Impact of research tax credit on R&D and innovation: evidence from the 2008 French reform*

(Work in Progress)

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Abstract

This paper presents a first ex post evaluation of the 2008 French reform of its research tax system. 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 – still preliminary – 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.

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1 Introduction

R&D and innovation are seen as key determinants of productivity and competitiveness and it has been recognized that the low growth performances of EU countries of the last decades can largely be attributable to their poor research performance, as compared to the US. As a consequence, most EU countries, in particular since the adoption of the Lisbon strategy, have provided tax incentives to increase business R&D, which still remains below the targeted level of 2% of GDP. In the actual context of large public deficit and given the amount of public spending involved, it is crucial to evaluate the impact and effectiveness of these policies. This study aims at empirically assessing the *ex post* impact of a research tax credit scheme on firm's R&D and innovation by focusing on the French experience.

An important literature has tried to analyze the impact of public policies in favor 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 analyze 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 to 0.45 in the Netherlands over the period 1996-2004 (Lokshin and Mohnen (2012)) and to 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 conclude to 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 research tax credit system on both R&D investments and innovation. In our empirical analysis, we will focus on the 2008 French reform, which was marked by the adoption of a pure volume-based scheme. In France, research tax credit (Crédit impôt recherche, aka CIR) was initiated in 1983 but has since been reformed significantly. It was initially incremental (based on the increase in R&D spending) and was seen by the government as a secondary measure to support business R&D, its amount reaching 495 million euros only. In 2004, the research tax credit was strengthened with the introduction of a share in volume in parallel (based on the amount of R&D). But the reform of 2008 which consisted in the adoption of a research tax credit scheme purely in volume is the more radical one. 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 reductions. 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 (as measured by a count of the number of patents) iii) the tax files which enables us to identify all the firms in France which benefit from the research tax credit as well as it 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 difference 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 and are currently trying to refine our empirical strategy.

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. 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 2 years after the implementation of the

reform. Though the time span of analysis is short and that patenting can take more years, these preliminary results suggest that the effects of research tax credit on innovation might be more limited than expected. Finally, our results enable us to shed light on the relative effectiveness of the volume scheme as compared to the incremental one.

We contribute to the literature on tax credit evaluation in several ways. First, existing evaluations in the case of France have not until now evaluated *ex post* the impact of the 2008 reform. This reform is important as the adoption of a purely base 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 dataset that underpin our empirical analysis and section 5 discusses the different strategies developed to estimate the impact of the reform. Preliminary results on R&D and on innovation are respectively presented in section 6 and 7 and last section concludes.

2 Previous findings

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 if it had not benefited from it. However, such a counterfactual case does not exist by definition for a firm which already takes advantage from the research tax credit. Moreover, 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 classes of methods: 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 modelling 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 research tax credit, 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. The econometric approach consists then 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) analyze 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 variation 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 by 10% in the user cost of R&D capital is associated with an increase of R&D by 1% in the short run and by 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 then 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 analyze the impact of R&D tax incentives in the Netherlands, which consists 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 to adopt instead instrumental variables. 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 too.

2.2 Quasi natural experiments

The main intuition of 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.

One 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 nevertheless 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 difference 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 indicator 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 investing the impact of the recent reform of the tax credit scheme in France on both R&D and innovation at the firm-level.

3 Research tax credit in France

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 tax burden.

3.1 The main reforms of the French research tax credit

In France, the research tax credit was initiated in 1983 but has since been reformed significantly (see Table 1 for a detail of the main annual 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, being inferior to R&D subsidies.

Table 1: The main evolution of the research tax credit system in France over the period 1983-2013

Type of Credit System	**Year of reform**	**Incremental rate (of the increase in R&D)**	**Volume rate (of the amount of R&D)**	**Ceiling of tax credit**
Incremental	1983	25% of [(n) – (n-1)]	no	3 millions francs
	1985	50% of [(n) – (n-1)]	no	5 millions francs
	1988	50% of [(n) – (n-1)] 30% of [(n) – (1987)]	no	10 millions francs
	1991	50% of [n-[((n-1) (n-2))/2]]	no	6,10 millions € 40 millions francs
Mixed incremental and in volume	2004	45%	5%	8 millions €
	2006	40%	10%	10 millions €
	2007	40%	10%	16 millions €
In volume	2008	no	30% for R&D expenditures <=100 M € (50% the first year of entry in the tax credit scheme and 40% the second year)	no
			5% for R&D expenditure >100 M €	
	2011	no	30% of R&D <= 100 M € (40% for the first year of entry in the tax credit and 35% for the second)	no
			5% for R&D expenditure >100 M €	
	2013	no	30% for R&D expenditures <=100 M €	no
			5% for R&D expenditures >100 M €	
			20% innovation expenditures (for SMEs only)	400 000 €

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 inferior to the Lisbon objective of reaching a level of business R&D of 2% of GDP and a level of total R&D of 3%. With those reforms, the tax credit reaches in France 1.7 billion euros in 2007 (MESR (2011)).

However, the reform of 2008, 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 asking for 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.

Fig. 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.

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

Figure 1: Evolution of the cost of the research tax credit (in millions euros) over the period 1999-2010

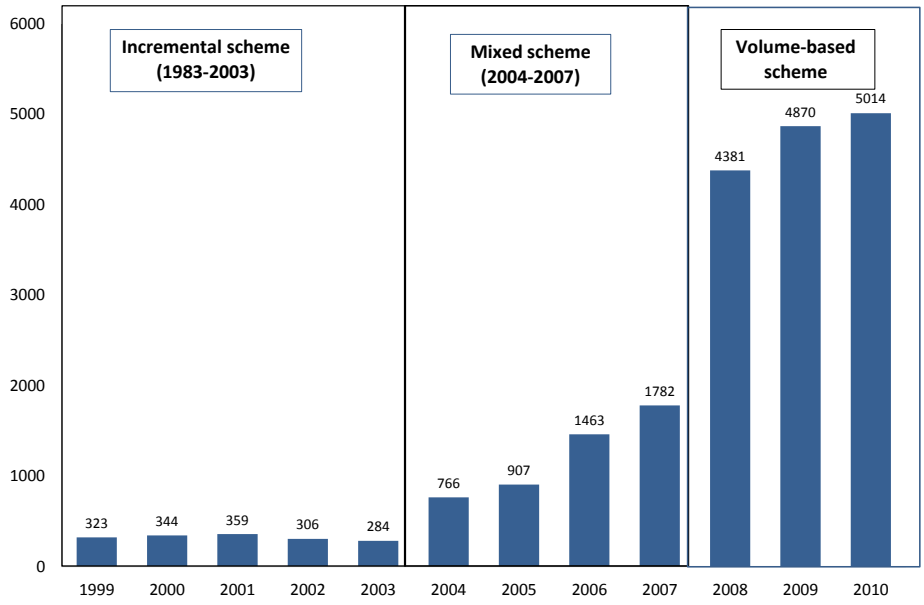
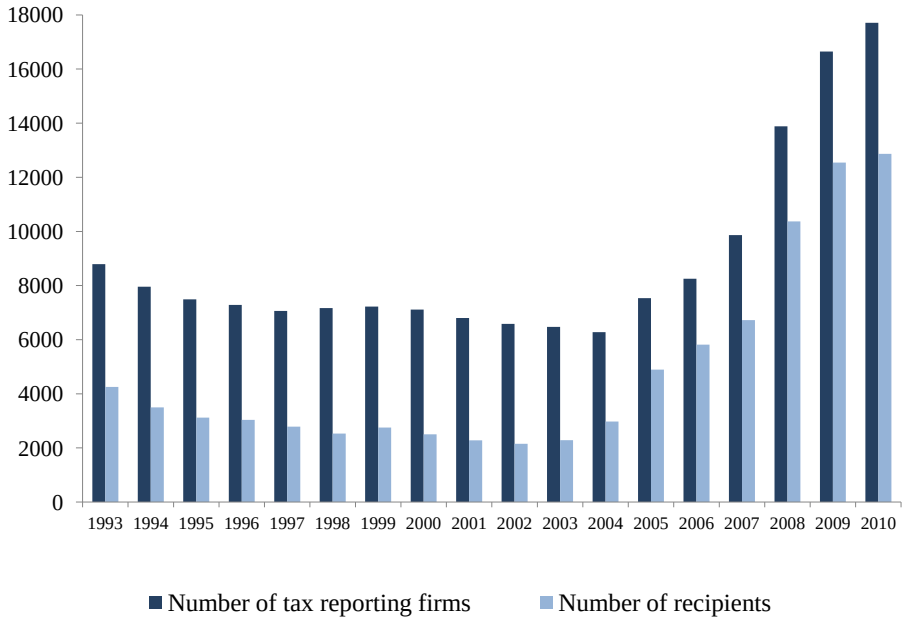


Figure 2: Evolution of the number of tax reporting firms and of the number of tax recipients over the period 1993-2010



3.2 Which firms gain and lose from the successive reforms?

Given that nearly each year, there has been some changes in the way the research tax credit was designed, or some changes in the rate of the tax credit or in the ceiling, the amount of tax credit firms can expect varies exogenously both over time and across firms. To better understand the potential effect the evolution of the research tax credit system in France, it is important to understand which firms gain or lose from the successive reforms. In order to identify the winner and the losers, we computed for each firm and each year the change in the marginal cost associated with the successive reforms as described in Table 1. Though we repeated this exercise for each firm and year on the period 2004-2010, for purpose of clarity, we focus in this section on the example of the 2008 reform for which we have particular interest in this study.

In order to compute the exogenous marginal gain associated with the 2008 reform, we have to compare the marginal cost of increasing R&D before and after the reform. In order to do so, we first compute the research tax credit that a firm can receive, with R&D expenditures in 2007 and according to the set of rules in force in 2007 (i.e. before the reform). We then compute what would be the marginal cost of increasing R&D expenditures by 100 euros. In a second step, we compute what would be the theoretical research tax credit that this company could receive with the same level of R&D expenditures but with the legislation that would apply in 2008 (i.e. after the 2008 reform). As previously, we then compute what would be the marginal cost associated with an increase of R&D expenditures by 100 euros, with the set of rules in force in 2008. Finally, in a third step, in order to assess the exogenous gain or loss in marginal cost associated with the 2008 reform, we compute the difference between these two marginal costs.

The computation of the tax credit and of the marginal cost associated with an increase in R&D expenditures by 100 euros, before and after the 2008 reform, as well as the marginal gain or loss associated with the 2008 reform are presented in Table 2. Though the figures regarding R&D expenditures and tax credit presented in this table are just examples, they reproduce all the possible cases in terms of change in marginal cost and marginal gains associated with the 2008 reform that we observed in our data. As one can see, some firms win while some other firms lose, which can be explained by the different elements entering the computation of the research tax credit before and after the reform in 2008. In order to clarify this, we detail below the computation of the research tax credit under the set of rules in 2007 and under the set of rules in 2008.

3.2.1 Computing the marginal cost of an increase in R&D by 100 euros with the set of rules in force in 2007

We start by describing the computation of the actual research tax credit (i.e. the one applying to R&D expenditures in 2007 with the set of rules in force in 2007). In 2007, the tax credit scheme is mixed, it has an incremental part which is equal to 40% of the variation of R&D expenditures in 2007 with respect to the average R&D expenditures of the past two years, a part in volume which is equal to 10% of the volume of R&D expenditures in 2007 and the

maximum amount of tax credit a firm can receive is limited to 16 million euros.

When firms have positive R&D expenditures and have increased their R&D expenditures, the computation of the tax credit is quite obvious. For instance, in row B of Table 2, R&D expenditures in 2007 amount to 1 million euros (column 1) and the variation in R&D expenditures with respect to the average R&D expenditures of the past two years is equal to 100,000 euros (column 2). In this case, the amount of actual research tax credit TCac is given by: $TC_{ac} = 100,000x0.4 + 1,000,000x0.1 = 140,000$ euros (see column 6). However, others elements have to be taken into account in the computation of the research tax credit as shown in column 6 of Table 2. First, if the variation in R&D expenditures with respect to the average R&D expenditures of the past two years is negative, the incremental share of the tax credit (which will be reported as negative the following year) is set to 0 and the firm only takes advantage of the research tax credit in volume. For instance, in row F, R&D expenditures in 2007 amounts to 1 million euros but the variation in R&D expenditures is negative so that the company receives a tax credit equals to 100,000 euros ($TC_ac = 0.4x0 + 0.1x1,000,000 = 100,000$ euros). Second, when a company has experienced a negative variation in its R&D expenditures in the previous year, this corresponds to a negative tax credit on the incremental share that is going to be reported on the current incremental share. For instance, let's consider the same case as before with R&D expenditures of 1 million euros and a variation in R&D expenditures of 100,000 euros but let's now assume that the firm has a negative past tax credit on the incremental share equals to 20,000 euros (see row C column 3)[2] In this case, the actual tax credit is given by $TC_{ac} = ((100,000x0.4) - 20000) + 1,000,000x0.1 = 120,000$ euros (see line 3 column 6). Third, when a company starts doing R&D for the first time in 2007, by definition, the average of R&D expenditures of the past two years is equal to 0, so that the variation in R&D is equal to the amount of R&D in 2007. In this case, the actual tax credit a firm can receive is therefore equal to 50% of R&D expenditures in 2007. This is illustrated in row E: a firm which invests 1 million euros in R&D for the first time in 2007 can receive a tax credit equal to 500,000 euros (with $TC_{ac} = 1,000,000x0.4 + 1,000,000x0.1 = 500,000$ euros). Finally, when the amount of tax credit a firm could receive is above the ceiling of 16 million euros, the research tax credit is set to 16 million as it is the case in row H.

With the different amounts of tax credit firms can receive with the set of rules into force in 2007, the marginal cost of increasing R&D expenditures by 100 euros can have three values: 50 euros, 90 euros or 100 euros. The firms which benefit the most from the mixed scheme and for which increasing R&D by 100 euros costs only 50 euros are the firms which have positive R&D expenditures and which tend to increase their R&D expenditures. Indeed, when firms have positive R&D expenditures in 2007 and experienced a positive variation in their R&D expenditures with respect to the two past year (cases A, D or E) and had not an important negative past tax credit (cases B)[3] , they benefit both from the incremental share

[2]This means that in 2006, the variation in R&D expenditures of this company with respect to the average of R&D expenditures in 2005 and 2004 was negative and equal to 50,000 euros.

[3]What matters is the difference between the actual incremental share and the past negative tax credit on the incremental share: when this difference is positive, the firm still benefits from both the incremental share and from the share in volume of the tax credit as in case C, while when this difference is null or negative, the firm only benefits from the share in volume as in case G.

and from the volume share of the tax credit. In this case, an increase in R&D expenditures by 100 euros costs only 50 euros. On the contrary, the firms which small benefit from the research tax credit in its 2007 form are the ones which had the tendency to reduce their R&D expenditures with respect to previous years. For instance, when firms have positive R&D expenditures in 2007 but reduced their expenditures with respect to the two past years (cases F or I) or had important negative past tax credit (case G), they only benefit from the share in volume. In this case, increasing R&D expenditures by 100 euros costs 90 euros (as they receive 10 additional euros of tax credit). Finally, firms for which the research tax credit does not change the marginal cost of R&D (i.e. an increase in R&D by 100 euros costs 100 euros) are those for which R&D expenditures are so big that the tax credit should be above the ceiling of 16 million euros (see column F). Quite intuitively, in 2007, when the tax credit has both a share in volume and an incremental share, the main factor affecting the marginal cost before the 2008 reform seems to be whether the firm tends to increase or decrease its R&D expenditures.

Table 2: Tax credit, marginal cost and marginal gain associated with the 2008 reform

	R&D in 2007	Variation of R&D with respect to ((n-1) + (n-2)/2)	Negative past tax credit	First year of R&D	Second year of R&D	Actual tax credit	Actual tax credit (R&D risen by 100 euros)	Marginal cost of R&D with actual tax credit 8=100-(6-7)	Theoretical tax credit with 2008 reform	Theoretical tax credit with 2008 reform (R&D risen by 100 euros)	Marginal cost with 2008 reform 11=100-(9-10)	Marginal gain with 2008 reform 12=8-11
	1	2	3	4	5	6	7	8	9	10	11	12
A	110 000 000	10 000 000	0	0	0	15 000 000	15 000 050	50	30 500 000	30 500 005	95	-45
B	1 000 000	100 000	0	0	0	140 000	140 050	50	300 000	300 030	70	-20
C	1 000 000	100 000	20 000	0	0	120 000	120 050	50	300 000	300 030	70	-20
D	1 000 000	100 000	0	0	1	140 000	120 050	50	400 000	400 040	60	-10
E	1 000 000	100 000	0	1	0	500 000	500 050	50	500 000	500 050	50	0
F	1 000 000	-100 000	0	0	0	100 000	100 010	90	300 000	300 030	70	20
G	1 000 000	100 000	40 000	0	0	100 000	100 010	90	300 000	300 030	70	20
H	80 000 000	30 000 000	0	0	0	16 000 000	16 000 000	100	24 000 000	24 000 030	70	30
I	1 000 000	-100 000	0	0	1	100 000	100 010	90	400 000	400 040	60	30

3.2.2 Computing the marginal cost of an increase in R&D by 100 euros after the 2008 reform

Let's turn now to the description of the computation of the research tax credit after the 2008 reform, when the tax credit is purely in volume. As explained above, given that we are interested only in the exogenous change in the marginal cost of increasing R&D by 100 euros linked to the reform, we compute for each firm, the research tax credit that a firm would receive with the set of rules in 2008 but with unchanged level of R&D expenditures (i.e. with R&D expenditures in 2007). With a system only volume-based, the computation of the research tax credit is much simpler. The research tax credit is equal to 30% of R&D expenditures for R&D expenditures ? 100 million euros and to 5% of R&D expenditures above this threshold. Thus for instance, when R&D expenditures in 2007 are equal to 1 million euro, the amount of research tax credit a firm can receive TC_{2008} is given by: $TC_{2008} = 1,000,000x0.3 = 300,000$ euros (see column 9 in cases B, C, F and G). When R&D expenditures in 2007 are superior to 100 million euros, as for instance, in case A, the computation of the research tax credit is slightly different. In this case, the R&D tax credit is given by: $TC_{2008} = 1,000,000x0.3 + (110,000,000 - 100,000,000)x0.05 = 30,500,000$ euros. Finally, after 2008, there are also preferential rates for firms which recently started to do R&D and recently asked for the research tax credit. Indeed, the research tax credit is equal to 50% of R&D expenditures the first time a company enters in the scheme (as in case E column 6) and to 40% the second year of entry (as in case I column 6) . One should note that with the 2008 reform, all negative past credits have been cancelled out and set to 0, in order not to complicate the computation of the research tax credit which is from now on only volume-based, which has been an important financial relief for many companies.

With these differences in the amount of tax credit a firm can receive with the set of rules in force in 2008, the marginal cost of increasing R&D expenditures by 100 euros can have several values: 50 euros, 60 euros, 70 euros, or 95 euros. The firms which benefit the most from the research tax credit under the 2008 legislation are the firms which recently entered in the tax credit scheme, as 100 euros of additional R&D costs only 50 euros the first year of entry, and 60 euros the second year of entry. In general the research tax credit in 2008 is quite generous for firms with less than 100 millions of R&D expenditures, as hundred additional euros of R&D expenditures cost only 70 euros. Finally, the system is a bit less advantageous for firms whose R&D expenditures were already above 100 million euros as an increase in R&D expenditures by 100 euros costs 95 euros. Given that the marginal cost of increasing R&D expenditures by 100 euros is computed, we can now turn to the identification of the firms which lose or win from the 2008 reform.

3.2.3 Which firms gain and lose with the 2008 reform?

In order to assess which firms win or lose from the reform, we take the difference between the marginal cost of increasing R&D expenditures, before and after the reform (difference between the actual and theoretical marginal costs in column 8 and 11 respectively).

As it can be seen, the firms which basically win with the 2008 reform are the firms which,

before the reform, were on a negative dynamic of R&D investment: either they experienced a negative variation in their R&D expenditures (case F or I) or had an important past negative research tax credit (case G), or they did not increase their R&D expenditures anymore given they had reached a level which was well above the tax credit ceiling. On the contrary, the firms which lose from the 2008 reform are those which had a positive dynamic of R&D investment before the reform: the firms which had expenditures well below the threshold of 100 million euros but which still managed to increase their R&D expenditures (such as in case B), the firms which tended to increase their R&D expenditures a lot despite having a negative past tax credit (case C), or the firms which had R&D expenditures above 100 million euros but still managed to increase their R&D expenditures. Finally, for new entrants, there are no gains or loss associated with the reform as the tax credit that a firm can get is the same under the legislation in 2007 and under the legislation in 2008[4].

Thus in order to summarize, the firms which gain in terms of marginal cost with the reform are those which tended to decrease their R&D expenditures before 2008 while those which loose from the reform tended to increase their R&D expenditures. This raises serious questions about the incentives given by the 2008 reform and the replacement of a mixed tax credit scheme (with both an incremental and a volume share) by a purely volume-based tax credit scheme. One should note however that here we are considering the marginal cost of increasing R&D expenditures. If it were about computing the average cost of R&D, the picture would be totally different with firms with the highest levels of R&D expenditures benefiting the most from the 2008 reform, due to the suppression of the ceiling of tax credit a firm can receive (see for instance the comparison of actual tax credit (column 6) and tax credit under the 2008 reform (column 9) for a firm which has 110 million euros of R&D expenditures, such as in case A).

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 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]Note that this result is quite puzzling given the high number of firms which entered in the tax credit scheme in 2008. One potential explanation is that as said earlier, the computation of the research tax credit is much simpler under the 2008 set of rules, and most firms probably did not understand that, already in 2007, when the system was both incremental and in volume, they would also had received a tax credit equal to 50% of their R&D expenditures.

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, of which 7% are registered more than 10 years and firms being included on average 3 years in the dataset.

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 official administrative and unique identifier, the "siren number". This siren number is the one used to gather all existing information in different dataset or sources about a specific French company. Unfortunately, in the PATSTAT dataset, the siren number of a French firm is not given, only the name of the inventor or of the company is known. 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[5]). 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

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

been under-investigated so far in France due to this lack of "sirenisation" of the PATSTAT dataset in the case of French firms.

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 the treated group (i.e. those firms which took advantage from the research tax credit) and the control group (those which do 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 150,000euros 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 an independent firm 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 affiliates 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 3: 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 difference, matching, and discontinuity in the tax credit scheme

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 difference 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 not impossible 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 individuals 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.

In order to tackle the non randomness of assignment into treatment, we are currently working on an alternative estimation strategy which relies on the exploitation of the exogenous change in the marginal cost of investing in R&D generated by the successive reforms of the research tax credit. Indeed, given that nearly each year, there have been some changes in the way the research tax credit was designed or computed, changes in the rate of the tax credit or in the ceiling of the tax credit, the amount of tax credit that a firm can expect varies exogenously both over time and across firms. This creates some discontinuities in the tax credit scheme that we can exploit to assess the impact of the successive reforms of the French research tax credit system over the period 2004-2010. With the assumption that firms did not anticipate this change and adapted their R&D behaviour in consequence, the reform creates some exogenous variation in the marginal cost of investing in R&D that we can exploit to assess how the research tax credit affects R&D investment. An important advantage of this method is that in this case, our sample includes only firms which take advantage from the research tax credit but for which the intensity of the treatment differs whether they lose or

win from the successive reforms. This therefore enables us to avoid the problem of selection bias we had in our previous estimations. However, as winning or losing from the successive reform depends crucially of one's past R&D behaviour, our results are still likely to be biased by endogeneity issues.

We now turn to the presentation of the results which are still preliminary and 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 Results of a Difference in Difference

Our aim is to evaluate the impact of the 2008 reform on the level of R&D expenditures. We adopt a difference in difference approach in which the dependent variable is the log of R&D expenditures. 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. Results of such estimations are presented in table 4 and they do not provide evidence of any significant positive impact of the 2008 reform. However, once we exploit the panel dimension of our data and control for firm fixed effects, the impact of the 2008 reform is positive and significant.

We start our analysis by a basic difference in difference approach. Results of such estimations are presented in Table 4. 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 reduce their R&D expenditures (the dummy Post 2008 being negative and significant). However 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 not significant, indicating that the positive gap in R&D expenditures of research tax credit (RTC) beneficiary firms is not increased after 2008. However, this basic specification has 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 in this case a negative and significant impact of the reform suggesting

that R&D expenditures are significantly lower for firms taking advantage from the research tax credit after 2008.

Table 4: Results of OLS regressions- Dependent variable: Log R&D expenditures

	(1)	(2)	(3)	(4)	(5)	(6)
Reform	-0.0265	-0.0837*	-0.0828**	-0.253***	-0.0805*	0.117
	(0.0378)	(0.0456)	(0.0388)	(0.0636)	(0.0449)	(0.109)
Dummy RTC	0.925***	0.614***	0.436***	0.913***	0.577***	0.292***
	(0.0269)	(0.0332)	(0.0286)	(0.0512)	(0.0312)	(0.0815)
Dummy Post 2008	-0.141***	0.0217				
	(0.0271)	(0.0365)				
Ln (turnover)t-1		0.169***	0.414***	0.495***	0.428***	0.637***
		(0.0213)	(0.0199)	(0.0301)	(0.0219)	(0.0416)
Ln (employees)t-1		0.463***	0.366***	0.291***	0.317***	0.213***
		(0.0254)	(0.0222)	(0.0327)	(0.0250)	(0.0484)
Constant	12.48***	8.226***	3.815***	4.119***	4.364***	3.937***
	(0.0167)	(0.249)	(0.290)	(0.328)	(0.362)	(0.471)
Industry FE	No	No	Yes	Yes	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes
Observations	40,889	18,537	17,373	7,014	11,555	2,087
R-squared	0.054	0.346	0.572	0.622	0.602	0.685

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

While these results appear counter-intuitive, one limit with previous estimations 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 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 negative coefficient of the reform decreases and becomes non significant in column (6). 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.

However, our previous estimates still suffer from some limits. There might be many other unobservable factors that affect firm R&D expenditures. One way to limit for potential omitted variable bias is to 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. Results of panel estimations are presented in Table 5 in which we repeated the same regressions as before but controlling for firm fixed effects. In column (1) to (3), all firms are included in the sample while in columns (4) to (6), we gradually restrict the sample in order to exclude firms with changes of tax credit status over the period of study. Once we control for firm fixed effects, the results indicate that there is a positive and significant impact of the 2008 reform. Besides, the impact of the reform is higher 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

Overall this difference in difference 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 given 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 Results of a Propensity Score matching analysis

In this section, we adopt a propensity score matching analysis combined with a difference in difference Blundell and 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 methods consists in first estimating the probability of treatment given a vector of characteristics and second to match each treated with one or several control groups (depending on the selected method). Since matching firms

Table 5: 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%.

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 6 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

Table 6: 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 7: Tests of the quality of matching

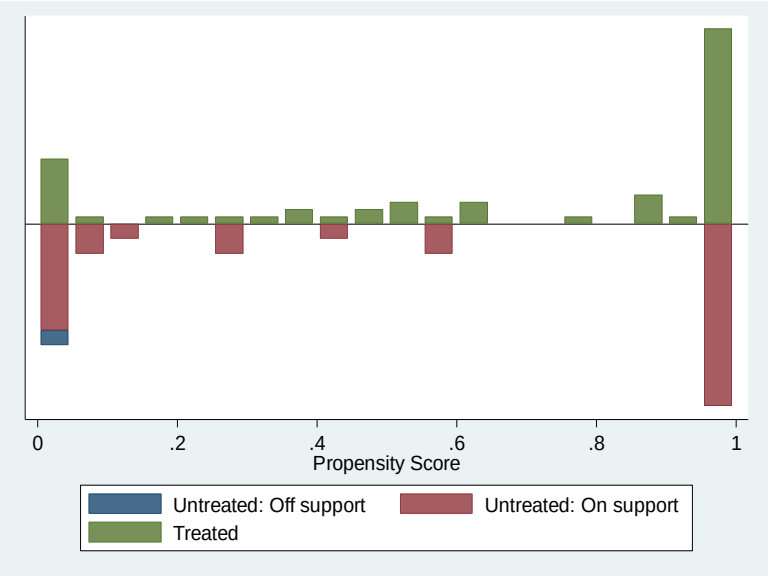
Unmatched	Mean	Mean	% reduct	t-tests			
Variable	Matched	Treated	Control	%bias	$\|bias\|$	t	p>t
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ln R&D	Unmatched	15.355	14.508	50.2		4.14	0.000
	Matched	14.754	14.721	1.9	96.2	-1.5	0.134
Ln Turnover	Unmatched	17.927	16.877	59.7		4.52	0.000
	Matched	17.492	17.396	5.5	90.8	-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 8: 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



confirms the idea that our previous estimates are likely to be biased. Results of the tests of the quality of the matching (see Table 7) 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.

The results of the average treatment on the treated are presented in Table 8. 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

Table 9: 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%.

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.

7.1 Preliminary results of a difference in difference analysis

In order to do so, we follow the same methodology as the one described previously and implement a difference in difference 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 9.

We do not find any direct impact of the reform on the number of patents at the firm-level.[6]We are nevertheless quite sceptical about these estimations. 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

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

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. We are currently trying to improve our empirical strategy to better assess the impact of the 2008 reform on patent applications.

8 Conlusion

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.

References

Bloom, N., R. Griffith, and J. Van Reenen (2002): "Do R&D tax credits work? Evidence from a panel of countries 1979-1997," *Journal of Public Economics*, 85(1), 1–31.

Blundell, R., and M. C. Dias (2009): "Alternative Approaches to Evaluation in Empirical Microeconomics," *Journal of Human Resources*, 44(3).

Cappelen, d., A. Raknerud, and M. Rybalka (2012): "The effects of R&D tax credits on patenting and innovations," *Research Policy*, 41(2), 334–345.

Corchuelo, B. (2006): "Incentivos fiscales en I+D decisiones de innovación," *Revista de Economía Aplicada*, XIV(40), 5–34.

Czarnitzki, D., P. Hanel, and J. M. Rosa (2011): "Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms," *Research Policy*, 40(2), 217–229.

David, P. A., B. H. Hall, and A. A. Toole (2000): "Is public R&D a complement or substitute for private R&D? A review of the econometric evidence," *Research Policy*, 29(4-5), 497–529.

Duguet, E. (2010): "The Effect of the R&D Tax Credit on the Private Funding of R&D: An Econometric Evaluation on French Firm Level Data," Discussion paper, mimeo.

Haegland, T., and J. Moen (2007): "Input additionality in the Norwegian R&D tax credit scheme," Discussion paper, Report 2007/04, Statistics Norway.

Hall, B., and J. Van Reenen (2000): "How effective are fiscal incentives for R&D? A review of the evidence," *Research Policy*, 29(4-5), 449–469.

Ientile, D., and J. Mairesse (2009): "A policy to boost R&D: Does the R&D tax credit work?," EIB Papers 6/2009, European Investment Bank, Economics Department.

Lhuillery, S., M. Marino, and P. Parrota (2013): "Fine tuning of public R&D policies," Discussion paper, mimeo.

Lokshin, B., and P. Mohnen (2012): "How effective are level-based R&D tax credits? Evidence from the Netherlands," *Applied Economics*, 44(12), 1527–1538.

MESR, F. (2011): "Rapport au Parlement sur le crédit d'impôt recherche 2010," Discussion paper, Ministry of Higher Education and Research.

Mulkay, B., and J. Mairesse (2013): "The R&D Tax Credit in France: Assessment and Ex-Ante Evaluation of the 2008 Reform," NBER Working Papers 19073, National Bureau of Economic Research, Inc.

Raffo, J., and S. Lhuillery (2009): "How to play the Names Game: Patent retrieval comparing different heuristics," *Research Policy*, 38(10), 1617–1627.