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Abstract

This paper presents an ex post evaluation of the 2008 reform of the French research tax credit. The tax scheme was massively overhauled, with a switch to a pure volume-based design, leading to a large increase in the number of firms applying and an important increase in the cost of the scheme. Given the timing and the characteristics of the reform, measuring its causal impact is challenging. We have relied on four unique sources of data — R&D surveys, administrative tax data, firm characteristics and patent datasets — to assess how French firms have reacted to these changes in incentives. Our empirical strategies rest on combining difference in differences with matching methods and taking advantage of the particular way the 2008 reform has affected incentives to invest in R&D. Our results suggest a positive effect of the 2008 reform on R&D at both the intensive margin and extensive margin, but a possible lower impact on innovation than could have been expected.

Keywords: tax credit, evaluation, R&D, innovation; *JEL codes:* C23, H25, O32.

Résumé

Cet article vise à évaluer l'impact ex post de la réforme en 2008 du crédit impôt recherche (CIR) en France. Le dispositif a en effet été profondément modifié, devenant assis sur le volume des dépenses de R&D et non plus sur leur augmentation, ce qui a entraîné une hausse considérable du nombre d'entreprises déclarantes mais aussi du coût total du crédit impôt recherche. Pour tenter de mesurer l'impact causal de la réforme et évaluer comment les entreprises ont réagi en termes d'effort de R&D et d'innovation à ce changement de dispositif, nous avons rassemblé quatre bases de données uniques : les données de l'enquête R&D, des données de brevets, la base de gestion du CIR, et des données sur les caractéristiques des entreprises. Notre stratégie empirique repose sur une double différence combinée à un appariement par score de propension. Nos résultats suggèrent un effet positif de la réforme de 2008 sur la R&D à la fois pour les entreprises déjà présentes dans le dispositif (marge intensive) et pour celles qui sont entrées dans le dispositif (marge extensive) sur la période 2004-2010, mais un effet sur l'innovation plus faible qu'attendu.

Mots-clés: crédit impôt recherche, R&D, innovation; *Codes JEL:* C23, H25, O32.

Non-technical summary

R&D and innovation are seen as key determinants of productivity and long-term growth. However, in many European countries, in France in particular, R&D efforts are still far from the 2020 objectives of reaching a level of business R&D of 2% of GDP and a level of total R&D of 3%. As a consequence, governments have increasingly implemented policies aiming at sustaining R&D and innovation. Their main justification is that firms tend to under-invest in R&D, as compared to what would be socially optimal, given that these investments are risky and that firms cannot capture all the benefits of their R&D efforts. To correct these market failures, policies have mainly taken two forms: subsidies and research tax credits. Grant or subsidies can target specific projects with high social returns and high quality. Tax credit schemes have the advantage to reduce the marginal cost of R&D spending and to benefit to more firms (especially SMEs). In the context of constrained public finances and given the amount of tax expenditures involved, it is crucial to evaluate the impact and effectiveness of these policies.

The aim of this study is to empirically evaluate the *ex post* impact of the French research tax credit scheme on firm's R&D and innovation. In our analysis, we focus on the 2008 reform of the French tax credit system. In France, the research tax credit was initiated in 1983 but has since been reformed significantly. It was initially incremental (based on the increase in R&D spending). In 2004, a share in volume has been introduced in parallel (based on the amount of R&D). The reform of 2008 was even more radical with the adoption of a research tax credit scheme purely in volume. The rate of tax credit was raised to 30% of R&D expenditures up to 100 million euros and to 5% above. The French research tax credit became then the first source of public support to business R&D. In 2011, 17,000 firms took advantage of the scheme, and it is estimated to cost 3.07 billion euros in tax expenditures. Declared R&D spending qualifying for the tax credit amounted to 18.2 billion euros.

Our empirical study relies on the combination of four unique datasets over the period $2004 - 2010$: i) the yearly survey on R&D investments conducted by the French Ministry of Research which contains detailed information on firms' R&D; ii) the PATSTAT dataset of the European Patent Office which enables us to measure innovation at the firm-level; iii) the tax files which enables us to identify all the firms in France which benefit from the research tax credit as well as its amount, and iv) the FIBEN dataset of the Banque de France which is used to control for firms' economic and financial characteristics. Our final sample includes 48,111 firms, from which 51.3% have taken advantage of the research tax credit. Our econometric strategy relies on the implementation of a difference in differences which amounts to comparing R&D and innovation outcome for firms which benefit from the research tax credit and for those which do not, before and after the implementation of the reform. We also implement propensity score matching analysis and compare firms which have similar observable characteristics except that some of them only took advantage from the research tax credit.

Our results suggest that firms which did benefit from the R&D tax credit relative to those that did not ask for it have significantly increased their R&D expenditures after the 2008 reform. Our results also show that the estimated elasticity differs when we focus on the

intensive margin (i.e. when the sample is limited to firms which already ask for the research tax credit before the reform) or on the extensive margin (i.e. on firms which entered in the tax credit scheme over the period $2004 - 2010$). Nevertheless, we do not find evidence of a significant impact on innovation as measured by the number of patents at the firm level, up to two years after the implementation of the reform. Given the time span of analysis is shorter than the usual patenting process, once cannot conclude to the inefficiency of the scheme on innovation, but it still raises some concerns to the actual impact of these policies.

1 Introduction

R&D and innovation are seen as key determinants of productivity and competitiveness, and it has been claimed that the low growth performances of EU countries in the last decades, compared to the US, stem from their lack of innovation. The policy response at the EU level has been to set ambitious targets of R&D spending – supposed to reach 2% of GDP – as part of its "Lisbon strategy". One of the instruments largely used across the EU has been the development of tax incentives for private firms to invest in R&D. In the context of constrained public finances and given the amount of tax expenditures involved, it is crucial to evaluate the impact and effectiveness of these policies. This study aims at empirically assessing the *ex post* impact of the French research tax credit scheme on firm's R&D and innovation.

An important literature has tried to analyse the impact of public policies in favour of business R&D (see David, Hall, and Toole (2000)) and in particular to assess the effect of tax credits schemes on R&D investments (see Hall and Van Reenen (2000); Ientile and Mairesse (2009), for reviews of existing literature). Many studies rely on structural econometric models in which the level of R&D investment of a firm is determined by the user cost of capital R&D. This method has been in particular used by Bloom, Griffith, and Van Reenen (2002) to analyse the effect of tax credit schemes on the level of R&D investments in nine OECD countries over the period 1979-1997. Results indicate that a 10% decrease in the user cost of R&D raises R&D investments by 10% in the long run. At the firm level, the long run elasticity is smaller and estimated at 0.45 in the Netherlands over the period 1996-2004 (Lokshin and Mohnen (2012)) and at 0.4 in the case of France over the period 1981-2007 (Mairesse and Mulkay, 2013). Other studies have instead relied on quasi-natural experiments to assess the *ex post* impact of research tax credit schemes on firm level R&D investments. Hægland and Møen (2007) use a discontinuity linked to the existence of ceilings in eligible R&D expenditures and find that the research tax credit implemented in 2002 in Norway had a positive and significant impact on firm R&D investments. Duguet (2010) in the case of France evaluates the impact of the incremental tax credit scheme over the period 1993-2003 using propensity score matching techniques. The results show that one euro of tax credit leads to an increase in private R&D of one euro.

Overall, these studies tend to find a positive effect of research tax credits on R&D investments. However, a number of questions are still pending. First it is still difficult to establish a consensus on the impact of these policies on R&D investments as tax incentive schemes differ largely in terms of design and studies differ largely in terms of coverage and methodology. Second, with the exception of the study Czarnitzki, Hanel, and Rosa (2011) which finds a significant impact of the research tax credit in Canada on innovation, evidence is still scarce about the effect of these policies on R&D output. This is an important outcome to evaluate as one main concern of policy makers is that public funding might be used to support activities with a low content in R&D, or activities that would have been carried out even in the absence of the policy. Finally, tax credit schemes take different forms in different countries, and little is known about the relative effectiveness of incremental versus volume base schemes.

The aim of this paper is to contribute to this literature by evaluating the impact of the

French research tax credit system on both R&D investments and innovation. In our empirical analysis, we will focus on the 2008 reform, which led to the adoption of a pure volume-based scheme. A research tax credit (*Crédit impôt recherche*, aka CIR) was created in France in 1983 but has since been reformed significantly. It was initially a limited policy, compared to other measures to support R&D like direct subsidies. Its design was incremental, i.e. based on the increase in R&D spending from one year to the other. In 2004, a major reform introduced an element of the tax credit in proportion to the volume of R&D. The reform of 2008 is even more radical with the adoption of a research tax credit scheme purely in volume. This led to a large increase in the cost of the scheme. The rate of tax credit was raised to 30% of R&D expenditures up to 100 million euros and to 5% above. The French research tax credit became then the first source of public support to business R&D. In 2011, 17,000 firms took advantage of the scheme, and it is estimated to cost 3.07 billion euros in tax expenditures. Declared R&D spending qualifying for the tax credit amounted to 18.2 billion euros.

Our analysis relies on an *ex post* econometric evaluation of the 2008 reform. Our empirical analysis is based on the combination of four datasets over the period $2004-2010$: i) the yearly survey on R&D investments conducted by the French Ministry of Research which contains detailed information on firms' R&D; ii) the PATSTAT dataset of the European Patent Office which enables us to measure innovation at the firm-level; iii) the tax files which enables us to identify all the firms in France which benefit from the research tax credit as well as its amount, and iv) the FIBEN dataset of the Banque de France which is used to control for firms' economic and financial characteristics. Our final sample includes 48,111 firms, from which 51.3% have taken advantage of the research tax credit. Our econometric strategy relies on the implementation of a difference in differences which amounts to comparing R&D and innovation outcome for firms which benefit from the research tax credit and for those which do not, before and after the implementation of the reform. The fact that each year in France, nearly 49% of firms which are registered in the R&D survey and which have positive R&D expenditures do not ask for the research tax credit can have several explanations: firms might not be aware of the policy, their R&D activities might not be eligible to the tax credit, asking for the research tax credit might be too complex and costly or firms might want to avoid a tax audit. Nevertheless, as we cannot exclude the possibility of a selection bias in the sample of treated and control firms, we also implemented propensity score matching analysis.

Our results suggest that firms which did benefit from the R&D tax credit relative to those that did not ask for it have significantly increased their R&D expenditures after the 2008 reform. Our results also show that the estimated elasticity differs when we focus on the intensive margin (i.e. when the sample is limited to firms which already ask for the research tax credit before the reform) as the reform led to a large number of firm entry in the tax credit scheme which are relatively smaller in terms of R&D investments. More importantly, we do not find evidence of a significant impact on innovation as measured by the number of patents at the firm level, up to two years after the implementation of the reform. Given the time span of analysis is shorter than the usual patenting process, once cannot conclude to the inefficiency of the scheme on innovation, but it still raises some concerns to the actual impact of these policies.

We contribute to the literature on tax credit evaluation in several ways. First, existing evaluations of the research tax credit have not so far estimated the *ex post* impact of the 2008 reform. This reform is important as the adoption of a purely volume based scheme translated into a considerable increase in the amount of the tax credit that each firms can receive and by an important increase in the number of firms which could actually benefit from it. Besides, it enables us to assess the relative effectiveness of volume base schemes with respect to incremental base schemes, a topic on which evidence in the existing literature is still scarce. This has important implications in the design of these policies. Second, our study suggests that the impact of the research tax credit on R&D output is rather low. One could argue that innovation and patenting take time so that it is not surprising not to find any impact of tax credit schemes on innovation in the short term. However, these results also suggest that tax credit schemes tend to support R&D investments with relatively low returns. It might therefore be necessary to redesign these tax incentives by introducing, as it has just been decided in France, some tax credit specifically targeted towards innovation activities in order to ensure that tax credit schemes contribute to foster R&D but also innovation at the firm-level.

After reviewing existing evidence on the impact of tax credits (section 2), we present the design of the French scheme in section 3, detailing how the 2008 reform has affected firms' incentives to invest in R&D. Section 4 presents the different datasets that underpin our empirical analysis and section 5 discusses the different strategies developed to estimate the impact of the reform. Results on R&D and on innovation are respectively presented in section 6 and 7 and last section concludes.

2 Previous literature

Ideally, to assess the impact of the research tax credit, one would like to compare the R&D and innovation activities of a firm which takes advantage from the research tax credit with those of the same firm had it not benefited from it. Applying for the research tax credit reveals *per se* differences between applicants and non applicants which are likely to be correlated with their R&D and innovation behaviour. In particular, firms which do ask for the research tax credit are likely to be more efficient in dealing with administrative and accounting, more specialized in R&D and innovation, and they are also likely to be the ones expecting the highest potential gains from research tax credit. In order to tackle this selection bias issue, previous studies have used two main approaches: some studies have relied on structural econometric models while other authors have relied on quasi natural experiments (see Hall and Van Reenen (2000) or Ientile and Mairesse (2009) for reviews of existing evidence).

2.1 Structural econometric models

Many studies rely on structural econometric methods which consist in modeling the economic behaviour of firms' R&D investments. In these models, the level of R&D investments is determined by the user cost of capital R&D, which is defined as the annual cost of using capital R&D. The user cost of capital R&D takes into account the price of R&D, the opportunity costs

of locked-in funds, the capital R&D depreciation rate, the inflation rate, the potential subsidies received by the firm and finally some remaining tax parameters, including the research tax credit. The econometric approach consists in assessing the impact of the research tax credit in two steps. First, one has to compute the impact of the research tax credit on the user cost of capital R&D. In a second step, one can assess econometrically the change in R&D investments associated with the change in the user cost, controlling for all other factors likely to affect R&D (firm characteristics and past R&D investments to account for the potential dynamic of R&D investments).

This method has been used in many studies to evaluate the impact of the research tax credit on R&D investments at the country level or at the firm level. Bloom, Griffith, and Van Reenen (2002) analyse the effect of the research tax credit on the level of R&D investments in nine OECD countries. They estimate an econometric model of R&D investment over the period 1979-1997. They exploit the time and cross-country variations in the rules of implementation of tax credit schemes and their successive reforms to identify the impact of changes in the user cost of R&D capital on the level of private R&D. They conclude that tax credit schemes have a positive impact on R&D investments: a decrease of 10% in the user cost of R&D capital is associated with an increase of R&D of 1% in the short run and of 10% in the long run. Mulkay and Mairesse (2013) also use this method to evaluate the impact of the research tax credit on R&D investments in France but at the firm level. The authors estimate the user cost of R&D capital by taking into account the research tax credit and then estimate the impact of the user cost of R&D capital on the optimal level of R&D. Over the period 1981-2007, the price elasticity of R&D capital is 0.4. By computing the impact of the research tax credit on the user cost of R&D capital, they are able to provide an ex ante evaluation of the 2008 reform. Lokshin and Mohnen (2012) analyse the impact of R&D tax incentives in the Netherlands, which consist in a tax rebate on employer social contributions depending on the wage bill linked to R&D. In order to do so, they estimate a dynamic factor model of demand to measure the response of R&D investments to changes in the user cost of R&D capital induced by these tax incentives. The econometric model is estimated on a panel of firms over the period 1996-2004. Results show that firm R&D behaviours respond to changes in the user cost of capital R&D: the short term elasticity is 0.25 and the long run elasticity is 0.45. Finally, this method has also been used by Corchuelo (2006) to evaluate the impact of a modification of the research tax credit in Spain in 1995 on the decision to start R&D and on the amount of R&D expenditures in case of positive R&D expenditures. Results over the period 1990-1998 indicate that a decrease in the user cost of R&D capital affects more the decision to start R&D (extensive margin) than the volume of R&D investment (intensive margin).

These structural economic approaches have the advantage to be derived directly from the economic behaviour of firm R&D investments. Nevertheless they present some caveats. First, the level of R&D investments and the user cost of R&D capital are likely to be simultaneously determined, which would imply finding instrumental variables, that are not easy to come by. Second, the construction of the R&D user cost requires gathering detailed and precise information at the firm level, with a risk of important measurement errors depending on data

quality. Finally, variation in the user costs are likely to be more pronounced in the time dimension rather than across firms, so that it might be difficult to disentangle the impact of the introduction of the research tax credit from any other macroeconomic shock. For these reasons, some studies have instead relied on quasi-natural experiments, and this is the strategy that we adopt here.

2.2 Quasi-natural experiments

The main intuition behind these methods is to rely on the exploitation of discontinuities in the implementation and rules of tax credit schemes to define exogenously a group of treated firms and a group of controls.

A first approach can consist in using the time dimension of a tax credit scheme and to compare for instance the growth rate of R&D expenditures before and after the introduction or the modification of the tax credit scheme. One limit of such approach is that one cannot isolate the effect of the implementation of the tax credit scheme from any other shock which could also affect R&D expenditures. One solution to tackle this issue is to implement instead a difference in difference. The main idea is to use another discontinuity in the tax credit schemes which explains why, for some exogenous reasons, some firms take advantage from the research tax credit while some others do not (these discontinuities can for instance stem from the existence of eligibility criteria in terms of firm size, sectors or amount of R&D). In this case, one compares two groups of firms, those which benefit from it and those which do not; before and after the implementation of the policy. The main advantage with the comparison of two groups of firms before and after the implementation of the policy, is that it enables to control for any other macroeconomic shock than the policy which would be common to the two groups of firms but also to control for any differences between the two groups of firms which would be constant over time. This method has been in particular used by Haegland and Moen (2007) in their econometric evaluation of the research tax credit implemented in Norway in 2002. They compare R&D investments of firms whose R&D expenditures are just below or above the ceiling of 4 million Norwegian Krones before and after the implementation of the policy, the main idea being that firms with R&D expenditures above this ceiling do not benefit from research tax credit on their marginal investments. Results show that the tax credit scheme has a positive and significant impact on firms R&D investments.

Nevertheless, a crucial problem in the absence of discontinuity is that the selection of firms which do ask for the research tax credit is not exogenous. And as soon as these differences between treated and controls are not constant over time there are likely to be correlated with the probability of treatment and with the outcome of interest. Some studies have therefore relied instead on propensity score matching, that might or not be combined with difference in differences approaches. The main principle of the propensity score matching is to match each firm with some observations which, according to their observables characteristics, had the same probability to be treated and to compare R&D and innovation between these treated and control firms. This method has been used by Duguet (2010) in the case of France to evaluate the research tax credit in France over the period 1993-2003 when it was purely incremental (i.e. based on the growth of R&D expenditures). Results show that the research tax credit in

France has a positive impact on private R&D expenditures: one additional euro of tax credit would rise R&D expenditures by a bit more than one euro. Lhuillery, Marino, and Parrota (2013) evaluate the effect of public R&D subsidy and tax credit on private R&D expenditures in a sample of French firms during the period 1993-2009 and find evidence of additionality effects for R&D, tax credit and total support when comparing large dose recipients with other categories of treated or untreated firms. This method has also been used recently to assess the impact of the research tax credit on innovation activities at the firm level. Czarnitzki et al. (2011) also used propensity score matching to evaluate the impact of a Canadian research tax credit on innovation. They conclude that it has a positive impact on some innovation indicators but not on all. In the case of Norway, Cappelen, Raknerud, and Rybalka (2012) show that the Norwegian tax credit has a positive impact on the development of new processes but not on the introduction of new products and neither on patenting.

Overall, regardless of the method used, studies tend to conclude to a positive impact of the implementation or research tax credit schemes on R&D inputs. The evidence is however more mixed, though still relatively scarce, regarding the impact of these tax incentives on R&D output such as innovation of products and process or patents. This study aims at contributing to this literature by investigating the impact of the recent reform of the tax credit scheme in France on both R&D and innovation at the firm-level.

3 The French research tax credit

As indicated by its name, the main principle of the research tax is to encourage firms' R&D investment by enabling firms to deduct a share of their R&D expenditures from their taxable profits. In France, the research tax credit was initiated in 1983 but has since been reformed significantly (see Table 1 for a description of the main reforms). It was initially incremental: only firms which did increase their R&D spending could take advantage from it. The research tax credit was then only a secondary measure in favour of business R&D for the French government, its total average annual amount, assessed to 465 million euros over the period 1994-2003, remained below the amount of R&D subsidies.

With the 2004 reform, the research tax credit has been strengthened with the introduction of a share in volume (based on the amount of R&D) in parallel. The main advantage of the introduction of a share in volume is that any positive R&D expenditure eligible to the research tax credit can give rise to some research tax credit. The research tax credit is then composed of an incremental share (which is equal to 45% of the increase in R&D expenditures in year n with respect to the average of R&D expenditures registered in years $n-1$ and $n-2$) and a share in volume equal to 5% of R&D, with a ceiling of 8 million euros.[1] The 2004 and 2006 reforms are particularly linked to the willingness of the French government to increase business R&D, still below the Lisbon objective of 2% of GDP and a level of total R&D of 3%. With those reforms, the research tax credit reached in France 1.7 billion euros in 2007 (MESR, 2011).

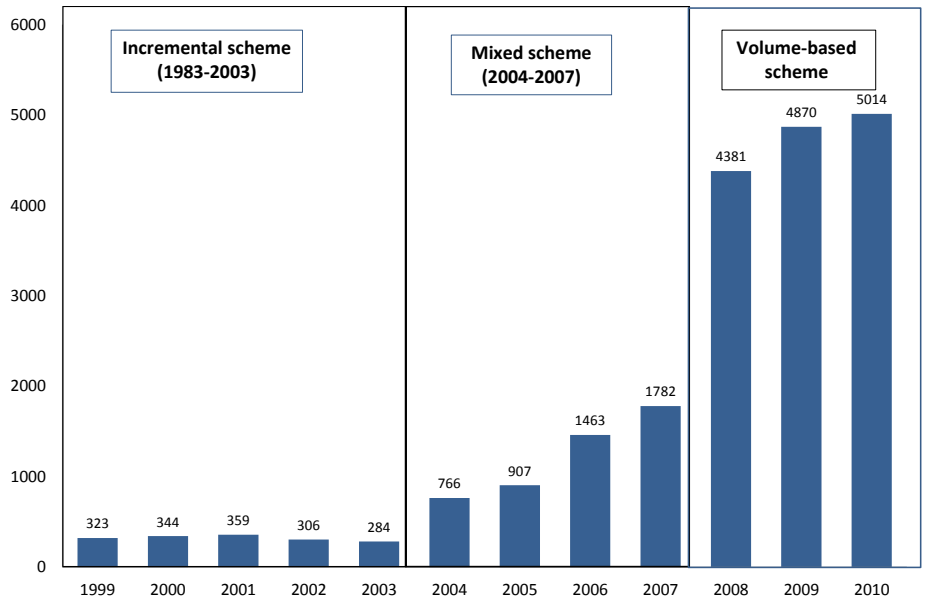
[1]The incremental share has been decreased to 40% and the share in volume has been increased to 10% in 2006.

Table 1: Design of the French research tax credit (1983-2014).

Design of tax credit	**Year of reform**	**Formula of research tax credit**	**Maximum amount (in million euros)**
Incremental	1983	0.25*[RD(t) – RD(t-1)]	€0.4 M.
	1985	0.50*[RD(t) – RD(t-1)]	€0.7 M.
	1988	0.50*[RD(t) – RD(t-1)] 0.30*[RD(t) – RD(1987)]	€1.5 M.
	1991	$0.50 * \left[RD(t) - [\frac{RD(t-1)+RD(t-2)}{2}]\right]$	€6.10 M.
Mixed incremental and in volume	2004	0.45*[RD(t) – RD(t-1)] + 0.05*RD(t)	€8 M.
	2006	0.40*[RD(t) – RD(t-1)] + 0.10*RD(t)	€10 M.
	2007	0.45*[RD(t) – RD(t-1)] + 0.10*RD(t)	€16 M.
In volume	2008	0.30*RD(t), if $RD(t) <= 100$ M € 30 + 0.05*[RD(t)-100], if $RD(t) > 100$ M €	–
		0.50*RD(t) if first year in tax credit scheme	
		0.40*RD(t) if second year in tax credit scheme	
	2011	0.30*RD(t), if $RD(t) <= 100$ M € 30 + 0.05*[RD(t)-100], if $RD(t) > 100$ M €	–
		0.40*RD(t) if first year in tax credit scheme	
		0.35*RD(t) if second year in tax credit scheme	
	2013	0.30*RD(t), if $RD(t) <= 100$ M € 30 + 0.05*[RD(t)-100], if $RD(t) > 100$ M €	–
		20% innovation expenditures (for SMEs only)	€0.4 M.

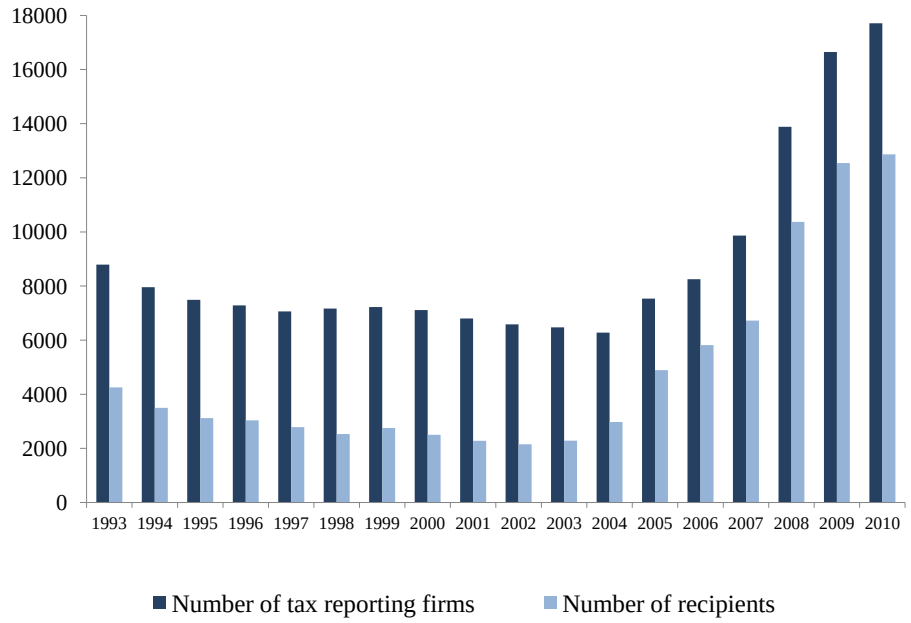
Note: $RD(t)$ is the amount of R&D in year t.

Figure 1: Amount of the French research tax credit (1999-2010).



NOTE: The series represented presents the amount of tax credit awarded each year which can differ from the tax credit effectively paid each year.
SOURCE: GECIR dataset.

Figure 2: Number of firms receiving the research tax credit (1993-2010)



However, the 2008 reform, on which we focus in this analysis, is the most important and the most radical one. The research tax credit is simplified with the adoption of a purely volume based scheme. The research tax credit depends then only on the amount of the R&D expenditures invested a given year and the ceiling regarding the maximum amount of tax credit a firm can receive is suppressed. The research tax credit is equal to 30% of R&D expenditures below 100 million euros, and it is equal to 5% of R&D expenditures above this level. For those firms which ask for it for the first time, the rate is equal to 50% the first year of entry in the scheme and to 40% the second year, those rates having been decreased to 40% and 35% respectively with the finance law for 2011. Thus, with the reform of 2008, which makes the research tax credit much more attractive in France, the research tax credit becomes the first source of public support to business R&D. It covers 17,000 firms in 2010, the amount of tax credit claimed by firms reaches 5.05 billion euros for a business R&D of 18.2 billion euros.

Note that since, the research tax credit has still been slightly modified in 2013 with the suppression of these preferential rates for firms claiming the research tax credit for the first time and with the introduction of an innovation tax credit, which is equal to 20% of innovation expenditures with a ceiling of 400 000 euros for SMEs. However, the main rates remain the ones of 2008 suggesting that it is still important to assess the impact of this 2008 reform.

Figure 1 below presents the total amount of research tax credit provided to firms per year. Clearly there is a rise in the importance of the research tax credit in France, which is concomitant with its successive reforms namely the reforms of 2004, 2006 and 2008.

Figure 2 presents the evolution of the number of firms which ask for the research tax credit as well as the number of firms which benefit from it over the period 1993-2010. The main reason why the number of beneficiary firms is lower is that many firms belong to a group, and in France, while all the affiliates fill in a research tax credit file, only the headquarter receives the tax credit and shares it with its different affiliates. In both cases, this graphic highlights an important increase in the number of firms taking advantage from the research tax credit in France over our period of interest, namely 2004-2010.

4 Data

Our econometric analysis relies on the combination of four datasets at the firm-level: the yearly survey on R&D investments which contains detailed information on firms' R&D expenditures, the PATSTAT dataset on patents which is used to measure innovation, the tax files GECIR which enable us to identify all the firms in France which take advantage from the research tax credit as well as its amount, and finally the FIBEN dataset of the Banque de France which is used to control for firms' economic and financial characteristics. This section details each of these dataset.

4.1 The R&D survey from the French Ministry of Higher Education and Research

The R&D survey is carried out each year in France on a sample of firms which are supposed to be engaged in some R&D activities. For each firm, the dataset contains information on R&D activities such as the amount of R&D expenditures (internal R&D expenditures or outsourced to other firms), on the different sources of R&D funding (private or public), on the number of researchers, on the main field of research, and on some innovation activities such as the number of patents, this last information being however available some years only. This dataset contains 88,580 observations over the period 1993-2010. This is an unbalanced panel with many firms being followed only a few years in the sample. Indeed, we have 26,958 firms, of which 70% are registered less than 4 years in the dataset, and 7% are registered more than 10 years.

4.2 The PATSTAT dataset of the European Patent Office

This dataset gathers information on nearly all patent applications carried out in more than 80 countries. We use this dataset to identify all the French patents applications. However, in order to match this dataset with our firm-level data, we had to do a substantial work of matching through the name of applicants. Indeed, all firms in France have an unique administrative identifier, the "SIREN number". This firm identifier is usually available in all firm-level datasets, but is missing in the PATSTAT dataset. Only the name of the firm or the name of the inventor is given. We therefore developed an algorithm to match the PATSTAT dataset with our data at the firm-level through the names of applicants. Building on the existing literature (see in particular Raffo and Lhuillery (2009)), this matching procedure includes three stages: the parsing stage, the matching stage and the filtering stage. In our case, the parsing stage includes the cleaning and harmonization of the names as well as the encoding of the names using the double metaphone algorithm, which allows matching names which would have different spelling. In a second step, the matching relies on the minimization of the Levenshtein distance between names and is mainly based on the less frequent word entering the name of the applicant. Finally the filtering stage which consists in using complementary information to identify and reject true and false positive matches, is based first on artificial intelligence (which enabled us to establish a threshold of acceptation or of rejection of the matching) and second is further refined using the address and year of creation of the company (see Mohamed and Py, 2013 for more details[2]). The ranking of the top 30 firms in terms of number of patents applications resulting of our matching procedure is very consistent with the ranking proposed by the French National Institute for Intellectual Property. Moreover, tests performed based on a sample of 750 companies for which the exact matching of names was handmade suggest a good quality of our matching procedure. This work therefore enables us to also measure the impact of the research tax credit on innovation at the firm level, through a count of the number of patent applications, an aspect which has been under-investigated so far in France due to this lack of firm identifier in the PATSTAT

[2]This document is available upon request, in French only for the moment.

dataset.

4.3 The tax file GECIR on the research tax credit

This dataset contains exhaustive information on the firms in France which take advantage from the research tax credit as well as its amount. This dataset, available on the period 1993-2010 which contains 160,205 observations, enables us to identify firms which took advantage from the research tax credit and those which did not. This is an unbalanced panel, composed of 41,542 firms, appearing on average 4 years in the dataset. On average, firms receive a research tax credit of 150,000 euros over the period. Nevertheless there is much variation across firms and time due to the numerous reforms of the research tax credit system in France. For the purpose of the analysis, we are interested more in the identification of firms which receive the tax credit a given year than in the amount of tax credit received. Some firms might not benefit from the research tax credit a given year either because they did not increase their R&D expenditure, because they did not invest in R&D, or because they had some past negative tax credit. We therefore consider that a firm – not part of a holding – is a research tax credit recipient if it declares a strictly positive amount of tax credit. Regarding firms which belong to a group, we consider that they benefit from the research tax credit as soon as the head company of the group declares a strictly positive R&D tax credit. Indeed, in France, in the case of a group, the research tax credit is fully received by the head company of the group, which in turn is free to redistribute it among its affiliates according to its own ruling shares. All the subsidiaries which are having positive R&D expenditures and which belong to a group company which receives the tax credit are therefore very likely to be also tax credit recipients.

4.4 The dataset FIBEN on firm characteristics from the Banque de France

The *Fichier interbancaire des entreprises* (FIBEN) is built by the Banque de France. This dataset gathers descriptive and accounting information on a large number of French firms. It is used by the Banque de France as a tool to follow the financial behaviour of French firms and is the basis for the microeconomic analysis of the production system of the French economy. This dataset contains very detailed information on firm characteristics: descriptive information ("siren" identifier, legal entity, sector classification, location of headquarter), accounting and financial information (coming directly from balance sheets for firms with a turnover above 750,000 euros), and finally some information relative to payment incidents and credit positions. The dataset contains on average 200,000 yearly observations available over the period 1993-2011. However, regarding the sample of interest in this study, we have in total 130,283 firms over the period 1993-2010. This is again an unbalanced panel of 31,788 firms, with 25% of firms being registered up to 3 years in the dataset, and firms being followed on average 4 years.

4.5 Final dataset: descriptive statistics

We are able to merge these four datasets thanks to unique "siren" firm identifiers. In the rest of the analysis, we restrict the sample to the period 2004-2010. First, we are interested in the evaluation of the 2008 reform so we need to have some information before and after the reform. More importantly, until 2003 the tax credit system was incremental, while a share in volume has been introduced in 2004. We therefore excludes the year previous to 2004 to avoid capturing the effect of the 2004 reform. Our final sample includes 48,111 observations over the period 2004-2010. Given that we need to have information on firms R&D expenditures both for research tax credit recipients and for non recipients, our sample is limited to firms present in the R&D survey. Our final sample is an unbalanced panel of $20,681$ firms, with 54% of firms being present less than 4 years, and 20% of firms on the whole period of study. In our final sample, on average, 51.3% of firms take advantage from the research tax credit. However, as highlighted previously, the number of firms taking advantage of the research tax credit has increased a lot with the 2008 reform, the share of firms taking advantage of the research tax increasing from 23% in 2004 to 63% in 2010. While the fact that some firms do not ask for the research tax credit can be useful for the econometric analysis, as those firms can constitute a control group, the main question is whether the non RTC recipients (potential control group) are comparable in terms of characteristics with RTC recipients (potential treated firms) before the 2008 reform. The table below presents as an illustration, the mean and median number of employees, turnover, R&D expenditures and number of patents applications for RTC recipients and non recipients in 2005, i.e. before the 2008 reform.

Table 2: Comparison of Research tax credit (RTC) recipients and non recipients (in 2005).

Variables	Mean		Median	
	RTC recipients	Non recipients	RTC recipients	Non recipients
Number of employees	680	263	98	73
Turnover	96,300,000	57,100,000	16,700,000	12,000,000
R&D expenditures	8,582,841	2,740,864	485,000	233,000
Patents applications	38	10	4	2
Observations	2260	2831	2260	2831

As it can been seen, RTC recipients are on average larger in terms of size (measured in terms on number of employees or in terms of turnover), they also tend to invest more in R&D and innovation. These differences remain also important when one compares the medians. These descriptive statistics therefore suggest that tax credit recipients (the potential treated firms in the econometric analysis) and non recipients (the potential controls) differ largely in terms of economic characteristics and this is confirmed by the two-tailed t-tests on mean difference that we performed but that are not reported here. A major challenge in the

evaluation of this 2008 reform will therefore consist in reducing the potential bias resulting from the selection of firms into the tax credit scheme.

5 Empirical strategy

In this study, our aim is to evaluate the impact of the research tax credit on R&D at the firm level focusing on an assessment of the 2008 reform. Yet, properly evaluating this reform is far from obvious for several reasons.

5.1 Challenges in the evaluation of the 2008 reform

First, a proper evaluation of this reform should tackle potential selection bias issues. Ideally one would like to compare the R&D behavior of firms when they do take advantage from the research tax credit and when they do not. Given that this counterfactual does not exist by definition for the same firm, we will have to compare firms which do take advantage from the research tax credit with firms which do not. The main difficulty here is that it is unclear why some firms ask for the research tax credit and others do not. There are several potential explanations: firms might not be aware of the policy, their R&D activities might not be eligible to the tax credit, asking for the research tax credit might be too complex and costly or firms might want to avoid a tax audit. One has to be aware that some of the factors which contribute to explain why some firms ask for the research tax credit and others do not are likely to be correlated also with the R&D behaviour of firms. One first challenge in our estimations will be therefore to reduce this potential selection bias in the construction of our treated and control groups.

Second, a proper evaluation of this reform should disentangle effects of the reform on the intensive margin (i.e. the increase in R&D for firms already in the tax credit scheme) from effects of the reform on the extensive margin (i.e. on firms which decide to enter in the tax credit scheme after the reform). Indeed, with the 2008 reform, as shown previously, there has been a huge increase in the number of firms asking for the research tax credit due to the simplification of the tax credit system. Those firms are on average smaller in terms of R&D. Estimates of the impact of the 2008 reform are therefore likely to be biased if one do not treat separately those firms which entered in the tax credit scheme after the 2008 reform or firms which change of treatment status over the period of study.

Finally and more generally, a proper evaluation of this reform should also control for potential unobservable factors other than the 2008 reform which are likely to affect the R&D behavior of firms. One has to be aware that this reform is particularly difficult to evaluate given that it occurred in 2008 and that our period study covers the years 2004 to 2010. Given that this coincides with the 2008 financial crisis, firms R&D behaviors are likely to have been particularly affected by this important negative macroeconomic shock.

5.2 Difference in differences and propensity score matching analysis

In order to tackle these potential issues, we implement different empirical strategies which have each their advantages and drawbacks. We start our analysis by implementing a difference in differences approach which amounts to comparing R&D investments for firms taking advantage of the research tax and firms which do not take advantage from it, before and after the implementation of the policy. The main advantage of this approach is that by comparing two groups of firms, the treated and the controls, before and after the implementation of the reform, we are able to control both for the differences between the two groups of firms which are constant over time and for potential macroeconomic shocks which are constant between the two groups of firms. The key identifying assumption behind this approach is that these two groups of firm would have behaved similarly in terms of R&D and innovation in the absence of tax credit reform. This is a strong assumption given that it is possible that those firms which apply for research tax credit may have particular characteristics that could be correlated with growth of R&D investment.

In order to take into account observable characteristics, we also implement a propensity score matching analysis. It consists in comparing the R&D behavior of firms which are similar in terms of observable factors and which have therefore ex ante the same probability to get the research tax credit. Nevertheless, if this method has the advantage to reduce the potential selection bias, one should be aware that the bias is generally not eliminated, unless exposure to treatment can be considered purely random among observations who have the same value of the propensity score. Moreover, the extent to which the selection bias into treatment is reduced depends crucially on the quality and on the richness of the control variables on which the propensity score is computed and the matching is performed. As we will see, though the tests of the quality of our matching seem to be good, due to data limitations, we cannot exclude that unobservable characteristics could explain the choice to apply for the research tax credit and also affect our outcome of interest.

We now turn to the presentation of the results which, for the reasons just outlined above, have to be interpreted with caution.

6 Results: the impact of the RTC on firms R&D

In this section, our aim is to assess the impact of the research tax credit on R&D at the firm level. We start our analysis by implementing a difference in difference approach. We then turn to a propensity score matching estimation, which enables us to refine the analysis by comparing the R&D behavior of firms which are more similar on a vector of observable factors and which had therefore similar probability to get the research tax credit before the 2008 reform.

6.1 Difference in differences estimations

Our aim is to evaluate the impact of the 2008 reform on the level of R&D expenditures. We adopt a difference in differences approach in which the dependent variable is the log of R&D

expenditures. Our empirical specification is given by:

$$LogR\&D_{it} = \alpha + \beta X_{it-1} + \gamma RTC + \eta POST2008 + \lambda Reform + \delta_i + \mu_t + \epsilon_{it} \quad (1)$$

Where:

- $R\&D_{it}$ stands for R&D expenditures of firms i at time t
- X_{it-1} stands for a vector of lagged time varying firm characteristics
- RTC is a dummy taking value one if the firm asks for the research tax credit
- $POST2008$ is a dummy taking value one after 2008
- $Reform$ is a dummy taking one for firms benefiting from the RTC after 2008
- δ_i and μ_t stand respectively for firm and year fixed effects.

We therefore compare the level of R&D expenditures for firms which take advantage from the research tax credit and for those which do not, before and after the reform in 2008. In this specification, our variable of interest is therefore a dummy equal to 1 only for firms which benefit from the research tax credit after 2008. In the empirical analysis, we take advantage of the panel dimension of our data to control for firm fixed effects. There are many factors specific to firms and constant over time which are likely to affect R&D expenditures and which can be captured by controlling for firm fixed effects. For instance, firms might be located in a very dynamic research environment or a firm strategy might just rely more, on average, on R&D expenditures. We will also control for time-varying characteristics which can affect firm R&D expenditures, in particular, firm size in terms of employees and turnover.

Results of such panel estimations are presented in Table 3 and overall, the impact of the 2008 reform is positive and significant. In columns (1) to (3), the sample includes all firms which were in the R&D survey, over the period 2004-2010, of which 51.3% have taken advantage from the research tax credit and therefore belong to the treated group. In column (1), results indicate that firms which do take advantage from the research tax credit have significantly larger R&D expenditures (the dummy which takes value 1 for Research tax credit being positive and significant). Results also indicate that after 2008, all firms tend to expand their R&D expenditures (the dummy Post 2008 being positive and significant). Finally the coefficient of our variable of interest (variable Reform which is a dummy taking value 1 for firms taking advantage from the research tax credit after the 2008 reform) is positive and ignificant, indicating that the positive gap in R&D expenditures of research tax credit (RTC) beneficiary firms is increased after 2008.

This basic specification has nevertheless to be refined. In column (2), we control also for the lagged turnover and number of employees in order to capture the effect of firm size on firm R&D expenditures and in column (3) we include industry and year dummies as R&D expenditures are likely to vary by industry and to be affected by economic cycles. Results indicate again a positive and significant impact of the reform suggesting that R&D

Table 3: Dependent variable: Log R&D expenditures - Panel with firm fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)
Reform	0.0523***	0.0687***	0.0677***	0.137***	0.0820***	0.122**
	(0.0186)	(0.0219)	(0.0219)	(0.0397)	(0.0285)	(0.0586)
Dummy RTC	0.0409***	-0.00838	-0.0123			
	(0.0130)	(0.0175)	(0.0175)			
Dummy Post 2008	0.102***	-0.0126				
	(0.0165)	(0.0199)				
Ln (turnover)t-1		0.182***	0.182***	0.142***	0.169***	0.231***
		(0.0227)	(0.0232)	(0.0397)	(0.0269)	(0.0732)
Ln (employees)t-1		0.188***	0.187***	0.143***	0.253***	0.199***
		(0.0312)	(0.0313)	(0.0410)	(0.0401)	(0.0451)
Constant	12.82***	9.657***	9.694***	10.40***	10.00***	9.987***
	(0.00849)	(0.345)	(0.354)	(0.634)	(0.418)	(1.272)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes
Observations	40,889	18,537	18,537	7,515	12,042	2,093
R-squared	0.019	0.034	0.036	0.026	0.047	0.105
Number of firms	16,853	6,559	6,559	3,303	3,129	372

Robust standard errors in parentheses, *** significant at the 1%, **significant at 5% and * significant at 10%.

expenditures are significantly for firms taking advantage from the research tax credit after 2008.

One limit with previous estimations, however, is that our regressions are based on the whole sample of firms. Given that the data come from the R&D survey, some of the firms appear in the sample of analysis only one year while some others appear several years. But more importantly, many firms changed of treatment status over the period of analysis and in particular started to take advantage from the research tax credit only after the 2008 reform. This heterogeneity in the sample of firms is likely to bias the results especially given that it is well known in France that the 2008 reform led to a huge increase of firms entering in the tax credit system (also called the extensive margin) with those new firms being on average smaller both in terms of size and of R&D expenditures than firms which were already taking advantage from the research tax credit before the 2008 reform. We therefore also run estimations with different samples in order to tackle these issues.

In column (4), in order to create the treated and control group, we exclude all firms which change of treatment status over the period of study by keeping in the sample of treated only firms which always take advantage from the research tax credit the years they appear in the sample and by keeping in the sample of controls only the firms which never ask for the research tax credit. In column (5), we restrict a bit more the sample by keeping only the firms that we observe at least 4 years and by considering as treated only the firms which ask at least 4 years for the research tax credit, the control group still consisting of firms which never ask for the research tax credit. Finally, in column (6), in order to focus on the evaluation of the reform only on the intensive margin (i.e. for firms which were in the tax credit scheme before the 2008 reform) we keep in the sample only the firms which are present in the sample on the

whole period 2004-2010. In this case, we consider as treated the firms which always ask for the research tax credit and in the control group the firms which never asked for the research tax credit during 7 years. The results indicate that when we restrict the sample in order to gradually exclude from the analysis all firms which change of treatment status over the period of study (in columns (4) to (6)), the impact of the reform larger and is the largest when we limit the analysis to firms which already took advantage from the research tax credit before 2008 (see comparison of column (3) and (6)). These results suggest that the reform of the research tax credit in France in 2008 has had a positive effect on firms R&D expenditure.

This confirms that our previous estimates were biased by the fact that some firms appear in our sample of analysis only some years due to the survey nature of some of our data and also that it is important to exclude firms with change status (especially those which enter in the tax credit scheme after the 2008 reform) in order to properly assess the impact of the 2008 reform on R&D expenditures. A remaining question is whether this is a positive impact given the amount of tax credit involved by the 2008 reform. One way to answer to this question is to compute the tax credit multiplier to understand how much one additional euro of tax credit generates of additional R&D. In order to do so, we compare the additional amount of R&D generated by the reform to the additional amount of tax credit received by firms with the 2008 reform. By doing so, when we limit the analysis to the balanced panel and focus on the intensive margin (column 6), we find an important tax credit multiplier as one euro of tax credit generates 2.3 euros of additional R&D. The tax credit multiplier is however near to unity when we consider the large sample (column 3) which includes also firms which entered in the tax credit system with the 2008 reform (extensive margin).

Overall this difference in differences approach suggests that the adoption of a tax credit scheme purely in volume (while it was both incremental and in volume before 2008) had the expected impact of boosting business R&D. However these results have to be interpreted with caution. First, one might worry that the results are affected by the time window selected. For instance, it might be that some results are partly driven by the year 2004, when there was already the first introduction of a share in volume. One could also worry that some firms have anticiped the reform and that the year 2007 is quite different from others. We therefore reproduced the analysis by excluding these years and using different time windows and our results remain relatively similar (see Table 8 in the Appendix). Second, some firms also received subsidies and part of the observed increase in R&D after the 2008 reform might come from public funding. In order to exclude this possibility, we reproduced our benchmark analysis by computing purely private R&D (defined as private R&D expenditure net of subsidies). The results on the impact of the 2008 reform, which are presented in Table 9 of the Appendix are again relatively similar. Finally, one last important concern lies in the fact that firms which do ask for the research tax credit and those which never asked for it are likely to differ in a way which is probably correlated with R&D expenditures. In order to test for the robustness of our results, we therefore turn to a propensity score matching analysis.

6.2 Propensity score matching estimations

In this section, we adopt a propensity score matching analysis combined with a difference in differences (Blundell and Costa Dias, (2009)). Since the assignment of firms into the tax credit system is not random, the estimation of the effect of 2008 reform described previously may be biased by confounding factors. The rationale behind the propensity score matching is that the bias is reduced when the comparison of outcomes is performed using treated and control firms who are as similar as possible. The method consists in estimating the probability of treatment given a vector of characteristics and then matching each treated with one or several control groups (depending on the selected method). Since matching firms on a large vector of characteristics is typically unfeasible, this method proposes to summarize pre-treatment characteristics of each firm into a single-index variable (the propensity score) on which is then performed the matching. As said previously, this method allows reducing but not eliminating the selection bias and the extent of the reduction of the bias depends crucially on the richness and quality of data. We therefore describe now how we proceed to the propensity score analysis. We first look at the impact of the research tax credit on R&D expenditures on the growth of R&D expenditures before and after the reform.

In this subsection, we are interested in the impact of the research tax credit on the growth of R&D expenditures as measured by the variation between firm average R&D expenditures over the period 2008-2010 and between firm average expenditures over the period 2004-2007. In line with our previous estimations and in order to avoid the problem of firms changing of treatment in status, our sample consists as in column (6) of table 5, only of firms that we observe during 7 years.

Table 4 below presents the results of logit estimation of the probability of treatment and of the computation of the propensity score. Our dependent variable is a dummy equal to one if the firm takes advantage of the tax credit during 7 years and 0 if the firm never takes advantage of the research tax credit during 7 years. In this first step, we introduce all the firm characteristics which are likely to affect the probability of getting the research ax credit: firm size in terms of turnover and in terms of number of employees, firms 'age, and finally firm debt in order to control for the fact that some firms might be financially constrained.

All these covariates are computed as an average over the period 2004-2007 at the firm level, as our goal is to match firms with similar pre treatment-characteristics. Results of the logit estimation suggest that the main determinant influencing the fact that a firm takes advantage of the research tax credit or not is its level of R&D expenditures. While not surprising, this confirms the idea that our previous estimates are likely to be biased. Results of the tests of the quality of the matching (see Table 5) indicate that the matching tend to reduce the differences in means of firm characteristics between treated and controls. Indeed, after the matching the differences in mean turnover, number of employees, debt and R&D expenditures are no longer significant while they are significantly different in the whole unmatched sample. Note that in order to refine the quality of the matching, we also imposed the common support assumption, which, as shown by the graph, enables to exclude from the sample of analysis the firms belonging to the untreated group (firms which never ask for the research tax credit) and which had a probability far too low to ask for the research tax credit.

Table 4: Probability of taking advantage from the RTC-logit estimations

Ln R&D	0.2392437*
	(0.13068)
Ln Turnover	0.3279265
	(0.2391)
Ln Employees	-0.1993829
	(0.3165)
Ln Debt	0.0661755
	(0.3244)
Age	-0.0073266
	(0.0048)
Constant	-7.566***
	(3.006)
Observations	349
Pseudo R2	0.0707

Table 5: Tests of the quality of matching

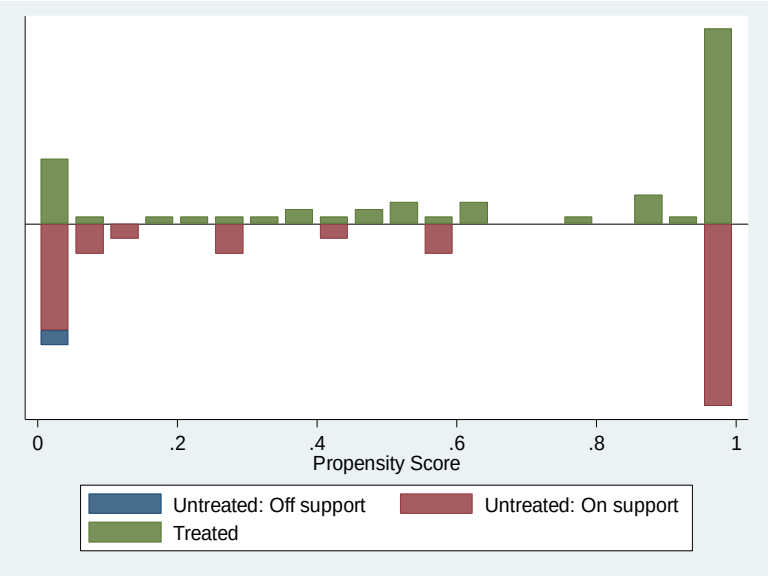
Unmatched	Mean	Mean	% reduct	t-tests			
Variable	Matched	Treated	Control	%bias	$\|bias\|$	t	p>t
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln R&D	Unmatched	15.355	14.508	50.2		4.14	0.000
	Matched	14.754	14.721	1.9	96.2	-1.5	0.134
Ln Turnover	Unmatched	17.927	16.877	59.7		4.52	0.000
	Matched	17.492	17.396	5.5	90.8	-1.56	0.121
Ln Employees	Unmatched	5.808	4.9558	51.2		3.84	0.000
	Matched	5.3338	5.2633	4.2	91.7	-1.3	0.195
Ln Debt	Unmatched	15.592	14.565	56.4		4.13	0.000
	Matched	14.974	14.93	2.4	95.7	-1.6	0.112
Age	Unmatched	32.887	36.91	-13.2		-1.07	0.286
	Matched	32.53	28.772	12.3	6.6	1.43	0.153

Sample	Pseudo R2	LR chi2	p>chi2	Mean Bias	Med Bias
Raw	0.074	26.12	0	46.1	51.2
Matched	0.025	7.84	0.165	5.3	4.2

Table 6: Results of the Average Treated Effects on the Treated

Outcome Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Variation in R&D expenditures						
before and after the reform	Unmatched	0.12189	0.02172	0.10017	0.05313	1.89000
	ATT	0.12331	-0.04997	0.17327	0.06201	2.79000

Figure 3: Common support restriction



The results of the average treatment on the treated are presented in Table 6. They suggest that the variation in average R&D expenditures (before and after the 2008 reform) is significantly higher for firms taking advantage from the research tax credit. These results seem to confirm that the adoption of a purely volume scheme has had a positive impact on firms R&D expenditures.

Nevertheless, if the quality of the matching seems reasonable, one should note that due to data limitations, and due to our very small number of observations, we control for only few firm characteristics in the performance of the matching, as compared to what can be found in the evaluation literature. In order to further check the robustness of our results we are currently trying to implement another empirical strategy which relies on the exploitation of the exogenous successive reforms of the French research tax credit system.

7 Effect of the RTC on innovation

Our results so far suggest that the research tax credit, more precisely, that the 2008 reform, which translated into the adoption of a purely base-scheme, has had a positive impact on R&D expenditures. However, there are concerns among policymakers that these types of tax incentives could favour either R&D investments with low marginal returns or could encourage some firms to relabeling some non R&D activities in R&D just to benefit from larger amount of tax credit. One way to check for this possibility is to also evaluate the impact of these tax incentives on innovation, or on some measures of R&D output. This section aims at investigating the impact of the 2008 reform on the number of patent applications at the firm-level.

Table 7: Dependent variable: Number of Patents applications - Negative binomial regressions
firm fixed effects

Reform	0.0826	-0.0607	-0.0391	-0.161	-0.0229	-0.123
	(0.0581)	(0.0751)	(0.0750)	(0.146)	(0.0935)	(0.229)
Dummy R&D tax credit	-0.198***	-0.110*	-0.0601	-0.0107	-0.0657	-0.0250
	(0.0499)	(0.0668)	(0.0738)	(0.147)	(0.0946)	(0.233)
Dummy Post 2008	0.0668*	0.0591	0.0585	-0.0183	0.0915	-0.133
	(0.0371)	(0.0520)	(0.0519)	(0.246)	(0.135)	(0.427)
Ln (turnover)t-1		0.0550	0.0481	0.0376	0.0616	0.0603
		(0.0403)	(0.0409)	(0.0642)	(0.0434)	(0.0805)
Ln (employees)t-1		0.0815	0.0894*	0.0371	0.0676	-8.88e-05
		(0.0519)	(0.0528)	(0.0763)	(0.0563)	(0.0944)
Ln (R&D expenditures)t-1		0.109***	0.114***	0.0957**	0.131***	0.176***
		(0.0238)	(0.0239)	(0.0428)	(0.0263)	(0.0538)
Constant	0.176***	-2.626***	-2.603***	-1.673*	-3.033***	-3.078**
	(0.0407)	(0.562)	(0.571)	(0.883)	(0.612)	(1.199)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes
Observations	10,479	5,637	5,637	1,848	4,614	965
Number of siren	2,239	1,257	1,257	453	977	171

Robust standard errors in parentheses, *** significant at the 1%, **significant at 5% and * significant at 10%.

7.1 Preliminary results of a difference in differences analysis

In order to do so, we follow the same methodology as the one described previously and implement a difference in differences analysis. The dependent variable is now defined as a count of the number of patent applications at the firm-level, the log of lagged R&D expenditures being now introduced as an explanatory variable. The dependent variable being a count, we implement negative binomial regressions with fixed effects. The results of this analysis are presented in Table 7.

We do not find any direct impact of the reform on the number of patents at the firm-level[3]. We nevertheless advice caution in interpreting these results. The only coefficient which appears significant is the log of past R&D expenditures. Though it is quite reasonable that firms which do invest more in R&D also patent more, there might be some limits with these estimations. First, looking more in detail at the sample of firms included in the final estimations, the correlation between the dummy post 2008 and the dummy post reform appears to very high, especially in the last column. This is due to the fact that only few firms do patent and that most of these firms do take advantage from the research tax credit, especially after the 2008 reform. Second and more generally, given that most firms in the sample never patent, a zero-inflated negative binomial model might be more appropriate. We also carried out some propensity score matching analysis but imposing the common support restriction we are left with 129 observations only. Finally, given that patenting can take some time, we also investigated the impact on patent applications up to 2 years after the reform but this considerably reduces the number of observations. If we have not been able to establish a positive causal impact of RTC on the number of patents filed, we cannot exclude a real impact does occur with a longer time lag.

[3]Note that we did the same estimations without controling for R&D and the impact of the 2008 reform is still non significant.

8 Conclusion

In this study, we evaluate the impact of the French research tax credit system on both R&D investments and innovation. In our empirical analysis, we focus on the *ex post* evaluation of the 2008 French reform, which was marked by a switch to a pure volume-based design, leading to a large increase in the number of firms applying and to an important increase in the cost of the scheme. Our econometric evaluation relies on the combination of four unique datasets: i) the yearly survey on R&D, ii) the PATSTAT dataset on patents, iii) the administrative tax files on firms taking advantage from the research tax credit and iv) the FIBEN dataset of the Banque de France on firms' economic and financial characteristics. Our empirical strategies combine difference in differences with matching methods.

Our preliminary results suggest that firms which did benefit from the R&D tax credit relative to those that did not ask for it have significantly increased their R&D expenditures after the 2008 reform. We also find that the estimated elasticity is higher when we focus on the intensive margin (i.e. when the sample is limited to firms which already ask for the research tax credit before the reform) as the reform led to a large number of firm entry in the tax credit scheme which are relatively smaller in term of R&D expenditures. Nevertheless, our very preliminary results do not show evidence of any effect of the 2008 reform on the number of patents at the firm level, suggesting that the French research tax credit system has a lower impact on innovation than expected.

Overall, the results suggest that the 2008 reform managed to promote the development of business R&D but that its impact on innovation is rather limited. However, given the characteristics of the 2008 reform, and given that patenting takes times, properly measuring the causal impact of this reform on R&D and innovation is particularly challenging. Our preliminary results therefore have to be interpreted with caution especially given the limited number of observations in our final sample. We are currently trying to refine this empirical analysis.

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A Robustness tests

Table 8: Impact of the 2008 Reform on R&D: different time windows

Dependent variable: Log R&D expenditures - Panel with firm fixed effects

	2005-2010			2004-2010 excluding year 2007			2006-2009		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Reform	0.0677***	0.0828***	0.109**	0.0887***	0.0926**	0.114*	0.0422*	0.0404	0.0475
	(0.0219)	(0.0289)	(0.0522)	(0.0271)	(0.0363)	(0.0627)	(0.0239)	(0.0281)	(0.0386)
Dummy RTC	-0.0123			-0.0297			0.0141		
	(0.0175)			(0.0227)			(0.0200)		
Ln (turnover)$_{t-1}$	0.182***	0.161***	0.215***	0.181***	0.155***	0.204***	0.184***	0.188***	0.194***
	(0.0232)	(0.0285)	(0.0599)	(0.0262)	(0.0344)	(0.0727)	(0.0314)	(0.0340)	(0.0510)
Ln(employees)$_{t-1}$	0.187***	0.279***	0.281***	0.238***	0.375***	0.268***	0.124***	0.191***	0.262***
	(0.0313)	(0.0426)	(0.0617)	(0.0363)	(0.0564)	(0.0491)	(0.0374)	(0.0459)	(0.0746)
Constant	9.694***	10.04***	9.595***	9.410***	9.652***	9.943***	9.956***	9.975***	9.862***
	(0.354)	(0.439)	(0.988)	(0.393)	(0.484)	(1.251)	(0.466)	(0.523)	(0.816)
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	18,537	11,239	3,359	15,736	8,407	1,891	12,225	8,255	3,828
R-squared	0.036	0.052	0.094	0.044	0.074	0.127	0.022	0.029	0.049
Number of siren	6,559	2,806	605	6,368	2,486	401	5,271	2,915	1,044

Robust standard errors in parentheses, *** significant at the 1%, **significant at 5% and * significant at 10%.

Table 9: Impact of the 2008 reform on private R&D (excluding subsidies)

Dependent variable: Log R&D expenditures without subsidies - Panel with firm fixed effects

	2004-2010			2005-2010			2004-2010 excluding year 2007		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Reform	0.0823***	0.0793***	0.122**	0.0823***	0.0870***	0.131**	0.0938***	0.0858**	0.130*
	(0.0239)	(0.0307)	(0.0586)	(0.0239)	(0.0305)	(0.0584)	(0.0295)	(0.0384)	(0.0699)
Dummy RTC	-0.0131			-0.0131			-0.0206		
	(0.0183)			(0.0183)			(0.0238)		
Ln (turnover)$_{t-1}$	0.192***	0.168***	0.231***	0.192***	0.165***	0.228***	0.199***	0.163***	0.207***
	(0.0278)	(0.0333)	(0.0732)	(0.0278)	(0.0305)	(0.0633)	(0.0318)	(0.0364)	(0.0786)
Ln (employees)$_{t-1}$	0.180***	0.290***	0.199***	0.180***	0.266***	0.258***	0.221***	0.351***	0.263***
	(0.0334)	(0.0482)	(0.0451)	(0.0334)	(0.0440)	(0.0574)	(0.0384)	(0.0559)	(0.0504)
Constant	9.446***	9.914***	9.987***	9.446***	9.981***	9.405***	9.155***	9.581***	9.846***
	(0.416)	(0.509)	(1.272)	(0.416)	(0.469)	(1.051)	(0.475)	(0.525)	(1.339)
Firm FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	18,361	9,380	2,093	18,361	11,171	3,339	15,589	8,353	1,879
R-squared	0.031	0.050	0.105	0.031	0.042	0.074	0.037	0.058	0.099
Number of siren	6,517	2,342	372	6,517	2,801	605	6,328	2,484	401

Robust standard errors in parentheses, *** significant at the 1%, **significant at 5% and * significant at 10%.

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