 – R&D intensity by industry for each of the 5 selected EU countries

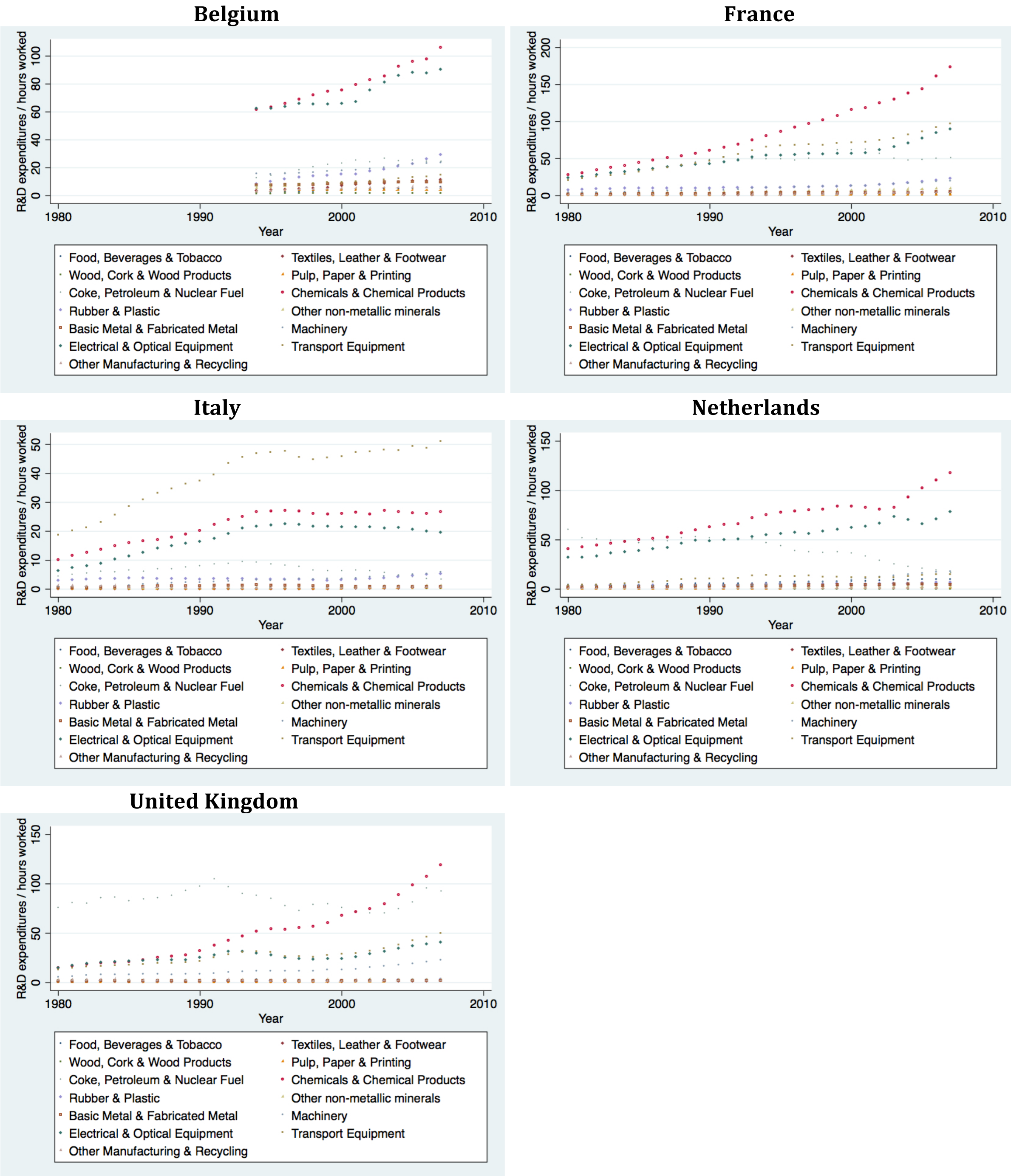
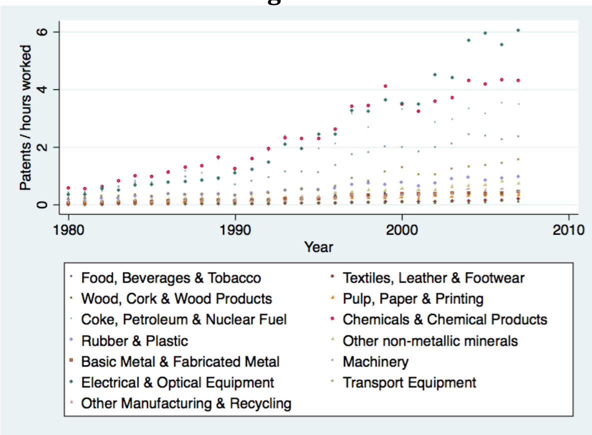
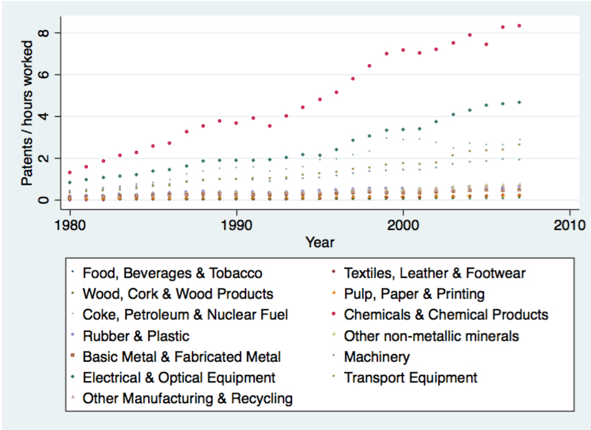


Figure A2 – Patenting intensity by industry for each of the 5 selected EU countries

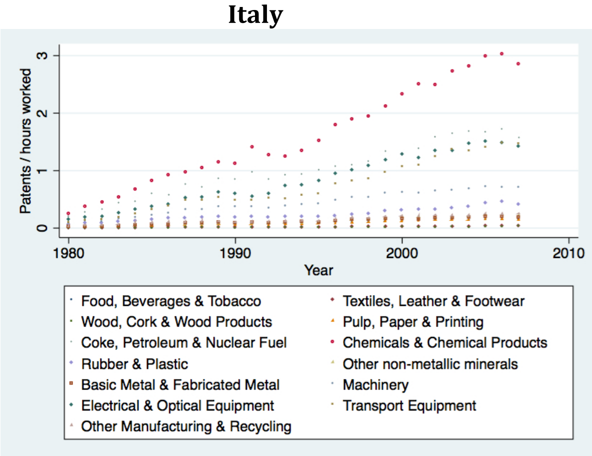
Belgium



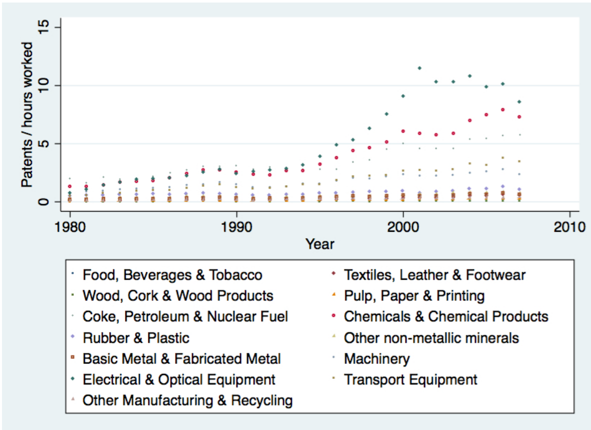
France



Italy



Netherlands



United Kingdom