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Tax incentives for business R&D in Belgium

Third evaluation

April 2019

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Abstract - Belgium has committed to raise investment in research and development (R&D) to 3% of GDP by 2020. In fulfilment of this commitment, the federal government introduced different tax incentives in support of business R&D. This paper presents the results of the third evaluation of the efficiency of these tax incentives, covering the period 2003-2015.

Jel Classification - H32, O32, O38
Keywords - R&D, tax incentives, subsidies, policy mix, additionality

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Executive summary

The Belgian federal government introduced several tax incentives in support of business research and development (R&D), in fulfilment of its commitment to raise investment in R&D to 3% of GDP. Between 2005 and 2007 four schemes were presented that grant firms partial exemption from payment of the withholding tax on the wages of R&D employees. In addition, as of 2007 firms can choose between a tax deduction and a tax credit for R&D investment and in 2008 a tax deduction of 80% of patent income was initiated.

Although still only a minority of R&D active firms in Belgium make use of the tax incentives, the number of beneficiaries increased gradually over the years, especially for the partial exemption from payment of the withholding tax on the wages of R&D employees with a master's degree, which in 2015 was used by 1,670 firms. Due to the growing popularity of the tax incentives and three successive increases in the rate of the partial exemption from the withholding tax, the budgetary cost has increased substantially. Whereas in 2006 government support through R&D tax incentives amounted to 0.03% of GDP, in 2015 it reached 0.33%. As a result, by 2015 Belgium had become the OECD country with the most generous R&D tax incentives relative to GDP.

Coincidentally, R&D expenditures relative to GDP, having declined considerably in Belgium between 2001 and 2005, increased from 1.81% in 2006 to 2.47% in 2015. The correlation between government support and R&D expenditures is positive across OECD countries. However, recently the European Commission among others started to wonder whether some countries may have moved beyond the optimal level of public support to business R&D.

This paper presents the results of the third evaluation of the R&D tax incentives that were introduced in Belgium between 2005 and 2008. The first evaluation covered the period 2001-2009 and only considered the four schemes of partial exemption from payment of the withholding tax on the wages of R&D employees. The second evaluation, covering the period 2003-2011, included an assessment of the tax credit for R&D investment and the tax deduction of 80% of patent income. The evaluation presented in this paper covers the period 2003-2015.

As the tax incentives aim at raising the R&D expenditures of firms, the main research question of the assessment concerns input additionality, the extent to which public support succeeds in stimulating additional R&D activities. The fact that firms autonomously decide whether to apply for subsidies or tax benefits and how much they will invest in R&D activities complicates the estimation of the causal impact of public support. In the absence of experiments in which public support is randomly attributed to firms, estimation of its impact needs to be based on observational data, with a prerequisite to account for the autonomous decisions of firms to establish 'causal' effects. Unfortunately, all existing estimation techniques have limitations, and none can be considered superior. As in the previous evaluations, this paper therefore presents the results of different estimation procedures and emphasizes conclusions that appear to be robust across estimates.

The evaluation takes advantage of the detailed information contained in the Belgian R&D Policy Mix database, which matches several sources. It contains information on support received by firms through the different tax incentives as well as through subsidies for R&D and innovation that are provided by regional agencies. The data on public support are matched with information on firm-level R&D activities from the biennial R&D surveys, information from the annual accounts of firms and data on the number of patents granted in Belgium. The database is rather unique in that it provides firm-level information on the amount of support received through subsidies and each tax incentive. As such the data enable the estimation of the efficiency of public support by linking the amount of support to the level of R&D expenditures at the firm level without the constraint of binary variables for support (firm receives support or not) as appears to be the case in most other countries. Moreover, as the amount of support is provided for each support scheme, the impact of each individual incentive can be estimated, controlling for the support provided through other relevant incentives. The complementarity, or lack thereof, between different support schemes can also be assessed.

The results presented in this paper are for the most part in line with the findings of the previous evaluations although more robust indications are provided for some partial exemption schemes. As in the previous evaluation, there are very robust indications of input additionality for the partial exemption from payment of the withholding tax on the wages of R&D employees with a master's degree. However, contrary to the previous evaluation indications of the efficiency of the partial exemption from payment of the withholding tax on the wages of R&D employees involved in research cooperation are now also found to be very robust. The partial exemption from payment of the withholding tax for Young Innovative Companies, for which little evidence of additionality was found in the previous evaluation is now, probably due to the larger number of observations, found to have robust positive estimates. There are also more robust indications of additionality for the partial exemption from payment of the withholding tax for R&D employees with a PhD or civil engineering degree.

As the rate of exemption is the same for PhDs or civil engineers and masters, and PhDs and civil engineers, by definition, have a master's degree, the usefulness of the distinction between the two partial exemption schemes based on the educational degree of R&D employees is not clear. Since 2018 firms can also benefit from a partial exemption for R&D employees with a bachelor's degree in qualifying study fields. This support scheme was introduced too recently to be included in this evaluation.

Whereas the third evaluation clearly provides robust evidence that the four schemes of partial exemption from payment of the withholding tax succeed in raising additional R&D, as in the previous evaluation it fails to find robust indications of efficiency for the R&D tax credit and the tax deduction for 80% of patent income. For both tax incentives, only one of the estimates is positive in a statistically significant way and even than additionality is limited.

This evaluation confirms the findings from previous evaluations that input additionality decreases if firms combine different support schemes.

The budgetary cost of the R&D tax incentives in Belgium has increased considerably without much indication of a slowdown in the rise of government support through R&D tax incentives as a percentage of GDP. The fact that the bulk of the budgetary cost is due to two tax incentives for which evaluations provide few indications of efficiency, suggests that there is some leeway in constraining the increase in the budgetary cost in a way that does not stifle the potential of tax incentives to raise additional R&D activities.

In 2016 the tax deduction for patent income was replaced by a tax deduction for innovation income. The rate of deduction was raised from 80% to 85% but in line with the Base Erosion and Profit Shifting (BEPS) guidelines of the OECD, some features reduce the generosity of the deduction. As the R&D Policy Mix data so far cover the period 2003-2015, the new tax deduction for innovation could not be assessed. The most obvious support scheme to consider for adjustment therefore seems the R&D tax credit. A limit to the total amount of support or a lower rate of deduction above a certain ceiling could be envisaged, as is the case in many other countries. The indications of decreasing efficiency for firms that combine different support schemes calls for coordination and reflection as to limits to the overall amount of public support received by firms.

The Belgian federal government reached an agreement on the reform of corporate income taxation in 2017. One of the main features is the reduction of the basic corporate income tax rate. By 2020 the rate will be reduced from 33.99%, which was applicable up to 2018, to 25% for large companies. For SMEs a rate of 20% will apply up to 100,000 euro in profits and 25% above that level. As a result of the reduced corporate income tax rate, the budgetary cost of R&D tax incentives based on corporate income taxation will be lower, for a given level of R&D investment or innovation income, than now. Somewhat ironically, the differentiation in basic rates between large companies and SMEs implies that the benefit of the specific R&D tax incentives is smaller for SMEs (up to 100,000 euro) than for large companies. As partial exemption from payment of the withholding tax on the wages of R&D employees reduces the wage costs that can be deducted from turnover to determine taxable income, the reduction in the corporate tax rate increases the budgetary cost of the partial exemption schemes.

Aside from apparently being more effective in raising R&D, the partial exemption from payment of the withholding tax has a clear advantage over tax incentives provided through corporate income taxation, from the perspective of market dynamism. R&D active start-ups and young firms often lack the profits to use corporate income tax incentives whereas they immediately benefit from the partial exemption from payment of the withholding tax on the wages of their R&D employees. The latter type of public support is therefore less biased against young firms than corporate income tax incentives.

Synthèse

Le gouvernement fédéral belge a introduit plusieurs incitations fiscales en faveur de la recherche et du développement (R&D) des entreprises afin de concrétiser son engagement à porter les investissements en R&D à 3 % du PIB. Entre 2005 et 2007, quatre régimes accordant une dispense partielle de versement de précompte professionnel sur les salaires du personnel R&D ont été instaurés. En outre, à partir de 2007, s'est ajoutée une possibilité de choix entre une déduction fiscale et un crédit d'impôt pour investissement en R&D. Enfin, une déduction fiscale à 80 % des revenus des brevets a été introduite en 2008.

Bien que seule une minorité des entreprises actives dans la R&D recourent aux incitations fiscales, le nombre de bénéficiaires a augmenté progressivement avec le temps, tout particulièrement pour la dispense partielle de versement de précompte professionnel sur les salaires du personnel R&D titulaire d'un master. En 2015, 1 670 entreprises y ont eu recours. En raison de la popularité croissante des incitations fiscales et de trois augmentations successives du taux de dispense partielle du précompte, le coût budgétaire de ces incitations a considérablement augmenté. Alors que les aides publiques sous la forme d'incitations fiscales à la R&D représentaient 0,03 % du PIB en 2006, elles ont atteint 0,33 % en 2015. Par conséquent, la Belgique est devenue, en 2015, le pays de l'OCDE le plus généreux en matière d'incitations fiscales à la R&D lorsqu'elles sont rapportées au PIB.

Parallèlement, les dépenses de R&D par rapport au PIB, qui avaient sensiblement baissé entre 2001 et 2005 en Belgique, sont passées de 1,81 % en 2006 à 2,47 % en 2015. La corrélation entre aide publique et dépenses de R&D est positive dans les pays de l'OCDE. Néanmoins, la Commission européenne notamment, a récemment soulevé la question de savoir si certains pays ne dépassaient pas le niveau optimal d'aide publique à la R&D des entreprises.

Cette étude présente les résultats de la troisième évaluation des incitations fiscales à la R&D introduites en Belgique entre 2005 et 2008. La première évaluation couvrait la période 2001-2009 et ne portait que sur quatre régimes de dispense partielle de versement du précompte professionnel sur les salaires du personnel R&D. La deuxième évaluation, qui englobait la période 2003-2011, évaluait aussi le crédit d'impôt à l'investissement en R&D et la déduction fiscale à 80 % des revenus des brevets. L'évaluation présentée ici porte sur la période 2003-2015.

Puisque les incitations fiscales visent à augmenter les dépenses R&D des entreprises, cette évaluation étudie principalement la question de l'additionnalité d'input, soit la mesure dans laquelle l'aide publique crée de nouvelles activités de R&D. L'autonomie des entreprises dans leurs décisions de solliciter ou non des subventions ou des avantages fiscaux et dans les montants investis dans les activités de R&D complique l'estimation du lien causal entre aide publique et accroissement de la R&D. En l'absence d'expériences où l'aide publique est allouée de manière aléatoire aux entreprises, les estimations de ses effets doivent se fonder sur des données observées et tenir compte de l'autonomie de décision des entreprises pour établir une causalité. Toutes les techniques d'estimation existantes ont néanmoins leurs limites, et aucune ne peut être considérée comme supérieure. Comme pour les évaluations précédentes, cette étude présente les résultats de différentes méthodes d'estimation et met l'accent sur les conclusions qui semblent solides dans les différentes estimations.

L'évaluation s'appuie sur les informations détaillées contenues dans la base de données belge R&D Policy Mix, qui regroupe plusieurs sources. Cette base de données contient des informations sur l'aide reçue par les entreprises sous la forme des différentes incitations fiscales et des subventions à la R&D et à l'innovation accordées par les agences régionales. Les données sur l'aide publique sont couplées avec informations sur les activités R&D des entreprises tirées des enquêtes bisannuelles sur la R&D, les données des comptes annuels des entreprises et les données sur le nombre de brevets délivrés. Cette base de données est plutôt unique en ce sens qu'elle fournit des renseignements, à l'échelle des entreprises, sur le montant de l'aide reçue par le biais de subventions et de chaque incitation fiscale. Ces données permettent d'estimer l'efficience de l'aide publique en établissant un lien entre le montant de l'aide et les dépenses de R&D dans l'entreprise sans la contrainte de variables binaires (l'entreprise reçoit ou non un soutien), comme cela semble être le cas dans la plupart des autres pays. En outre, étant donné que le montant de l'aide est fourni pour chaque régime, l'impact de chaque mesure individuelle d'incitation peut être estimé, en contrôlant pour l'aide allouée via d'autres mesures d'incitation pertinentes. La complémentarité ou l'absence de complémentarité entre différents régimes d'aide peut également être évaluée.

Les résultats présentés dans cette étude sont, pour la plupart, cohérents avec les conclusions des évaluations précédentes et fournissent des indications plus probantes pour certains régimes de dispense partielle. Comme dans son édition précédente, l'analyse fait apparaître des indications très solides d'additionnalité d'input pour la dispense partielle de versement du précompte professionnel pour les chercheurs titulaires d'un master. Par rapport à l'évaluation précédente, les indications d'efficience de la dispense partielle de précompte professionnel pour le personnel actif dans la coopération en matière de recherche se révèlent désormais très solides. La dispense partielle de versement de précompte professionnel en faveur des jeunes entreprises innovantes, dont l'additionnalité n'a guère été démontrée lors de l'évaluation précédente, donne désormais des résultats positifs robustes, en raison probablement du plus grand nombre d'observations. On relève également des indications plus solides d'additionnalité pour la dispense partielle de versement de précompte professionnel accordée au personnel R&D titulaire d'un doctorat ou d'un diplôme d'ingénieur civil.

Étant donné que le taux de dispense est maintenant le même pour les titulaires d'un doctorat, d'un diplôme d'ingénieur civil et d'un master et que, par définition, les titulaires d'un doctorat et les ingénieurs civils détiennent un master, la distinction entre les deux régimes de dispense partielle fondée sur le niveau de formation ne parait pas clairement utile. Depuis 2018, la dispense partielle a été étendue aux travailleurs R&D titulaires d'un bachelier académique ou professionnel dans des domaines d'études spécifiques. Ce dispositif est trop récent pour être inclus dans cette évaluation.

Alors que cette troisième évaluation montre clairement, au même titre que la deuxième, que les quatre régimes de dispense partielle de versement de précompte professionnel contribuent au développement des activités de R&D elle ne dégage pas d'indications solides d'efficience pour le crédit d'impôt à la R&D et la déduction fiscale à 80 % des revenus des brevets. Pour les deux incitations fiscales, une seule des estimations est statistiquement significative et, même dans ce cas, l'additionnalité est limitée.

Cette évaluation confirme les résultats d'évaluations précédentes selon lesquels l'additionnalité d'input diminue si les entreprises combinent différents dispositifs d'aide.

En Belgique, le coût budgétaire des incitations fiscales en faveur de la R&D a considérablement augmenté, sans aucun signe de ralentissement de la progression des aides publiques sous la forme d'incitations fiscales à la R&D en pourcentage du PIB. Dès lors que le coût budgétaire est principalement généré par deux incitations fiscales pour lesquelles les évaluations dégagent peu d'indications d'efficience, on peut penser qu'il existe une certaine marge de manœuvre pour limiter l'augmentation du coût budgétaire d'une manière qui n'entrave pas le potentiel des incitations fiscales à développer les activités de R&D.

En 2016, la déduction fiscale pour revenus de brevets a été remplacée par une déduction fiscale pour revenus d'innovation. Le taux de déduction a été porté de 80 % à 85 %, mais conformément aux lignes directrices de l'OCDE sur l'érosion de la base d’imposition et le transfert de bénéfices (BEPS), certaines modalités réduisent la générosité de la déduction. Étant donné que les données R&D Policy Mix ne couvrent que la période 2003-2015, la nouvelle déduction fiscale relative à l’innovation n’a pu être évaluée. De toute évidence, le premier régime d’aide à envisager pour l'ajustement semble être le crédit d'impôt à la R&D. On pourrait envisager de limiter le montant total d’aide ou d’abaisser le taux de déduction au-delà d’un certain seuil, comme c’est le cas dans de nombreux autres pays. Les indications d'efficience décroissante de l’aide aux entreprises qui combinent différents dispositifs de soutien appellent à coordonner l’aide publique et à réfléchir aux limites du montant global octroyé.

Le gouvernement fédéral belge s’est accordé en 2017 sur la réforme de l'impôt des sociétés. L’un des principaux axes de la réforme est la réduction du taux de base de cet impôt. D'ici 2020, le taux de 33,99 % appliqué jusqu’à 2018 sera ramené à 25 % pour les grandes entreprises. Pour les PME, un taux de 20 % s'appliquera à la première tranche de 100 000 euros de bénéfices et un taux de 25 % au-delà. Compte tenu de la réduction du taux de l'impôt des sociétés, le coût budgétaire des incitations fiscales à la R&D fondées sur cet impôt sera plus faible qu'actuellement, pour un niveau donné d'investissement en R&D ou de revenu d'innovation. Paradoxalement, la différenciation des taux de base pour les grandes entreprises et les PME laisse à penser que le bénéfice des incitations fiscales spécifiques à la R&D est plus faible pour les PME (jusqu'à 100 000 euros) que pour les grandes entreprises. Comme la dispense partielle de versement de précompte professionnel sur les salaires du personnel R&D réduit les coûts salariaux qui peuvent être déduits du chiffre d'affaires pour déterminer le revenu imposable, la réduction du taux de l'impôt des sociétés accroît le coût budgétaire des régimes de dispense partielle.

En comparaison avec les incitations fiscales octroyées dans le cadre de l'impôt des sociétés, la dispense partielle de versement de précompte professionnel est apparemment plus efficace pour le développement de la R&D et présente un net avantage du point de vue de la dynamique du marché. Les jeunes entreprises, notamment actives dans la R&D, ne dégagent pas souvent de bénéfices suffisants pour être éligibles aux incitations fiscales liées aux bénéfices imposables, alors qu'elles bénéficient immédiatement de la dispense partielle de versement de précompte professionnel sur les salaires de leur personnel R&D. Cette forme d’aide publique est dès lors moins défavorable aux jeunes entreprises que les incitations fiscales s’appuyant sur les bénéfices des entreprises.

Synthese

In het kader van haar verbintenis om de uitgaven voor onderzoek en ontwikkeling (O&O) te verhogen tot 3 % van het bbp, heeft de Belgische federale regering een aantal fiscale maatregelen genomen om de O&O-activiteiten van ondernemingen te ondersteunen. Tussen 2005 en 2007 werden er vier maatregelen voorgesteld die ondernemingen een gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van hun O&O-personeel verlenen. Daarnaast kunnen ondernemingen vanaf 2007 kiezen tussen een belastingaftrek en een belastingkrediet voor O&O-investeringen en in 2008 werd een belastingaftrek van 80 % voor octrooi-inkomsten ingevoerd.

Hoewel slechts een minderheid van de ondernemingen die actief zijn op het gebied van O&O gebruikmaakt van de belastingvoordelen, is het aantal begunstigden in de loop van de jaren geleidelijk toegenomen, met name voor de gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van O&O-personeel met een masterdiploma. In 2015 maakten 1 670 ondernemingen van dit voordeel gebruik. Door de toenemende populariteit van de belastingvoordelen en de drie opeenvolgende verhogingen van het percentage van de gedeeltelijke vrijstelling van bedrijfsvoorheffing zijn de budgettaire kosten aanzienlijk gestegen. Terwijl de overheidssteun via belastingvoordelen voor O&O in 2006 0,03 % van het bbp bedroeg, was dat in 2015 0,33 %. Bijgevolg was België tegen 2015 het OESO-land met de meest genereuze belastingvoordelen voor O&O in verhouding tot het bbp.

Tegelijkertijd zijn de O&O-uitgaven in verhouding tot het bbp, die tussen 2001 en 2005 in België sterk waren gedaald, gestegen van 1,81 % in 2006 tot 2,47 % in 2015. De correlatie tussen overheidssteun en O&O-uitgaven is positief in alle OESO-landen. Niettemin heeft de Europese Commissie onlangs de vraag gesteld of sommige landen het optimale niveau van overheidssteun voor O&O van ondernemingen niet overschrijden.

Deze paper presenteert de resultaten van een derde evaluatie van de belastingvoordelen voor O&O die België tussen 2005 en 2008 heeft ingevoerd. De eerste evaluatie had betrekking op de periode 2001-2009 en bestudeerde alleen de vier maatregelen van gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van O&O-personeel. De tweede evaluatie die betrekking had op de periode 2003-2011 beschouwde ook het belastingkrediet voor O&O-investeringen en de belastingaftrek van 80 % voor octrooi-inkomsten. De evaluatie in deze paper heeft betrekking op de periode 2003-2015.

Aangezien de belastingvoordelen bedoeld zijn om de O&O-uitgaven van ondernemingen te verhogen, wordt in deze evaluatie vooral gekeken naar de inputadditionaliteit, d.w.z. de mate waarin overheidssteun additionele O&O-activiteiten kan aanmoedigen. Het feit dat ondernemingen autonoom beslissen of ze subsidies of belastingvoordelen aanvragen en welk bedrag ze in O&O-activiteiten zullen investeren, bemoeilijkt de raming van de causale impact van de overheidssteun. Bij gebrek aan experimenten waarbij de overheidssteun willekeurig aan ondernemingen wordt toegekend, moet de schatting van de impact ervan worden gebaseerd op waargenomen gegevens en rekening houden met de beslissingsautonomie van ondernemingen, om 'causale' effecten vast te stellen. Helaas hebben alle bestaande schattingstechnieken beperkingen en kan geen enkele als superieur worden beschouwd. Net als bij de eerdere evaluaties presenteert deze paper de resultaten van verschillende schattingsprocedures en legt daarbij de nadruk op conclusies die robuust lijken in de verschillende ramingen.

De evaluatie is gebaseerd op gedetailleerde informatie uit de Belgische R&D Policy Mix databank, die verschillende bronnen combineert. Deze databank bevat informatie over de steun aan ondernemingen via de verschillende belastingvoordelen alsook via subsidies voor O&O en innovatie die door gewestelijke agentschappen worden toegekend. De gegevens over overheidssteun worden gekoppeld aan informatie over de O&O-activiteiten op ondernemingsniveau uit de tweejaarlijkse O&O-enquêtes, informatie uit de jaarrekeningen van ondernemingen en gegevens over het aantal verleende octrooien in België. Deze databank is vrij uniek omdat ze informatie op ondernemingsniveau verschaft over het bedrag van de steun die via subsidies en elk belastingvoordeel is ontvangen. De gegevens maken het dus mogelijk de efficiëntie van de overheidssteun te ramen door het bedrag van de steun te koppelen aan het niveau van de O&O-uitgaven op ondernemingsniveau, zonder de beperking van binaire variabelen voor steun (de onderneming ontvangt steun of niet), zoals in de meeste andere landen het geval lijkt te zijn. Aangezien het steunbedrag voor elke steunmaatregel is vastgesteld, kan de impact van elke individuele maatregel worden geschat, waarbij rekening wordt gehouden met de steun die door andere relevante maatregelen wordt verleend. Ook de complementariteit of het gebrek aan complementariteit tussen verschillende steunmaatregelen kan worden beoordeeld.

De in deze paper gepresenteerde resultaten zijn grotendeels in overeenstemming met de conclusies van de eerdere evaluaties, hoewel er meer robuuste aanwijzingen zijn voor sommige maatregelen van gedeeltelijke vrijstelling. Net als in de vorige evaluatie zijn er zeer robuuste aanwijzingen van inputadditionaliteit voor de gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van O&O-personeel met een masterdiploma. In tegenstelling tot de vorige evaluatie zijn er nu echter ook zeer robuuste aanwijzingen voor de efficiëntie van de gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van O&O-personeel dat betrokken is bij onderzoekssamenwerking. De gedeeltelijke vrijstelling van bedrijfsvoorheffing voor Jonge Innoverende Ondernemingen, waarvan de additionaliteit in de vorige evaluatie nauwelijks is aangetoond, levert nu robuuste positieve resultaten op, waarschijnlijk door het hogere aantal waarnemingen. Er zijn ook meer robuuste aanwijzingen van additionaliteit voor de gedeeltelijke vrijstelling van bedrijfsvoorheffing voor O&O-personeel met een doctoraatsdiploma of een diploma van burgerlijk ingenieur.

Aangezien het vrijstellingspercentage hetzelfde is voor doctors of burgerlijk ingenieurs en masters, en een doctor en burgerlijk ingenieur per definitie een masterdiploma hebben, is het nut van het onderscheid tussen de twee maatregelen van gedeeltelijke vrijstelling op basis van het opleidingsniveau van het O&O-personeel niet duidelijk. Sinds 2018 kunnen ondernemingen ook een gedeeltelijke vrijstelling krijgen voor O&O-personeel met een bachelordiploma in de in aanmerking komende studierichtingen. Die steunmaatregel werd te recent ingevoerd om in deze evaluatie te worden opgenomen.

Terwijl de derde evaluatie duidelijk aantoont dat de vier maatregelen van gedeeltelijke vrijstelling van bedrijfsvoorheffing additionele O&O-uitgaven generen, blijken er, net zoals in de vorige evaluatie, weinig robuuste aanwijzingen te zijn voor de efficiëntie van het belastingkrediet voor O&O en de belastingaftrek van 80 % voor octrooi-inkomsten. Voor de beide belastingvoordelen is slechts één van de geschatte coëfficiënten statistisch significant positief en zelfs dan is de additionaliteit beperkt.

Deze evaluatie bevestigt de bevindingen van eerdere evaluaties dat de inputadditionaliteit afneemt als ondernemingen verschillende steunmaatregelen combineren.

De budgettaire kosten van de belastingvoordelen voor O&O in België zijn sterk toegenomen zonder dat er aanwijzingen zijn dat de stijging van de overheidssteun via die voordelen als percentage van het bbp afneemt. Het feit dat het grootste deel van de budgettaire kosten te wijten is aan twee belastingvoordelen waarvoor de evaluaties weinig aanwijzingen voor efficiëntie bieden, suggereert dat er enige speelruimte is om de stijging van de budgettaire kosten te beperken op een manier die de mogelijkheden van de belastingvoordelen om O&O-activiteiten te stimuleren niet ondermijnt.

In 2016 werd de belastingaftrek voor octrooi-inkomsten vervangen door een belastingaftrek voor innovatie-inkomsten. Het aftrekpercentage werd verhoogd van 80 % tot 85 %, maar in lijn met de BEPS (Base Erosion and Profit Shifting)-richtlijnen van de OESO verminderen sommige kenmerken de generositeit van de aftrek. Aangezien de R&D Policy Mix data de periode 2003-2015 bestrijken, kon de nieuwe belastingaftrek voor innovatie niet worden geëvalueerd. De meest voor de hand liggende steunmaatregel die voor aanpassing in aanmerking komt, lijkt daarom het belastingkrediet voor O&O te zijn. Een beperking van het totale steunbedrag of een lager aftrekpercentage boven een bepaald plafond zou kunnen worden overwogen, zoals in veel andere landen het geval is. De aanwijzingen dat ondernemingen die verschillende steunmaatregelen combineren, steeds minder doeltreffend worden, vragen om coördinatie en reflectie over het beperken van het totale bedrag aan overheidssteun dat ondernemingen ontvangen.

De Belgische federale regering bereikte in 2017 een akkoord over de hervorming van de vennootschapsbelasting. Een van de belangrijkste kenmerken is de verlaging van het basistarief van de vennootschapsbelasting. In 2020 wordt het tarief verlaagd van 33,99 %, dat van toepassing was tot en met 2018, naar 25 % voor grote ondernemingen. Voor kmo's geldt een tarief van 20 % voor winsten tot 100 000 euro en 25 % boven dat niveau. Als gevolg van het verlaagde vennootschapsbelastingtarief zullen de budgettaire kosten van belastingvoordelen voor O&O op basis van de vennootschapsbelasting, voor een bepaald niveau van O&O-investeringen of innovatie-inkomsten, lager uitvallen dan nu het geval is. Ironisch genoeg impliceert de differentiatie van de tarieven tussen grote ondernemingen en kmo's dat het voordeel van de specifieke belastingvoordelen voor O&O kleiner is voor kmo’s (tot 100 000 euro) dan voor grote ondernemingen. Aangezien de gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van O&O-personeel de loonkosten vermindert die kunnen worden afgetrokken van de omzet om het belastbaar inkomen te bepalen, verhoogt de verlaging van het vennootschapsbelastingtarief de budgettaire kosten van de maatregelen van gedeeltelijke vrijstelling.

De gedeeltelijke vrijstelling van bedrijfsvoorheffing heeft niet alleen een groter effect op het verhogen van O&O, maar heeft ook een duidelijk voordeel ten opzichte van belastingvoordelen via de vennootschapsbelasting, vanuit het oogpunt van marktdynamiek. O&O-actieve jonge ondernemingen hebben vaak niet de winst om gebruik te maken van vennootschapsbelastingvoordelen, terwijl zij onmiddellijk gebruik kunnen maken van de gedeeltelijke vrijstelling van bedrijfsvoorheffing op de lonen van hun O&O-personeel. Deze laatste vorm van overheidssteun valt dus minder in het nadeel uit van jonge ondernemingen dan de vennootschapsbelastingvoordelen.

1. Introduction

This chapter provides a brief overview of the tax incentives that were introduced by the Belgian federal government in support of business R&D. It also shows the evolution in the use and budgetary cost of these tax incentives and the trend in R&D intensity.

1.1. Tax incentives for business R&D in Belgium

In fulfilment of its commitment to the Europe 2020 target to raise expenditures on research and development (R&D) to 3% of GDP, the Belgian federal government introduced different tax incentives in support of R&D activities by companies.

Between 2005 and 2007, four schemes were introduced that provide a partial exemption from payment of the withholding tax on the wages of R&D personnel: for companies involved in research cooperation with a university, a higher education institution or a scientific institution; for Young Innovative Companies (YIC)[1] and two schemes based on the educational degree of R&D employees. Since January 2018, companies can also benefit from a partial exemption for the remuneration of R&D employees with a bachelor's degree in qualifying study fields. The rate of exemption for this recent extension currently amounts to 40% but it will be raised to 80% by January 2020, equal to the current rate of exemption for the four existing schemes.[2]

Belgian companies can choose, as of 2007, between a tax deduction or a tax credit for investment in R&D (tangible and intangible fixed assets and patents)[3]. The tax deduction can be carried forward for an unlimited period if profits are insufficient to benefit from the deduction whereas the part of the tax credit that is not used after 5 years, is refunded. For 2019 the rate of deduction is 13.5% of the investment or acquisition value for a one-off deduction and 20.5% of the annual depreciation for a spread deduction.

From 2008 onwards, the federal government grants a deduction of 80% of qualifying gross patent income from the taxable basis for corporate income taxation. In 2016 the tax deduction for patent income was replaced by a tax deduction for innovation income. The new deduction is less generous as, in line with the OECD guidelines on Base Erosion Profit Shifting (BEPS), the tax deduction on innovation income applies to net income rather than gross income[4] and furthermore applies a Nexus ratio which links innovation income to the location where the costs to generate the eligible income are incurred. On the other hand, in addition to income from patents, the deduction also applies to income from plant variety

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1 A Young Innovative Company is defined (see Belgian Science Policy, 2006) as a company which:
- carries out research projects;
- has been set up for less than 10 years before January 1 of the year during which the advance payment exemption is granted;
- is not set up within the framework of concentration, a restructuration, an extension of a pre-existing activity or resumption of such activities;
- has made expenditures on R&D representing at least 15% of the total costs in the foregoing taxable period.

2 The federal government also introduced a partial exemption from payment of the withholding tax for universities and colleges, in 2003, and for recognized scientific institutions, in 2004. This report only considers the four schemes for companies.

3 A tax deduction reduces the taxable income whereas a tax credit reduces the amount of taxes that is due.

4 Gross income includes R&D expenditures for which a tax deduction already applies.

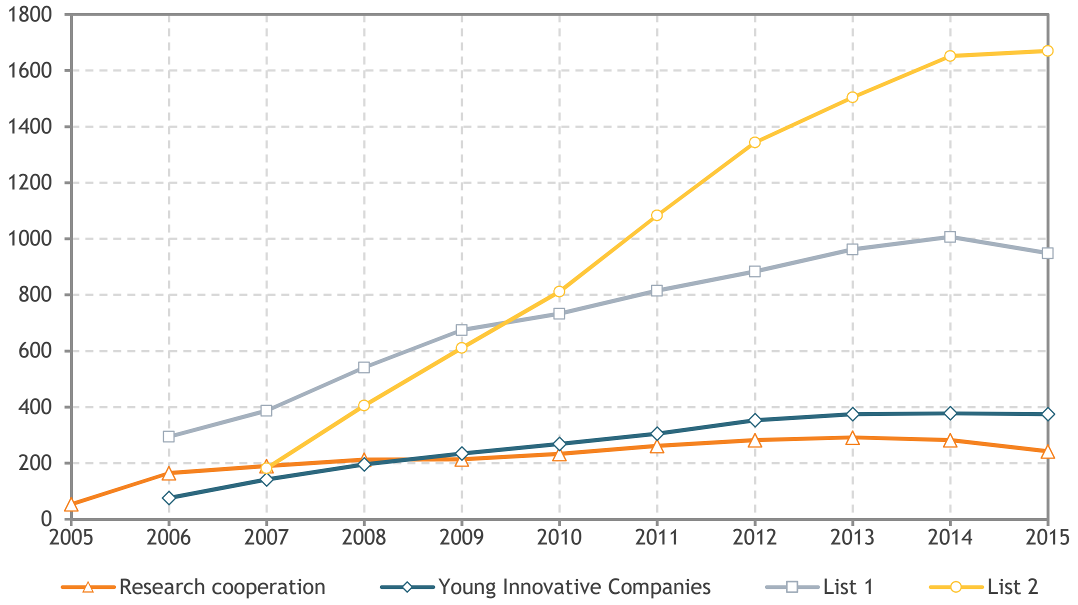
or breeders' rights; orphan medicinal products; data or market exclusivity and copyright-protected software and the rate of deduction is 85% instead of 80%. The patent income deduction is gradually phased out through a grandfather (transition) period that ends June 2021.

OECD (2018 a) provides more details on R&D tax incentives in Belgium and a comparison with other OECD countries.

1.2. Use of R&D tax incentives

Graph 1 shows the evolution of the number of firms that received a partial exemption from payment of the withholding tax on the wages of R&D personnel, based on the most recent available information.[5] List 1 refers to the list of educational degrees for which a partial exemption was introduced in 2006 (PhD in exact or applied sciences, PhD in (veterinary) medicine or a civil engineering degree) and List 2 to the degrees for which an exemption was introduced in 2007 (master's degree in sciences, except for social and human sciences). The partial exemption for firms involved in research cooperation with a university, a higher education institution or a scientific institution was introduced in 2005 and the scheme for Young Innovative Companies was introduced in 2006.

Graph 1 **Number of firms benefitting from partial exemption from withholding tax on remuneration R&D personnel (2005-2015)**



Source: Belgian Chamber of Representatives, written questions and answers 2016. List 1: PhD in exact or applied sciences, PhD in (veterinary) medicine or a civil engineering degree, List 2: Master's degree in (applied) sciences, except for social and human sciences.

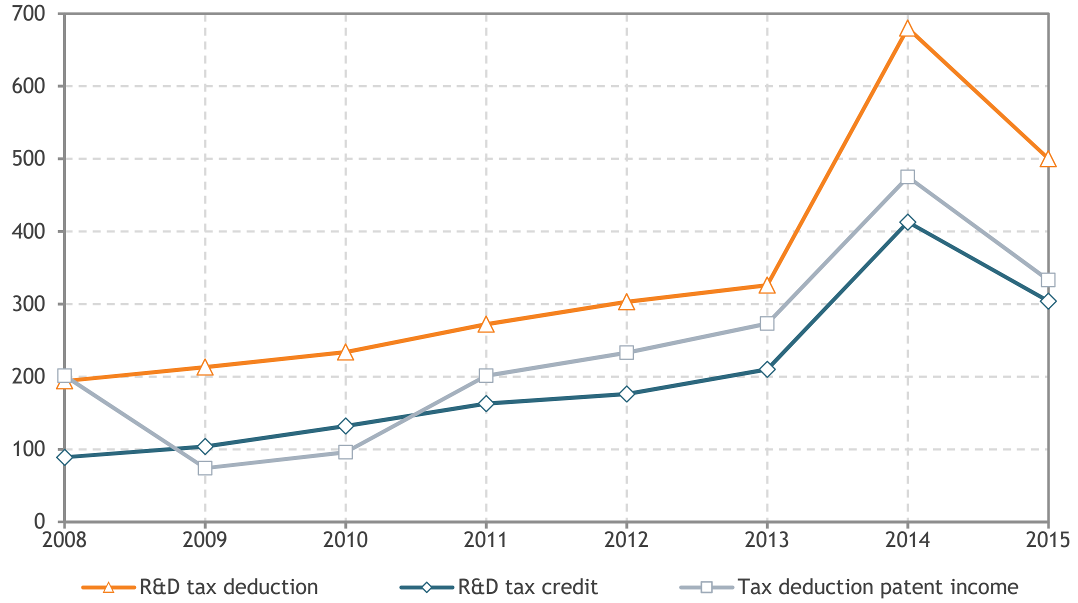
The graph shows the steady increase in the number of firms that benefit from the two schemes of partial exemption for R&D employees based on the educational degree, which are more general than the exemption for research cooperation or for YIC. In 2010, the number of firms that benefitted from a partial exemption for R&D employees with a List 2 degree exceeds the number of firms that benefitted from a

5 This does not include information on the tax deduction for innovation income, introduced mid-2016, or the partial exemption from the withholding tax for R&D personnel with a bachelor's degree, introduced in 2018.

partial exemption for R&D employees with a List 1 degree. The gap between the two schemes increased between 2010 and 2015. This evolution seems to indicate that as the rate of exemption is the same for both lists and List 1 contains List 2 (a researcher with a PhD also has a master's degree) many companies only apply for the partial exemption based on List 2. The number of Young Innovative Companies stabilized and the number of firms that benefit from a partial exemption for research cooperation decreased slightly from 2013 onwards.

Graph 2 shows the evolution, between 2008 and 2015, of the number of firms that used an incentive through corporate income taxation. Most firms opt for a tax deduction rather than a tax credit for R&D investment. All three schemes show a similar pattern, with a gradual increase up to 2013 and a sudden surge in 2014, followed by a substantial drop in 2015.

Graph 2 Number of firms benefitting from R&D tax incentives through corporate income taxation (2008-2015)



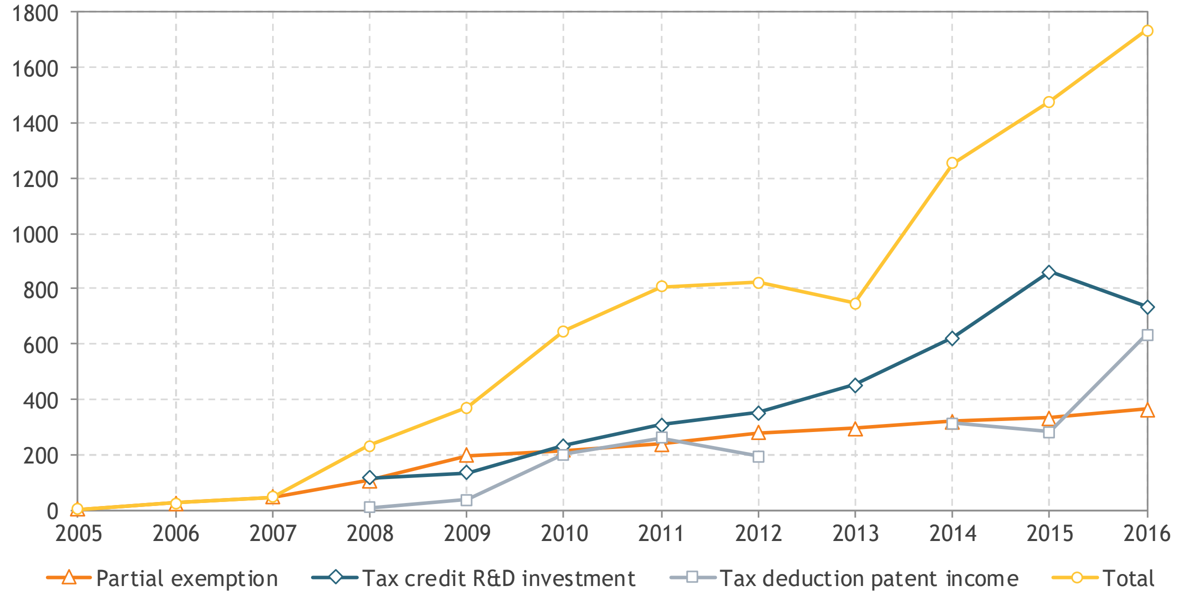
Source: Belgian Chamber of Representatives, written questions and answers 2016.

The increasing popularity of R&D tax incentives is reflected in the budgetary cost[6] as shown in graph 3. The budgetary cost of the four schemes of partial exemption from payment of the withholding tax (total amount for four schemes shown in the graph) increased gradually but the budgetary cost of the tax credit for R&D investment and the tax deduction for patent income show a much steeper increase. These two tax incentives account for the bulk of the budgetary cost of R&D tax incentives in Belgium. Although more firms use a tax deduction for R&D investment than a tax credit, the budgetary cost of the latter is substantially higher, indicating that large R&D firms more frequently than small firms opt for a tax credit rather than a tax deduction. The tax deduction for patent income is also predominantly used by large firms as revealed by the high budgetary cost despite the relatively small number of firms that use this incentive. The total budgetary cost of tax incentives for business R&D increased from about 254 million euro in 2008 to 1.7 billion euro in 2016. The tax credit for R&D investment, despite having

[6] The budgetary cost is defined as the tax revenue lost due to the incentive.

decreased by more than 100 million euro compared to 2015, accounted for 42% of the budgetary cost of all R&D tax incentives in 2016 and the tax deduction for patent income for another 37%.

Graph 3 Budgetary cost of tax incentives for business R&D (2005-2016)
Million euro



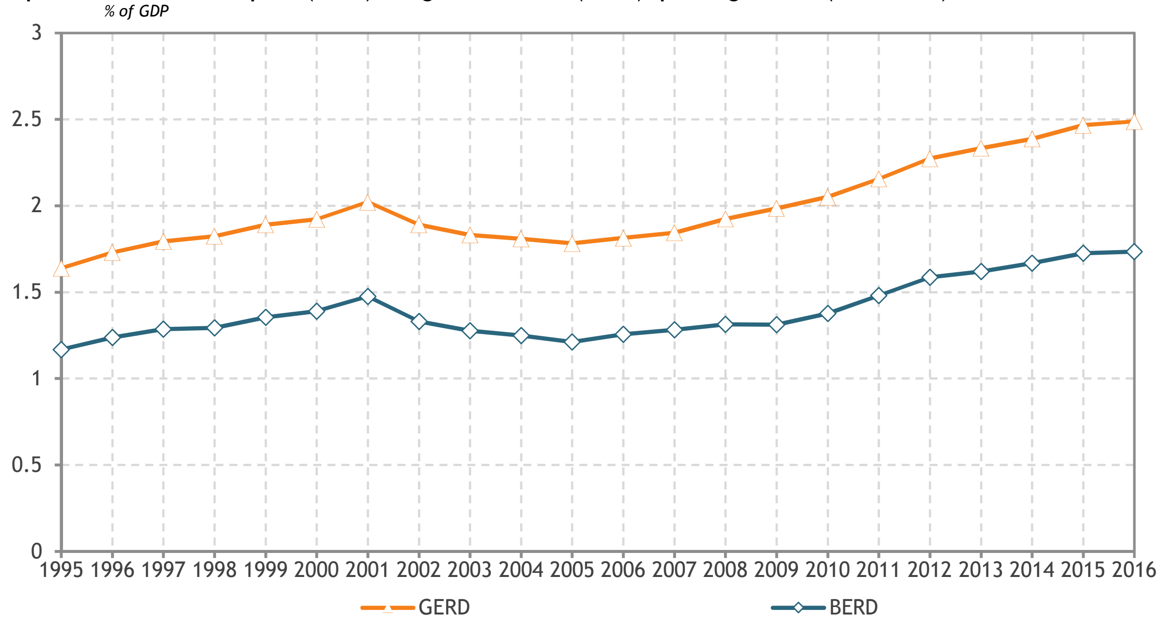
Source: Official statistics from the Annex to the "Budget des Voies et Moyens - Middelenbegroting" - Inventory of tax exemptions, deductions and credits having an impact on federal revenue. Data on the tax deduction for patent income not available for 2013.

1.3. R&D intensity

The tax incentives in support of business R&D provided by the federal government aim at raising the R&D intensity of Belgium, which as can be seen in graph 4, coincidentally bottomed out in 2005, the year when the first R&D tax incentive was introduced. Graph 4 shows R&D spending by the business enterprise sector (BERD) as well as gross domestic R&D spending (GERD) for Belgium, both as a percentage of GDP for the period 1995-2016. From 2006, both BERD and GERD gradually increased relative to GDP although the increase appears to taper off from 2012 onwards (data for 2016 are provisional). According to the OECD Main Science and Technology Indicators, with a 0.48% increase in BERD relative to GDP, between 2006 and 2016, Belgium ranked fourth in the list of countries in terms of strongest increase, after South Korea, Slovenia and Austria. Graph 3 and 4 indicate that the strong increase in the use and the budgetary cost of the R&D tax incentives that were introduced between 2005 and 2008 coincides with a substantial rise of R&D intensity. This correlation obviously does not prove any causal impact of tax incentives.

The budgetary impact of tax incentives in support of R&D receives heightened attention in discussions between the European Commission and Member States as questions arise as to whether some EU countries have moved beyond the optimal level of public support to business R&D (Council of the European Union 2018, European Commission 2018).

Graph 4 **Business enterprise (BERD) and gross domestic (GERD) spending on R&D (1995-2016)**
% of GDP



Source: OECD Main Science and Technology Indicators. Information for 2016 is provisional.

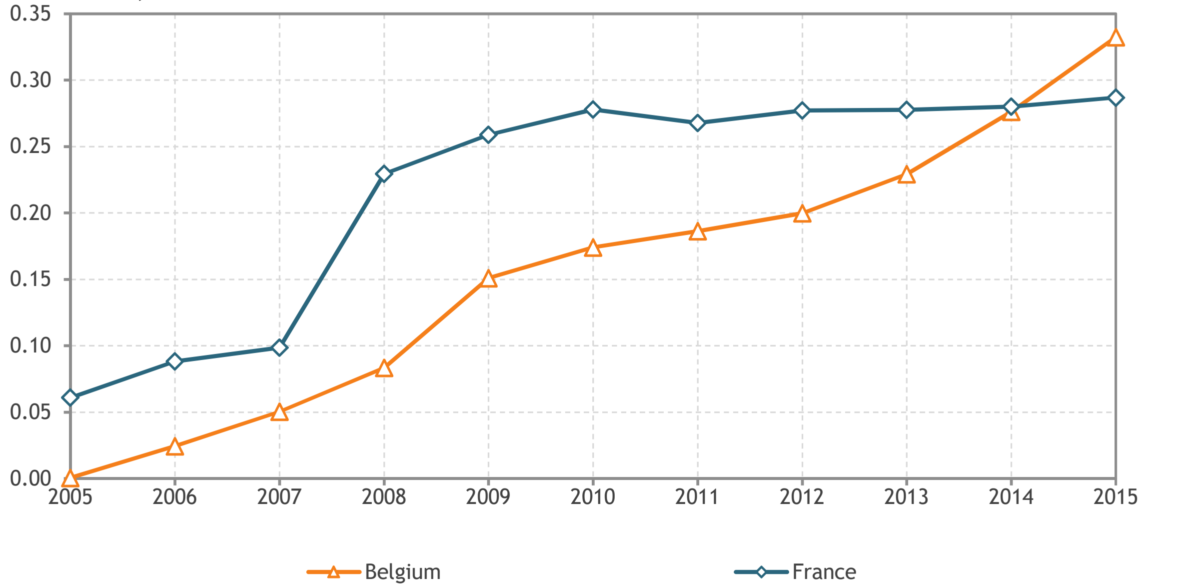
According to the OECD R&D Tax Incentive Database (http://www.oecd.org/sti/rd-tax-stats.htm), in 2015 Belgium was the OECD country with the most generous tax support of business R&D, relative to GDP, just before France but well ahead of most other OECD countries. The comparison of the evolution in Belgium and France is rather telling. Graph 5 shows government support through tax incentives in support of business R&D as a percentage of GDP in Belgium and France over the period 2005-2015.

The comparison between countries of public support for business R&D should be considered with caution given some issues that still need to be settled to assure cross-country comparability. Valenduc (2019) shows, for the case of Belgium, that not accounting for the interaction of different support schemes in statistics on government tax relief for R&D tax expenditure (GTARD) results in the overestimation of public support as the partial exemption schemes reduce the total wage costs that can be deducted from revenue considered for corporate income taxation. As it reduces deductible costs, part of the budgetary cost of the partial exemption of the withholding tax on the wages of R&D employees is recuperated through corporate income taxation.

The most important tax incentive for business R&D in France is the Crédit d'Impôt Recherche (CIR). In 2004, the "Jeune Entreprise Innovante" scheme provided young innovative SMEs with a reduction of wage contributions. In 2013 a specific scheme was introduced in support of SMEs (Credit d'Impôt Innovation - CII). In France, firms can also benefit from a reduced corporate tax rate on income and capital gains from patents. The French patent box is set to be reformed in 2019 in accordance with the OECD guidelines on Base Erosion Profit Shifting, as Belgium did in 2016 with the replacement of the patent box with a tax deduction on innovation income.

The French CIR has been reformed several times since its introduction in 1983. A major reform occurred in 2008. The cap of 16 million euro was dropped but more importantly the tax credit would henceforth apply to the volume of R&D expenditures rather than to the increase in R&D expenditures. The tax rate was set at 30%, with a more generous rate of 50% and 40% for the first and second year of CIR use. The 30% rate applies to R&D expenditures up to 100 million euro. Above 100 million euro, the rate is 5% (Dortet-Bernadet and Sicsic 2017). The shift from an incremental tax credit to a volume-based tax credit resulted in a dramatic increase of the budgetary cost in 2008, as can be clearly seen in graph 5. The cost further increased relative to GDP up to 2010, after which it stabilized.

Graph 5 Government support through R&D tax incentives Belgium and France (2005-2015)
% of GDP



Source: R&D tax expenditure and direct government funding of BERD (https://stats.oecd.org/Index.aspx?DataSetCode=RDTAX) Data downloaded 16th January 2019

The decrease in the general costs of R&D that are eligible for the CIR, explain the stabilization in the budgetary cost, from 2011 onwards (Mulkay and Mairesse 2018). Moreover, the more generous rates for the first years of CIR use were reduced in 2011 and dropped altogether in 2013. Harfi and Lallement (2019) review the rather mixed results from evaluations of the French CIR.

Government support through R&D tax incentives in Belgium was much lower than in France up to 2010 but from then onwards the gap started to close due to the stabilization in France and the continuous rise in Belgium, with Belgium surpassing France in 2015.[7]

In 2016 the tax credit for R&D investment accounted for 42% of the total budgetary cost of R&D tax incentives in Belgium. The rate of the R&D tax credit in Belgium is 13.5% which is well below the 30% rate in France but contrary to France the rate applies without any ceiling.[8] For the tax deduction for patent income there is also no cap or ceiling above which a lower rate of deduction applies. For the moment there are no changes in the Belgian R&D tax incentives that would lead to expect a slowdown in the budgetary cost although the impact of the replacement, mid-2016, of the tax deduction for patent income by a tax deduction for innovation income remains uncertain. Some features reduce the

[7] According to the latest data, government support through R&D tax incentives relative to GDP in Belgium would have decreased from 0.33% in 2015 to 0.30% in 2016 but data for 2016 are provisional and subject to change. As graph 3 shows, according to recent data, the rise in the budgetary cost of R&D tax incentives in Belgium did not appear to abate in 2016. For France data for 2016 are not available. Therefore 2016 is not considered in graph 5.

[8] The corporate income tax rate in France of 34.43% will be reduced to 28% in 2020.

generosity of the tax deduction for innovation income relative to the previous tax deduction for patent income but on the other hand the deduction for innovation income applies to a broader income base and the rate of deduction is 85% instead of 80%. Moreover, the tax deduction for patent income will only be phased out by 2021. In addition, since January 2018 a scheme of partial exemption from payment of the withholding tax for R&D employees with a bachelors' degree is in effect, with the current exemption of 40% set to be raised to 80% by 2020.

The reform of Belgian corporate income taxation that was agreed upon in 2017 will affect the budgetary cost of R&D tax incentives. The corporate income tax rate will be reduced from 33.99%, which was applicable up to 2018, to 25% for large companies by 2020. For SMEs a rate of 20% will apply up to 100,000 euro in profits and 25% above that level. The lower tax rate will reduce the budgetary cost of the R&D tax incentives based on corporate income taxation (tax deduction/tax credit for R&D investment and the tax deduction for innovation income). Somewhat ironically, due to the differentiation in tax rates the benefit of the specific R&D tax incentives is smaller for SMEs (up to 100,000 euro) than for large companies.

On the other hand, as partial exemption from payment of the withholding tax on the wages of R&D employees reduces the wage costs that can be deducted from turnover to determine taxable income, the reduction in the basic corporate tax rates increases the budgetary cost of the partial exemption schemes.

2. Research question and method of evaluation

The rationale to provide public support for R&D activities of private companies, rests primarily on the assumption that, due to market failures, private firms will invest less in R&D than socially optimal. By providing subsidies or tax incentives, governments aim at encouraging firms to perform R&D activities that they would not consider without support.[9] The efficiency of public support can be assessed by the extent to which the support stimulates additional private R&D activities.

European Commission (2014) discusses the requirements of evaluations of state aid.[10] Evaluation should include precise questions on the impact of public support that can be answered quantitatively, with necessary supporting evidence. The questions should be relevant to the objectives of the support schemes. The European Commission considers three levels to classify the impact of public support:

– Direct impact (for example, impact on the activities of the beneficiaries, different effects according to the characteristics of beneficiaries such as size or industry),
– Indirect impact (for example, spillover effects of the support on the activity of other firms or on other regions, aggregate effects on competition and trade),
– Proportionality and appropriateness (for example, is the public support proportionate to the problem that is addressed? Could the same effects have been obtained with less support or different support schemes).

As pointed out by European Commission (2014), most evaluations address the direct impact as it is more straightforward to assess direct effects than the two other levels. Assessment of the direct impact is however also relevant for the other levels as it provides indications of indirect effects and possible distortions. If support does not appear to incentivize beneficiaries, it can be assumed to be distortive as it provides beneficiaries with windfall gains.

To avoid a selection bias in the evaluation, relevant differences between beneficiaries of public support and non-beneficiaries should be accounted for. The appropriate method to address the selection issue depends on the design of the support scheme but it should be recognized that all methods have limitations and are only valid under specific assumptions. European Commission (2014) rightly argues that a forthright recognition and discussion of these limitations and assumptions is crucial for the credibility of the evaluation. It further points out that if firms benefit from several support schemes, all relevant schemes should be controlled for.

The potential selection bias in public support to business R&D is explicitly acknowledged in this evaluation.

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[9] A more detailed discussion of the rationale of public support to business R&D and the advantage and limitations of subsidies and tax incentives to stimulate additional R&D activities is provided by Dumont (2012).

[10] Not all R&D tax incentives are considered as state aid as defined by Article 107(1) of the Treaty on the Functioning of the European Union. In principle state aid is prohibited unless it is compatible with the internal market, according to Articles 107(2) and 107(3) of the Treaty. In 2014 the European Commission presented its *Framework for State Aid for Research and Development and Innovation* which relaxes state aid rules for public support to R&D as the promotion of research, development and innovation is an important Union objective laid down in Article 179 of the Treaty and R&D is identified as a key driver for achieving the Europe 2020 strategy objectives of smart, sustainable and inclusive growth.

Recognizing the limitations of all procedures that try to tackle the selection issue, the results of several methods are reported. Conclusions emphasize results that are robust across different estimations. Given the need to control for all relevant forms of public support, in addition to all tax incentives, the substantial direct support (subsidies) provided by regions is included in all estimations, turning to good account the detailed information contained in the R&D Policy Mix database.

Given the rationale of the R&D tax incentives that were introduced by the federal government, the main research question of this evaluation concerns *input additionality*:

> **How much additional R&D expenditures result from the tax incentives provided by the federal government?**

Complementary assessment considers *behavioural additionality*, the potential impact of tax incentives on the characteristics of R&D activities (for example, share of R&D expenditures that target basic or applied research or experimental development) and *output additionality*, the impact of tax incentives on the output of firms (for example, effects on profits or productivity).

The major difficulty in assessing the efficiency of public support is establishing its causal impact. Private companies decide autonomously how much they will spend on R&D activities and whether to apply for public support. As such it is not straightforward to assess whether public support stimulates additional R&D or rather subsidizes R&D activities that firms would carry out anyway. [11]

This paper does not consider a more comprehensive evaluation of tax incentives such as a cost benefit analysis which would include a calculation of spillovers, administration cost, compliance costs and opportunity costs or a general equilibrium analysis (see Mohnen 2017).

[11] A more detailed description of difficulties in establishing causal effects and technical details on the different estimation procedures can be found in Dumont (2015).

3. Data

This chapter provides a description of the data that are used for the evaluation of the federal R&D tax benefits and some descriptive statistics on the use and combination of the different schemes of public support for business R&D.

3.1. R&D Policy Mix database

As for the two previous evaluations (Dumont 2013, 2015), the data used in this evaluation are provided by the R&D Policy Mix database, created by the Federal Public Service Finance. In the database, information from the Belgian biennial R&D survey, provided by the Federal Science Policy Office, is linked to data on the direct support (subsidies) for R&D and innovation provided by the regions and data on the tax incentives granted by the federal government (partial exemption from advance payment of the withholding tax for R&D personnel; tax credit for investment in R&D and the deduction of 80% of qualifying gross patent income). The database also contains information, from the National Social Security Office, on innovation premiums granted by companies to employees who have created added value by innovation. The innovation premium consists in an exemption from personal income tax as well as exemption from social security contributions. The Federal Public Service Economy provides data on the number of patents granted by the Belgian Office for Intellectual Property. The data are matched with information from annual accounts (for example, value added, firm age and number of employees). The first evaluation covered the period 2001-2009 and the second evaluation the period 2003-2011. This evaluation considers four additional years, 2012-2015. As such the evaluation does not consider the two most recent changes in federal tax incentives to business R&D: the tax deduction for innovation income, introduced in 2016, and the partial exemption from payment of the withholding tax for R&D personnel with a bachelor’s degree in qualifying study fields, which is provided since January 2018.

The R&D Policy Mix database contains information on the total amount of support received by individual firms, through direct support (subsidies) as well as through indirect support (tax incentives). This permits to link the amount of support received by firms to their level of R&D expenditures without the need to be confined to binary variables for public support (firm receives support or not) as appears to be the case for most other countries. It also allows to assess individual schemes while controlling for other relevant channels of support to business R&D.

In view of the categorization of innovation policy instruments by Borrás and Edquist (2013), the scope of the policy mix considered in this evaluation is however limited. They consider three categories of instruments:

1. Regulatory instruments (for example, intellectual property rights and competition policy),
2. Economic and financial instruments,
3. Soft instruments (for example, recommendations or voluntary technical standards),

and four categories that instruments can target:

1. Provision of knowledge inputs to the innovation process,
2. Demand-side activities (for example, creating new product markets),
3. Provision of constituents for innovation systems (for example, creation of innovation networks),
4. Support services for innovating firms (for example, incubator activities).

The evaluation reported in this paper only considers the impact of financial instruments (2nd category of instruments) on the provision of knowledge inputs (1st category of innovation activities). A systemic assessment of the complementarity between all existing instruments of innovation policy in Belgium is clearly warranted but beyond the scope of this paper.

By including the total amount of direct support received by firms as a single variable, the evaluation furthermore does not assess the substantial mix of policy instruments provided by the three regions in support of R&D and innovation. The direct support variable is included as it is necessary to control for all relevant support schemes but the estimates of the efficiency of direct support should be considered with caution as they do not reflect the diversity of policy instruments within and between regions. The focus in this evaluation is on the efficiency of the tax incentives provided by the federal government.

3.2. Descriptive statistics

Table 1 shows the average and median amount of support for regional subsidies and the different R&D tax incentives for firms, in 2015. As shown in graph 3, the tax deduction for R&D investment has a relatively low budgetary impact. According to official data the budgetary cost for 2014 was 40 million euro. With 500 firms benefitting from this deduction, this implies an average amount of 80,109 euro per firm. Data on the tax deduction for R&D investment is not available for the years 2013 up to 2015. Most analyses and estimations in this evaluation will only consider the support schemes for which data is available for the entire period up to 2015. As table 1 shows, the average and median amount of support in 2012, the most recent year available for this tax incentive in the Policy Mix database, are rather low, in line with the official data for 2015.

The substantial difference between the average and the median amount of support reveals the skewness of support, in line with the strong skewness of R&D expenditures as shown in table 2. The partial exemption for R&D employees with a master's degree is by far the most popular tax incentive, with 1,641 firms benefitting from this support scheme in 2015.[12] Firms can only benefit from the tax credit if there are enough profits after all applicable tax deductions. If the amount of the tax credit exceeds profits firms can only benefit from the tax credit to the extent of the profits. As mentioned in the introduction, the part of the R&D tax credit that is not used after five years, is refunded.

[12] The total amount of public support and the number of firms benefitting from the different schemes do not fully match the official statistics reported in chapter 2 as the R&D Policy Mix database does not contain all beneficiaries and tax benefits are fully attributed to the year of R&D activities to which they apply. The descriptive statistics reported in this section are indicative and should not be considered as official statistics.

Table 1 Average and median amount of public R&D support and number of firms benefitting in 2015
In euro

	Average	Median	Number of firms
Regional subsidy	134548	50000	1094
Research cooperation	65038	19966	216
Young Innovative Company	34171	17931	326
PhDs and civil engineers	217183	35503	922
Master	146075	35582	1641
Tax credit R&D investment	2632834	41356	322
Tax deduction R&D investment (2012)	36006	1518	270
Tax deduction 80% patent income	1185966	63226	398

Note: The second column shows the average amount of public support for companies that benefitted from the given instrument in 2015. The third column shows the median amount of public support and the final column the number of firms that benefitted from the support.

The gap between the average and the median amount is very large for the tax credit and the tax deduction of 80% of patent income. These two tax incentives are more skewed than the other schemes of public support, as can also be seen in table 2, which shows the share in R&D expenditures and public support in 2015, by quartile (each of four equal groups into which the population of firms can be divided according to a given criterion, in this case the level of R&D expenditures or the amount of public support).

Table 2 Share of each quartile in R&D expenditures and public support for R&D in 2015
In %

	First quartile	Second quartile	Third quartile	Fourth quartile
R&D expenditures	0	1	4	94
Regional subsidy	2	7	14	77
Research cooperation	1	5	13	81
Young Innovative Company	3	9	19	68
PhDs and civil engineers	1	3	7	89
Master	1	4	11	84
Tax credit R&D	0	0	1	99
Tax deduction 80% patent income	0	1	3	96

Note: The second up to the fifth column show the share of the first up to the fourth quartile in total R&D expenditures or the total amount of subsidies or tax benefits received by firms in 2015. The first (fourth) quartile groups the quarter of the firms with the lowest (highest) R&D expenditures or amount pf public support received.

Table 3 shows the evolution, between 2008 and 2015, of the concentration of R&D expenditures and public support in the top 25% (fourth quartile). Regional subsidies appear to have become a bit more skewed towards the top 25%, with the share of the fourth quartile rising from 71% in 2008 to 77% in 2015. However, except for the partial exemption for Young Innovative Companies, regional subsidies are still less skewed than the tax benefits. The tax credit and the tax deduction for 80% of patent income are highly skewed, even more so than R&D expenditures. Despite the increasing number of firms that benefit from the R&D tax credit, this tax incentive has become even more skewed over time, with the share of the fourth quartile rising from 92% to 99% in 2015.

Table 3 Evolution of the fourth quartile in R&D expenditures and public support for R&D (2008-2015)
In %

	2008	2009	2010	2011	2012	2013	2014	2015
R&D expenditures	95	95	96	95	95	95	95	94
Regional subsidy	71	68	68	74	76	79	79	77
Research cooperation	87	87	86	85	85	81	80	81
Young Innovative Company	69	69	72	72	72	71	69	68
PhDs and civil engineers	86	87	88	88	89	89	89	89
Master	86	87	86	84	85	85	84	84
Tax credit R&D	92	89	95	95	97	96	99	99
Tax deduction 80% patent income	96	99	97	96	97	98	98	96

Note: The table shows the evolution, from 2008 to 2015, of the share of the fourth quartile in total R&D expenditures and the share of the fourth quartile in the total amount of subsidies or tax benefits received by firms.

The use of the support schemes differs across industries. This is shown in table 4 which provides the top ten industries in terms of their share (in %) in total R&D expenditures and the total amount of support provided for each individual support scheme. The share in public support denotes the share in the sum of support received by firms that reported R&D expenditures in the 2016 R&D survey and therefore not the share in total support for that specific scheme. The two-digit NACE code of industries is shown in brackets (a list of all two-digit codes with a full description is provided in Annex 1).

Table 4 The ten industries with the highest share in total R&D expenditures and public support for R&D (2015)
In % (two-digit NACE code in brackets)

	1	2	3	4	5	6	7	8	9	10
R&D expenditures	20.9	11.2	8.5	6.6	5.9	5.8	5.1	4.3	4.0	3.1
	(21)	(72)	(62)	(46)	(20)	(70)	(71)	(26)	(28)	(77)
Regional subsidy	14.8	14.2	8.4	7.3	6.9	6.7	6.3	5.5	3.3	3.0
	(62)	(72)	(26)	(71)	(28)	(21)	(46)	(70)	(38)	(20)
Research cooperation	16.4	14.2	11.7	11.6	9.1	7.0	6.4	5.4	4.3	2.3
	(30)	(70)	(62)	(72)	(71)	(20)	(77)	46)	(24)	(26)
Young Innovative Company	37.2	13.6	12.8	11.0	3.2	3.1	2.7	1.8	1.8	1.7
	(62)	(71)	(72)	(26)	(73)	(70)	(30)	(69)	(46)	(58)
PhDs and civil engineers	25.0	11.0	9.8	7.8	7.3	5.5	4.7	4.6	4.6	3.5
	(21)	(72)	(62)	(70)	(20)	(46)	(77)	(26)	(71)	(28)
Master	9.7	9.6	9.0	8.1	7.3	7.1	6.3	5.1	4.9	4.3
	(72)	(62)	(71)	(46)	(45)	(26)	(21)	(70)	(28)	(20)
Tax credit R&D	46.5	22.6	7.2	5.4	5.0	3.9	3.4	1.4	1.4	0.9
	(21)	(77)	(72)	(62)	(46)	(20)	(26)	(24)	(71)	(23)
Tax deduction 80% patent income	67.4	9.7	6.6	2.1	1.8	1.7	1.4	1.3	1.2	1.0
	(21)	(28)	(30)	(72)	(26)	(10)	(29)	(71)	(46)	(27)

Note: The table shows the share, in 2015, in total R&D expenditures and the amount of support received for each individual support scheme, for industries ranked from first (1) to tenth (10). Shares are denoted in % and the two-digit NACE code is provided in brackets. A description of all industries by two-digit NACE code is provided in Annex 1. The shares in public support denote the share in the sum of support of firms that reported R&D expenditures in the 2016 R&D Survey.

The three industries with the highest share in R&D expenditures, Manufacture of basic pharmaceutical products and pharmaceutical preparations (21), Scientific research and development (72) and Computer programming, consultancy and related activities (62) unsurprisingly also have high shares in public support. Scientific research and development and Computer programming, consultancy and related activities have a relatively high share in direct support (regional subsidies) whereas firms in Manufacture of basic pharmaceutical products and pharmaceutical preparations clearly are by far the main beneficiaries of the R&D tax credit and even more so of the tax deduction of 80% of patent income, with a share of 67.4%.[13] The partial exemption for Young Innovative Companies is mainly used by market service industries such as Computer programming, consultancy and related activities (62), Architectural and engineering activities; technical testing and analysis (71) and Scientific research and development (72). With a share in total R&D expenditures of 2.4% (ranked 11th), Manufacture of other transport equipment (30) is the industry with the highest share in the partial exemption of the withholding tax for research cooperation and holds the third position for the tax deduction of 80% of patent income. Rental and leasing activities (77), with a share of 3.1% in total R&D expenditures has a share of 22.6% of support provided through the R&D tax credit.

For the evaluation of the efficiency of R&D tax incentives, data on the R&D expenditures of firms is required. In the R&D Policy Mix database this information is provided through the R&D surveys which are carried out every even year. Based on the information from the survey carried out in 2016, table 5 shows to what extent the amount of public support for R&D received by firms in 2015 can be matched with information on their R&D expenditures. For about half of the firms that received a subsidy or a tax benefit in 2015, information on R&D expenditures is available, except for the tax credit and the tax deduction of 80% of patent income for which this share is much lower.

Table 5 Responses of firms with public support as to R&D expenditures in 2015 (2016 R&D Survey)

	Performed R&D	Did not perform R&D	No response	Not in list R&D firms
Regional subsidy	484 (44%) [66%]	78 (7%)	336 (31%)	196 (18%)
Research cooperation	110 (51%) [71%]	13 (6%)	72 (33%)	21 (10%)
Young Innovative Company	160 (49%) [49%]	8 (2%)	101 (31%)	57 (17%)
PhDs and civil engineers	480 (52%) [70%]	34 (4%)	307 (33%)	101 (11%)
Master	801 (49%) [63%]	84 (5%)	567 (35%)	189 (12%)
Tax credit R&D	162 (50%) [84%]	11 (3%)	76 (24%)	73 (23%)
Tax deduction 80% patent income	147 (37%) [65%]	16 (4%)	98 (25%)	137 (34%)

Note: The table shows the response in the 2016 R&D Survey, of firms that received public support for R&D in 2015, on the question whether they performed R&D in 2015 (second column) or not (third column). The fourth column shows the number of firms that received support but did not respond to the survey and the final column shows the number of firms that are not included in the list of firms to which the R&D survey is sent. The numbers in round brackets denote the share of each of the four groups in the total number of firms that received support through that specific scheme. The numbers in square brackets, in the second column, denote the share of firms that reported to have perform R&D in 2015, in the total amount of support for that specific scheme.

The firms which received support and reported R&D expenditures in 2015 account for a disproportionate share in the total amount of public support as can be seen by comparing the numbers in square brackets to the number in round brackets in the second column of table 5. As only those firms that report R&D expenditures are considered for estimation the numbers show that for each scheme, except for the partial exemption for Young Innovative Companies, firms that account for 63% of support, or more, are included in the estimations.

Some firms, though relatively few, that received tax incentives in support of R&D in 2015 responded not to have had any R&D expenditures in that year. A larger share of firms with support did not respond to the 2016 R&D survey. Finally, for each support scheme there are some firms that do not appear on

[13] As pointed out before the share denotes the share in support received by firms that reported R&D expenditures in the 2016 R&D Survey and therefore not the share in the sum of support received by all firms, respective of their response to the R&D survey.

the list of firms to which the R&D survey is sent. Especially for the tax credit and the tax deduction of 80% of patent income the share of these firms is relatively high.

Table 6 considers firms that did respond to the R&D survey and reported R&D expenditures for a given year, over the period 2008-2015, and shows the share of these R&D active firms that benefitted from support in the same year. The share of R&D active firms that benefit from the partial exemption for R&D employees with a master's degree increased from 13% to 36%.

Table 6 Evolution in the share of R&D active firms that receive public support
In %

	2008	2009	2010	2011	2012	2013	2014	2015
Regional subsidy	18	19	16	22	17	18	20	22
Research cooperation	7	6	7	7	4	5	5	5
Young Innovative Company	5	5	6	6	6	7	7	7
PhDs and civil engineers	18	21	22	20	20	22	19	21
Master	13	17	22	24	25	30	29	36
Tax credit R&D	2	3	3	4	4	5	6	6
Tax deduction 80% patent income	2	2	4	4	4	5	5	7

Note: The table shows the share of firms that report R&D expenditures in the R&D survey, that received support for R&D through one of the schemes. Due to some corrections in the data on regional subsidies the share for 2011 is slightly smaller than that reported in the report of the second evaluation (Dumont 2015: Table 4 on page 18).

In relative terms, there was also a strong increase in the share of R&D active firms that benefit from a tax credit or a tax deduction of 80% of patent income. The most surprising takeaway from table 6, however, is that even in 2015 only a minority of R&D active firms use the tax benefits in support of R&D that were introduced between 2005 and 2008.[14] In 2015, 52% of R&D active firms used at least one of the available R&D tax incentives, up from 29% in 2008.

The use of public support, subsidies as well as tax benefits, clearly increases with the level of R&D expenditures. Table 7 shows the share of firms within each of the four quartiles of R&D expenditures – first quartile being the bottom 25% of R&D active firms and the fourth quartile the top 25% of R&D active firms – that used a given support scheme in 2015.

Of the top 25% of R&D active firms in 2015, 61% benefitted from the partial exemption of the withholding tax for R&D employees with a master's degree. This still implies that 39% of the firms with the highest R&D expenditures do not use this support scheme. For the other schemes the shares of the fourth R&D quartile are even lower.

[14] In 2012, the last year with information on this support scheme, 5.76% of R&D active firms benefitted from the tax deduction for R&D investment.

Table 7 **Share of R&D active firms that receive public support by quartile of R&D expenditures in 2015**
In %

	First R&D quartile	Second R&D quartile	Third R&D quartile	Fourth R&D quartile
Regional subsidy	7	18	24	27
Research cooperation	2	3	5	8
Young Innovative Company	2	6	9	8
PhDs and civil engineers	5	6	17	44
Master	10	23	33	61
Tax credit R&D	1	3	7	18
Tax deduction 80% patent income	2	4	5	12

Note: The table shows the share of firms that report R&D expenditures for 2015, in the 2016 R&D survey, that received support for R&D through one of the schemes, for each of the four quartiles of R&D expenditures. (First quartile: bottom 25% R&D active firms up to forth quartile: top 25% of R&D active firms). As the quartiles are not evenly distributed, the unweighted average over the four quartiles does not necessarily equal the share for 2015 reported in the last column of table 6.

The extent to which firms combine different schemes of public support for R&D is shown in table 8.

Of firms that received direct support in 2015, through regional subsidies, 34% only received direct support and did not use any tax incentive. One percent of the firms with direct support in 2015 combined this with the partial exemption for research cooperation, for Young Innovative Companies and two percent for R&D employees with a PhD or civil engineering degree, respectively but not with another tax incentive.

Table 8 **Policy mix: combinations of public support for R&D in 2015**
In %

	Regional subsidy	Research coopera-tion	YIC	PhDs and civil engi-neers	Master	Tax credit R&D	Tax deduction 80% patent income
Single use	34	33	34	18	36	7	18
Combined with one other instrument:							
Subsidy		5	4	2	4	9	13
Research cooperation	1		0	0	0	1	1
Young Innovative Company	1	0		0	1	2	2
PhDs and civil engineers	2	1	1		5	2	2
Master	7	0	4	8		5	15
Tax credit R&D	0	0	1	0	0		0
Tax deduction 80% patent income	0	0	0	0	0	0	
Combined with more than one support scheme	54	61	56	70	54	74	50

Note: The table shows the share of firms that received, in 2015, only one of the given forms of public support (single use), combine it with one of the other benefits (second up to seventh line) or combine it with at least two other benefits (last line).

Of firms that received subsidies in 2015, 7% combined this direct support with the partial exemption for R&D employees with a master's degree but no other tax incentive. Finally, 54% combined direct support with at least two tax incentives. For firms that benefitted from a R&D tax incentive in 2015, the share that combined this incentive with at least two other support schemes is even more substantial. For example, of firms that used the partial exemption for R&D employees with a PhD or civil engineer degree in 2015, 70% combined this tax incentive with at least two other support schemes. For firms that used the tax credit for R&D investment, 74% combined this with at least two other support schemes. The fact that firms tend to combine different schemes of public support to R&D needs to be acknowledged in the estimation of the extent to which individual support schemes succeed in stimulating additional R&D activities.

Table 9 reports the average and median of some firm characteristics for firms that use a given support scheme and firms that did not receive any support for R&D in 2015.

Firms that benefit from specific support schemes appear to be distinct in terms of some variables. Firms that use tax incentives have, on average, a much higher level of R&D expenditures and R&D intensity. They are generally also larger and older than firms that do not receive support or that receive direct support (subsidies).

Table 9 Descriptive statistics by support scheme (2015)

	No support		Subsidy		Exemption R&D cooperation		Exemption YIC	
	Average	Median	Average	Median	Average	Median	Average	Median
R&D expenditures	191	14	2760	112	8533	250	594	152
R&D/value added	6	0	29	8	36	12	37	21
Total public support	0	0	838	76	3419	75	168	45
Number of employees	107	26	225	44	322	59	62	44
Firm age	27	25	23	19	26	20	7	5
Capital/employee	85	30	71	35	52	31	92	50
Net profitability	20	14	18	13	18	10	27	23
Financial independence	36	35	40	39	38	36	36	40
Long term debt rate	20	14	20	14	21	17	22	15
	Exemption PhDs and civil engineers		Exemption Master's degree		Tax credit R&D investment		Tax deduction 80% patent income	
	Average	Median	Average	Median	Average	Median	Average	Median
R&D expenditures	5217	552	2737	278	8991	821	9243	465
R&D/value added	27	10	22	6	22	4	5	2
Total public support	1787	128	768	76	4716	239	3134	134
Number of employees	350	95	250	80	861	180	514	72
Firm age	30	26	28	25	23	13	29	26
Capital/employee	121	31	74	31	73	36	53	32
Net profitability	17	14	18	13	-7	5	31	23
Financial independence	44	42	41	40	42	19	46	45
Long term debt rate	20	13	19	11	22	17	16	11

Note: R&D expenditures, total public support and capital per employee are denoted in 1000 euro. All other variables are expressed in % except number of employees and firm age.

Except for Young Innovative Companies and firms that benefit from the tax deduction of 80% of patent income, firms with public support for R&D are however not more profitable, on average, than firms that do not receive any support. They generally have a higher financial independence. The difference in long-term debt rate is not large except for firms that use the tax deduction of 80% of patent income, which on average have a lower debt rate. The group of firms that benefit from the R&D tax credit stands out from the rest in terms of low profitability and a large difference between the average and median of R&D expenditures and total public support.

Firms using the patent box appear to have the highest financial independence, which could be explained by the combination of the notional interest deduction and the tax deduction for patent income.[15]

[15] The combination of the two provisions allows companies to exempt, from taxable profits eligible to the tax deduction for patent income, up to five times the rate of the notional interest deduction. The notional interest is a fictitious interest calculated on the equity (net assets) of a company. The deduction aims at reducing tax discrimination between debt financing and equity financing and thereby stimulates a higher share of assets on the balance sheet of companies.

4. Estimation methodology

The tax incentives that were introduced between 2005 and 2007 aim at raising investment in R&D in Belgium. This can be achieved by encouraging R&D active firms to consider additional R&D activities (the intensive margin of R&D) or to spur firms that are not active in R&D to start doing R&D (the extensive margin of R&D).[16]

The baseline specification used in this paper to estimate the impact of tax incentives on business R&D is a regression of R&D expenditures on the amount of support received by firms through the different schemes of public support:

$$ln(RD_{it}) = \alpha_0 + \beta^{reg}\, ln\left(X_{it}^{reg}\right) + \beta^{coop}\, ln\left(X_{it}^{coop}\right) + \beta^{YIC}\, ln(X_{it}^{YIC}) + \beta^{PhD}\, ln(X_{it}^{PhD}) + \beta^{Master}\, ln(X_{it}^{Master}) + \beta^{Credit}\, ln\left(X_{it}^{Credit}\right) + \beta^{Patent}\, ln(X_{it}^{Patent}) + \varepsilon_{it} \quad (1)$$

Dependent variable:

RD_{it} : internal R&D expenditures (excluding the total amount of public support) of company *i* in year *t*

Explanatory variables (public support for R&D):

X_{it}^{reg} : total amount of regional subsidies received

X_{it}^{coop} : total amount saved through partial exemption of the withholding tax on the wages of researchers cooperating with a university, college or a scientific institution

X_{it}^{YIC} : total amount saved through partial exemption of the withholding tax on the wages of R&D personnel in Young Innovative Companies (YIC)

X_{it}^{PhD} : total amount saved through partial exemption of the withholding tax on the wages of researchers with a PhD degree in exact or applied sciences, doctor degree in (veterinary) medicine or a civil engineering degree

X_{it}^{Master} : total amount saved through partial exemption of the withholding tax on the wages of researchers with a master's degree (excluding social or human sciences)

X_{it}^{Credit} : total amount saved through the tax credit for R&D investment

X_{it}^{Patent} : total amount saved through the tax deduction of 80% of qualifying gross patent income

[16] The R&D intensity of a country, R&D expenditures relative to GDP, can increase because R&D active firms increase their R&D intensity, because firms without R&D activities start doing R&D but also through reallocation, for example when R&D active companies increase their share in total value added relative to firms without R&D activities.

ε_{it}: error term (assumed to be randomly distributed with an expected value of 0 and a constant variance)[17]

Given the highly skewed distribution of R&D expenditures and public support (as shown in table 2 and 3) all variables are considered in logarithm, increasing the likelihood of the assumption that errors ε_{it} are normally distributed. The dependent variable in the baseline specification is total R&D expenditures reported by a company minus the total amount of public support for R&D received by the company, following David, Hall and Toole (2000), Clausen (2008), Cerulli (2010) and Zúñiga-Vicente et al. (2014). Only real responses of firms in the R&D survey as to their R&D expenditures are considered and only firms with non-zero R&D expenditures are included in estimations. Estimation of the impact of public support therefore relies on the fact that not all R&D active firms receive public support, as well as on variation in the amount of direct or tax support received by firms with R&D activities.

Although the focus of this evaluation is on federal tax incentives, the total amount of direct support for R&D received by firms is also included in the econometric specification. In Belgium, regional agencies provide substantial direct support, mainly through subsidies, for R&D and innovation activities of companies. An unbiased estimation of the efficiency of tax incentives therefore requires the inclusion of the direct support received by firms. The inclusion of the total amount of direct support arguably gives short shrift to the policy mix of regional agencies as it does not account for the diversity of the regional subsidy programmes and differences between the three regions. The direct support variable should be seen more as a control variable in the estimation of the efficiency of the federal tax incentives than as a variable reflecting the efficiency of regional subsidies, which is beyond the scope of this evaluation.

The estimation includes control variables that denote characteristics that may affect the R&D investment decisions of firms such as value added, the number of employees, firm age and capital intensity. In addition, region, industry and year dummies are included. Time-varying industry-specific characteristics are considered by including industry-year dummies, following Aghion et al. (2012) and Einiö (2014).[18]

The assessment of the efficiency of public support is complicated by the fact that firms decide autonomously how much they invest in R&D but also whether to apply for direct or indirect support. Firm-level subsidies are awarded through competitive procedures, based on the assessment of project proposals, by regional agencies. The granting of subsidies is subject to selection by agencies and self-selection by companies. Although all R&D active firms are eligible to benefit from most tax incentives in Belgium[19], only a minority of R&D active firms appears to apply for indirect support, as shown in table 6. This indicates that there is also self-selection in the application for tax incentives. If the selection by agencies that award subsidies and the autonomy of firms to decide how much to invest in R&D and whether to apply for tax incentives, are not accounted for, estimates of the impact of public support to business R&D are likely to be biased. Different estimation procedures exist to address the selection bias

[17] A traditional regression (Ordinary Least Squares, OLS) will only provide unbiased estimates if the assumptions regarding the error term (sometimes labelled as disturbance or residual term) hold. With real observational data, the strong assumptions (e.g., homoscedasticity and no serial correlation) are often violated. Procedures that relax the assumptions need to be considered to account for the possible bias in the estimates.

[18] It is not possible to include all dummies in all estimations, due to multicollinearity.

[19] There is an obvious age condition (see footnote 1 on page 10) for the partial exemption for Young Innovative Companies.

and endogeneity in the assessment of the impact of public support. As pointed out by European Commission (2014) it is necessary to acknowledge that all methods have limitations and are only valid if certain assumptions hold. As in the previous evaluation, the estimation strategy adopted in this paper is to start from a panel (fixed effects) estimation, which accounts for unobserved time-invariant firm heterogeneity, and to compare these results with the estimates from other procedures to assess whether robust conclusions can be obtained (in line with the recommendations by European Commission 2014 and Zúñiga-Vicente et al. 2014). In addition to the results from fixed effects panel estimation, the next chapter reports the results of a selection model, instrumental variables and dynamic panel estimation. Details of the advantage and limitations of these different estimation procedures can be found in Dumont (2015).

5. Results

This chapter reports the results of panel (fixed effects) estimation of the impact of the federal tax incentives on R&D expenditures of companies. These results are compared to estimates from other procedures that address the issue of selection and endogeneity that complicates the estimation of the causal impact of public support to business R&D. Section 5.1 considers the input additionality of public support, in effect, the extent to which support raises R&D expenditures of companies. In section 5.2 results are reported on behavioural additionality, for example the impact of public support on the orientation of R&D activities (share of basic and applied research and experimental development). Section 5.3 considers the potential impact of support on output (productivity, profitability and patents).

5.1. Input additionality

5.1.1. Baseline estimation: fixed effects

Table 10 reports the results of fixed effects estimation of specification (1), as shown in chapter 4. A fixed effects estimation is an Ordinary Least Squares (OLS) estimation in which firm-specific dummies are included that are constant over time.[20] In the context of public support to business R&D, fixed effects capture unobserved firm characteristics that influence the firm's R&D activities and its demand for public support, such as R&D experience, experience with the application for public support and firm-specific technological capabilities and opportunities (Lichtenberg 1984, Henningsen et al. 2015).

Specification (1) on p.27 considers all variables in logs. A logarithmic transformation increases the likelihood of the assumption that errors are normally distributed. However, in order to keep all observations for which the amount of support received by firms is zero[21], ln(x+1) is considered instead of ln(x) so that the logarithm is also defined for zero values, following Lehto (2007). This transformation may however provide biased estimates, for example, due to heteroskedasticity as pointed out by Santos Silva and Tenreyro (2006). An alternative that permits to keep zero-valued observations is the Inverse Hyperbolic Sine (IHS) transformation: $\ln(x + \sqrt{x^2 + 1})$. Bellemare and Wichman (2018) discuss the interpretation of the coefficients from estimations with IHS transformation, which are not elasticities as is the case in a log-log specification although for large positive values, the IHS transformation can be treated like a natural logarithm transformation. The last column in table 10 reports the results of a fixed effects estimation in which variables have been IHS-transformed rather than through ln(x+1) as for the estimates reported in the other columns.[22]

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[20] A fixed effects estimator is often called a within estimator as fixed effects estimates can also be obtained by OLS on variables after within transformation (subtracting, from each variable (dependent and independent), the average for each firm). A robust Hausman test (RHAUSMAN Stata procedure) clearly rejects the null hypothesis of random effects. The results of a random effects estimation are therefore not reported.

[21] Given that only a minority of R&D active firms benefit from subsidies or tax incentives, the variables denoting the amount of support received by firms each year are predominantly zero.

[22] IHS transformation permits to include negative values. Observations for which net R&D expenditures are negative, in effect those firms for which total public support received appears to exceed reported R&D expenditures, are not included in the HIS estimation.

Table 10 Results of fixed effects panel estimation (2003-2015)

	Log 1	Log 2	IHS
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Regional subsidy	0.09 (7.90) ***	0.09 (7.69) ***	0.09 (8.02) ***
Research cooperation	0.12 (4.58) ***	0.12 (4.34) ***	0.12 (4.58) ***
Young Innovative Company	0.12 (3.25) ***	0.14 (3.38) ***	0.12 (3.27) ***
PhDs and civil engineers	0.08 (4.76) ***	0.08 (4.44) ***	0.08 (4.78) ***
Master	0.14 (8.67) ***	0.14 (8.43) ***	0.14 (8.71) ***
Tax credit R&D	0.01 (0.24)	0.02 (0.71)	0.01 (0.27)
Tax deduction 80% patent income	-0.02 (-1.14)	-0.02 (-1.03)	-0.02 (-1.07)
Control variables:			
Value added	0.09 (1.03)	0.07 (0.79)	0.09 (1.00)
Number of employees	1.57 (8.57) ***	1.58 (8.39) ***	1.64 (8.48) ***
Age	-1.54 (-3.95) ***	-1.47 (-3.63) ***	-1.64 (-3.98) ***
Capital intensity	0.30 (3.17) ***	0.32 (3.41) ***	0.31 (3.14) ***
Industry (two-digit NACE)	Yes	No	Yes
Year dummies	Yes	No	Yes
Industry - year dummies	No	Yes	No
R-squared (within)	0.06	0.12	0.06
Number of observations	16,280	16,280	16,280

Note: The table shows the results of fixed effects estimation of specification (1) on p.27. All variables are considered in logs. Region dummies are dropped due to multicollinearity. IHS: Inverse Hyperbolic Sine (see text). *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

The second column in table 10 shows the results of a fixed effects estimation with two-digit industry dummies and year dummies. The results of a fixed effects estimation with industry-year dummies are shown in the third column. The results of the three alternative panel estimations are very similar, in terms of the coefficient estimates as well as statistical significance. Considering industry-year dummies, instead of industry and year dummies, substantially increases explained variance with an R-squared of 0.12 compared to 0.6 for the estimations that include industry and year dummies. This indicates the important role of industry-year specific explanations of R&D activities. For all three alternative estimations, the coefficients of regional subsidies and the four schemes of partial exemption of the withholding tax are positive and statistically significant. The coefficient of the R&D tax credit is positive in all three estimations but very low and moreover not statistically significant.[23] The coefficient of the tax deduction of 80% of patent income is negative but not statistically significant in any of the three estimations.

Large and capital-intensive firms tend to spend more on R&D whereas the impact of firm age is negative.

Annex 2 compares the results of an estimation in which all support schemes are jointly considered in one estimation (as reported in table 10) to the results of estimations in which each scheme is considered separately, without accounting for support received through other schemes. Ignoring support received through other schemes clearly results in overestimation of the efficiency of individual support schemes.

[23] Greenland et al. (2016) discuss the actual meaning and common misinterpretation of statistical significance.

A panel estimation with net profitability, financial independence and the long-term-debt rate as additional control variables provides similar results but given many missing observations for these variables the number of observations drops considerably to 9,146. None of the three additional control variables is statistically significant. An estimation that allows for first-order autocorrelation provides similar results as in table 10. The results of these additional estimations are not reported but available upon request.

Table 11 shows the results of a fixed effects panel estimation in which the tax deduction for R&D investment and the amount of the innovation premium paid to employees is included in addition to the other support schemes (see section 3.1 for more details). For the tax deduction, the R&D Policy Mix database only contains information up to 2012. The total amount of the innovation premium is limited. The coefficient of the tax deduction for R&D is statistically significant and positive in all three specifications. The coefficient of the innovation premium is not statistically significant.

Table 11 Results of fixed effects panel estimation with additional variables for public support (2003-2015)

	Log 1	Log 2	IHS
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Regional subsidy	0.09 (6.88) ***	0.09 (6.93) ***	0.09 (7.28) ***
Research cooperation	0.11 (4.52) ***	0.11 (4.47) ***	0.11 (4.39) ***
Young Innovative Company	0.12 (2.69) ***	0.13 (2.96) ***	0.11 (2.49) **
PhDs and civil engineers	0.08 (4.70) ***	0.07 (4.52) ***	0.07 (4.18) ***
Master	0.14 (9.29) ***	0.14 (9.27) ***	0.14 (9.95) ***
Tax credit R&D	0.01 (0.55)	0.02 (0.91)	0.01 (0.56)
Tax deduction 80% patent income	-0.02 (-0.75)	-0.02 (-0.66)	-0.01 (-0.57)
Tax deduction R&D (available up to 2012)	0.09 (3.44) ***	0.08 (3.04) ***	0.07 (2.76) ***
Innovation premium	0.00 (0.01)	-0.00 (-0.06)	-0.01 (-0.38)
Control variables:			
Value added	0.09 (1.20)	0.06 (0.85)	-0.08 (-1.37)
Number of employees	1.56 (12.94) ***	1.57 (12.90) ***	1.73 (13.66) ***
Age	-1.56 (-5.95) ***	-1.49 (-5.60) ***	-1.47 (-6.29) ***
Capital intensity	0.30 (4.72) ***	0.32 (5.03) ***	0.29 (4.43) ***
Industry (two-digit NACE)	Yes	No	Yes
Year dummies	Yes	No	Yes
Industry - year dummies	No	Yes	No
R-squared (within)	0.06	0.12	0.06
Number of observations	16,266	16,266	16,266

Note: The table shows the results of a fixed effects estimation of specification (1) with two additional support schemes compared to table 10: the tax deduction for R&D investment, for which data are only available until 2012, and the innovation premium. All variables are considered in logs. IHS: Inverse Hyperbolic Sine (see text). *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

All variables used in the estimation that are expressed in euro are deflated using official Belgian deflators. Estimation with alternative OECD deflators, not reported, provides similar results. All estimations that are further reported in this paper use the official Belgian deflators.

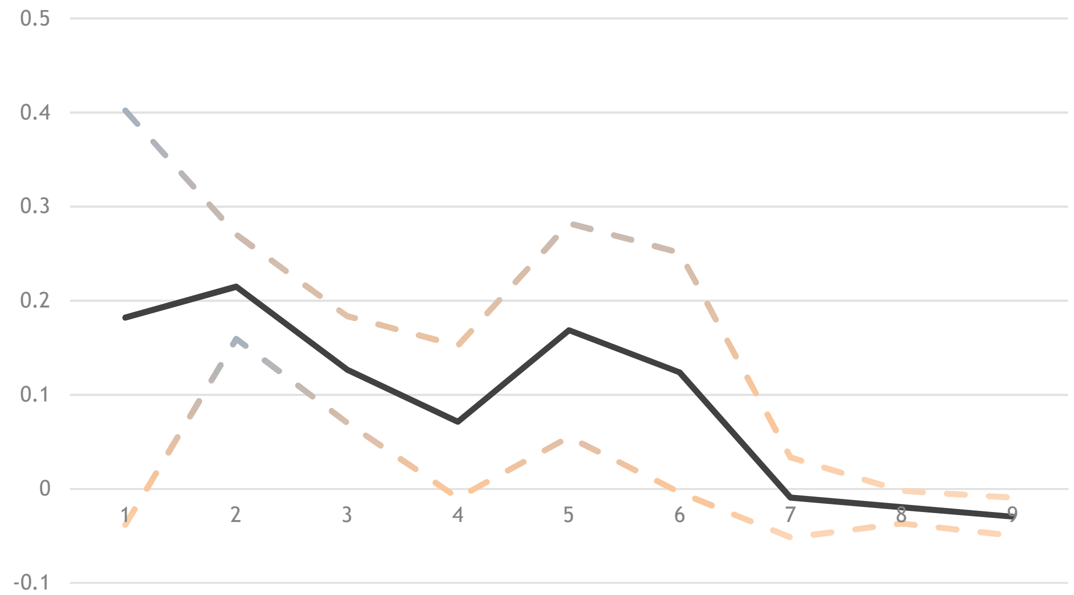
Estimations with total R&D expenditures (internal and external) provides similar results. When external R&D expenditures are considered, only the coefficients of regional subsidies and the partial exemption for research cooperation are positive and statistically significant.

The impact of public support on R&D expenditures may differ according to the level of support. To provide an indication of the potential non-linear impact of support, graph 6 up to graph 12 show estimates of the elasticity by decile[24] of the level of support, for regional subsidies and the different tax incentives. The first decile shows the elasticity at the 10% lowest level of support provided and the ninth decile the elasticity at the 10% highest level of support. The two dashed lines in each graph show the 95% confidence interval for the coefficient (elasticity) estimate. For the elasticity to be positive and statistically significant, the lower bound of the confidence interval should be positive or at least not far below zero.

Although the estimate of elasticity is not linked in a linear way with the absolute amount of support received by firms, for most support schemes the estimate tends to decline with the level of support and the lowest estimates are found at the higher deciles. This is especially the case for regional subsidies and to a lesser extent for the four schemes of partial exemption from payment of the withholding tax on the wages of R&D employees.

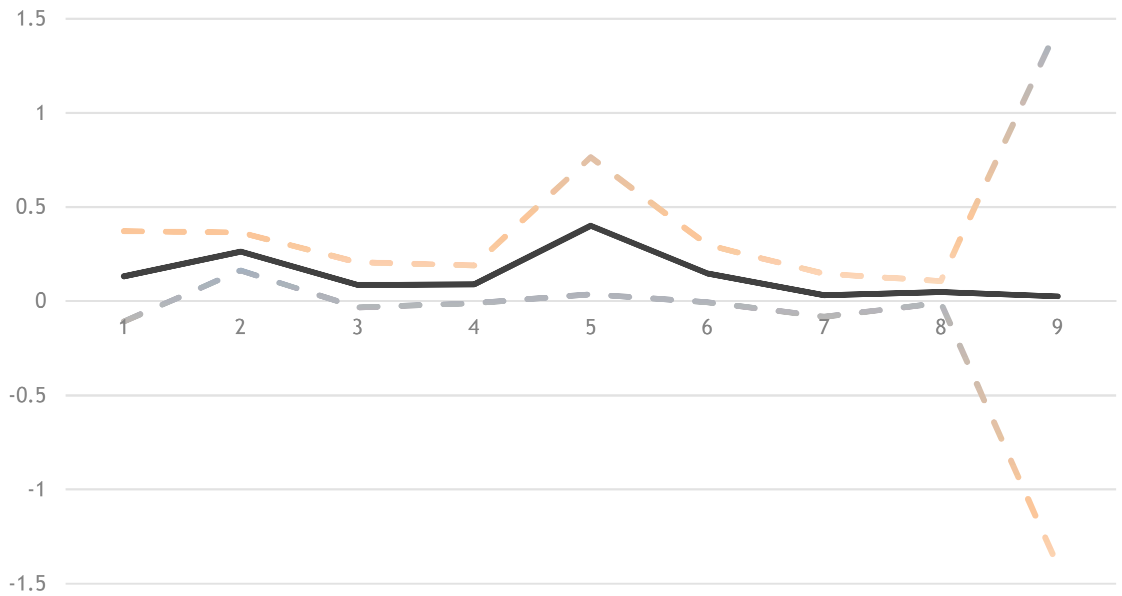
For the R&D tax credit the elasticity is lower for the first two deciles and reaches a maximum at the third and fourth decile. However, in line with the results reported in table 10, the coefficient is always close to zero and not statistically significant at any decile. Equally in line with the results in table 10, the coefficient of tax deduction of 80% of patent income is negative except at the ninth decile and not statistically significant at any decile.

Graph 6 Elasticity by decile of regional subsidies

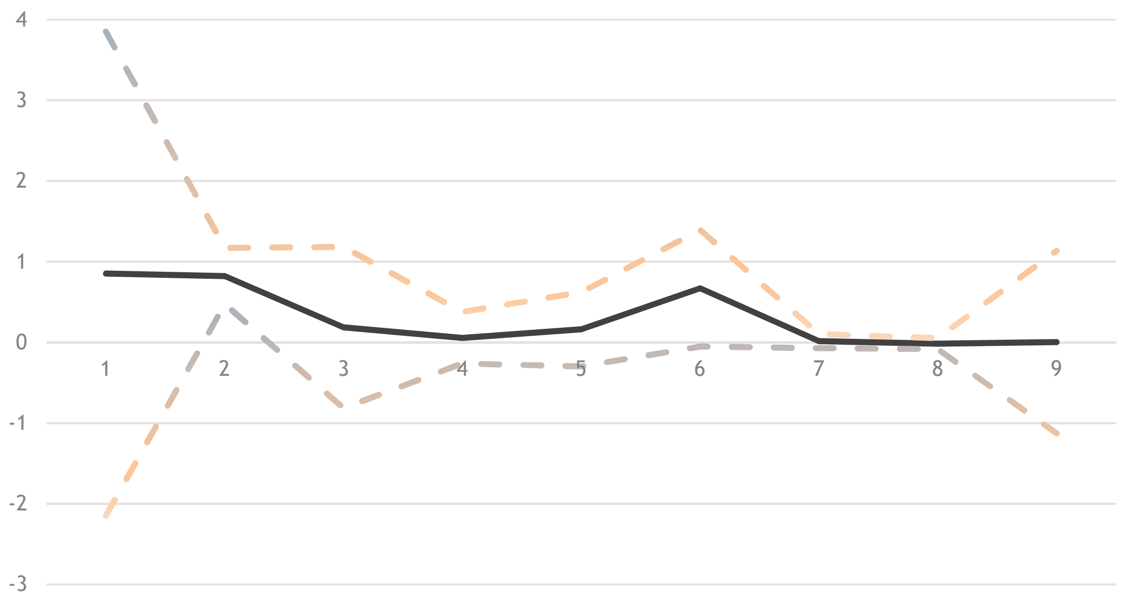


[24] A decile is any of the nine values that divide firms, ranked according to a given criterion, into ten equal parts.

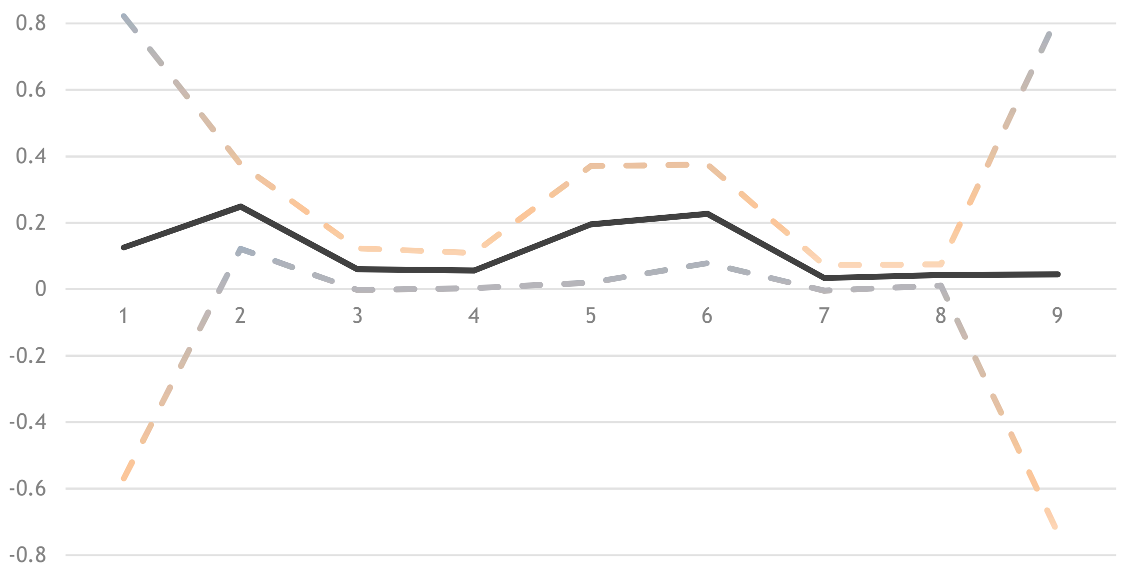
Graph 7 Elasticity by decile of partial exemption of the withholding tax for research cooperation



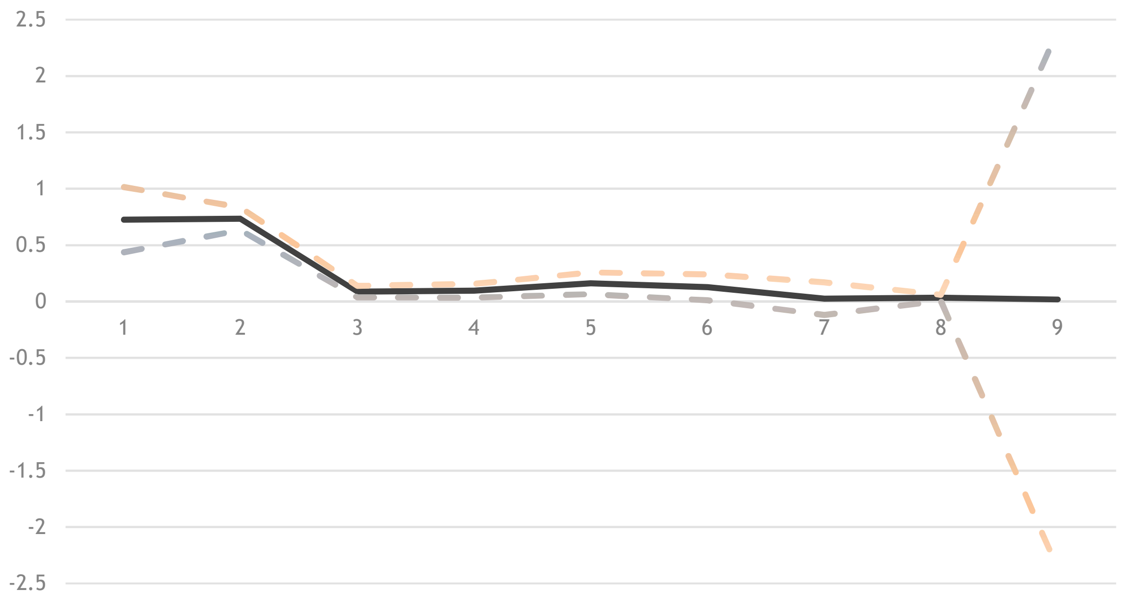
Graph 8 Elasticity by decile of partial exemption for Young Innovative Companies



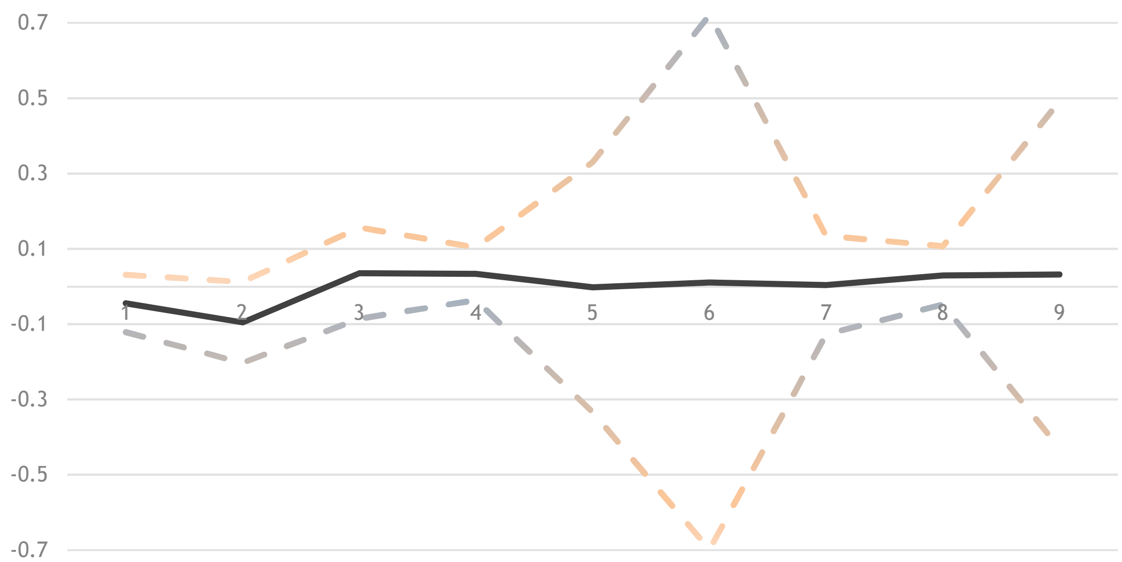
Graph 9 Elasticity by decile of partial exemption for PhDs and civil engineers



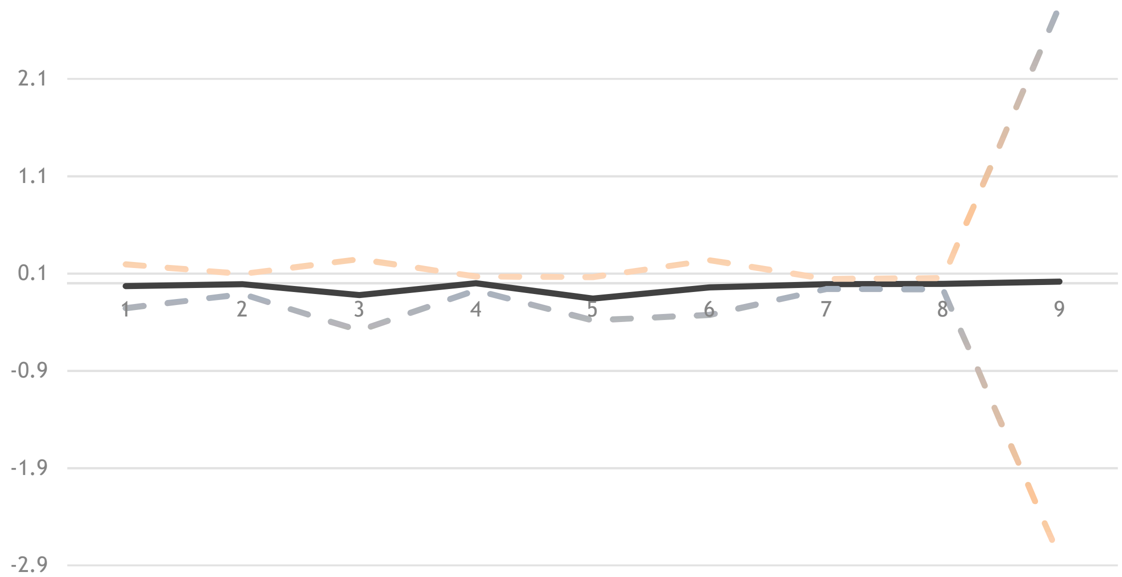
Graph 10 Elasticity by decile of partial exemption for R&D employees with a master's degree



Graph 11 Elasticity by decile of the R&D tax credit



Graph 12 Elasticity by decile of the tax deduction of 80% of patent income



The efficiency of public support is sometimes evaluated by considering the impact on R&D intensity rather than on the level of R&D expenditures. As the tax incentives introduced by the federal government aim at increasing R&D intensity (R&D expenditures in % of GDP) in Belgium, this may indeed seem the appropriate target. However, firms appear to aim at constant R&D intensity (see, for example, Cohen and Klepper 1996, Symeonidis 1996, Klette and Kortum 2004, Coad and Rao 2010) and as such R&D intensity may not be an appropriate target variable in firm-level estimations. Table 12 reports the results of fixed effects estimation in which four alternative dependent variables are considered: R&D intensity (R&D expenditures relative to value added), R&D expenditures per employee, the number of researchers and finally researchers as a share of total personnel.[25]

The results in table 12 are to a large extent in line with those reported in table 10, with some notable exceptions. For R&D intensity denoted as the ratio of R&D expenditures to value added[26] and for R&D expenditures per employee the sign is negative and statistically significant for regional subsidies. For the two other dependent variables the sign of regional subsidies is positive and statistically significant. The coefficient of the partial exemption of the withholding tax for R&D employees with a PhD or civil engineering degree is positive and statistically significant for three out of four estimations.

Table 12 Results of fixed effects panel estimation with alternative dependent variables (2003-2015)

Dependent variable:	$\frac{R\&D\ expenditures}{value\ added}$	$\frac{R\&D\ expenditures}{Number\ of\ employees}$	*Number of researchers (FTE)*	$\frac{R\&D\ personnel}{Number\ of\ employees}$
Explanatory variables:				
Regional subsidy	-0.02 (-4.40) ***	-0.02 (5.46) ***	0.01 (5.84) ***	0.01 (4.97) ***
Research cooperation	0.01 (0.85)	0.01 (1.58)	0.01 (1.77) *	0.01 (1.68) *
Young Innovative Company	0.01 (0.65)	-0.01 (-0.74)	0.02 (2.21) **	0.01 (1.10)
PhDs and civil engineers	0.01 (2.87) ***	0.00 (0.82)	0.01 (2.45) **	0.01 (1.85) *
Master	0.01 (1.36)	0.00 (1.16)	0.01 (3.33) ***	0.01 (3.06) ***
Tax credit R&D	0.00 (0.19)	0.00 (0.05)	0.00 (0.86)	0.01 (1.53)
Tax deduction 80% patent income	-0.01 (-1.42)	-0.01 (-0.91)	-0.00 (-0.70)	-0.01 (-1.38)
Control variables:				
Value added		-0.00 (-0.52)	0.02 (1.33)	-0.01 (-0.93)
Number of employees	0.32 (5.64) ***		0.53 (11.14) ***	
Age	-0.19 (-1.90) *	-0.28 (-3.28) ***	-0.03 (-0.42)	-0.25 (-3.87) ***
Capital intensity	0.05 (1.91) *	0.11 (3.95) ***	0.03 (1.80) *	0.06 (3.19) ***
R-squared (within)	0.34	0.09	0.18	0.12
Number of observations	13,003	13,003	13,326	13,326

Note: The table shows the results of fixed effects (within) panel estimation using alternative dependent variables. All variables are considered in logs except the dependent variable in the last estimation (column). As this variable is bounded between 0 and 1, a logistic transformation has been applied. Industry-year dummies are included in all estimations. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

Equally in line with the results in table 10, the coefficient of the R&D tax credit is not statistically significant in any of the four estimations and the impact of the tax deduction of 80% of patent income is negative but not statistically significant.

Goolsbee (1998) argued that part of the increase in R&D expenditures due to public support may be explained by an increase in the wages of researchers, if the supply of high-skilled workers is inelastic. His estimates for the U.S. suggest that estimates of the efficiency of R&D policy may be overestimated by 30 to 50% due to higher wages for researchers. Lokshin and Mohnen (2013) provide more recent evidence of an impact of public support on the wages of researchers in the Netherlands. Dumont,

[25] Lichtenberg (1984) argues that R&D employment may provide a better indicator of real R&D input than inaccurately deflated R&D expenditures.

[26] Using R&D expenditures relative to sales to denote R&D intensity provides similar results but as sales is not available for many small firms, the number of observations drops to 8,896. Results are available upon request.

Spithoven and Teirlinck (2016) show that accounting for changes in the composition of R&D personnel reduces the estimates of the impact of public support on the wages of researchers. Table 13 shows the results of fixed effects estimation in which the average wage of R&D employees is considered as the dependent variable. In the last column, the share of three educational categories of R&D employees are included in the estimation. The partial exemption for PhDs and civil engineers appears to have a statistically significant positive impact on the average wage of R&D employees but this result is not robust to inclusion of the share of PhDs in R&D employment.

Table 13 Results of panel estimation of the impact of public support on the average wage of R&D employees (2003-2015)

Dependent variable: average wage R&D employees		
Explanatory variables:		
Regional subsidy	0.00 (1.14)	0.01 (1.80)
Research cooperation	0.01 (1.20)	0.01 (1.18)
Young Innovative Company	-0.00 (-0.05)	-0.00 (-0.12)
PhDs and civil engineers	0.01 (2.09) **	0.01 (1.42)
Master	-0.00 (-0.91)	-0.01 (-1.49)
Tax credit R&D	0.00 (0.16)	0.00 (0.30)
Tax deduction 80% patent income	-0.00 (-0.72)	-0.00 (-0.05)
Control variables:		
Share PhD		0.34 (2.33) ***
Share University - Tertiary (2nd stage)		0.30 (2.81) ***
Share Tertiary (1st stage)		0.24 (2.18) ***
Value added	-0.00 (-0.06)	-0.01 (-0.84)
Number of employees	0.06 (1.18)	0.02 (0.31)
Age	0.07 (0.90)	0.09 (1.01)
Capital intensity	0.06 (2.28) **	0.08 (2.61) ***
R-squared (within)	0.23	0.07
Number of observations	5,326	4,023

Note: The table shows the results of fixed effects (within) panel estimation using the average wage of R&D employees as dependent variable. Region and industry-year dummies are included in the estimations. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

The efficiency of public support to business R&D may differ for specific sub-groups of firms. The criterion that is most often used to distinguish firms is firm size. Straathof et al. (2014) conclude that it is difficult to draw conclusions on efficiency by firm size as results differ across studies and countries. They point at some evidence that the impact of support for start-up firms exceeds the average impact but conclude that there is also not much evidence on how efficiency of tax incentives varies with firm age. Table 14 reports the results of fixed effects panel estimation for four different groups of firms, distinguished by number of employees. Except for the tax deduction of 80% of patent income, all coefficients of public support are positive and statistically significant for firms with up to 50 employees.

For the other groups, the results are more mixed. In the group of firms with 50 up to 100 employees only the impact of the partial exemption of the withholding tax for R&D employees with a PhD or civil engineering degree is statistically significant. For larger firms, more elasticity estimates are statistically significant although the coefficients tend to be smaller than for the group of firms with up to 50 employees. For firms with more than 250 employees, the negative coefficient for the tax credit is also statistically significant. This result suggests that a limit may be warranted, especially given the high budgetary cost of the tax credit and the lack of indications of its efficiency. The extremely high coefficient for Young Innovative Companies for the group of firms with 100 up to 250 employees is not reliable and is somewhat problematic as not many Young Innovative Companies could be expected to belong to this firm size category (see discussion of the results of table 15 on the issue of Young Innovative Companies).

Table 14 Results of fixed effects panel estimation by firm size (2003-2015)

	# employees <= 50	50 < # employees <= 100	100 < # employees <= 250	250 < # employees
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Regional subsidy	0.08 (5.03) ***	0.05 (1.38)	0.08 (2.36) **	0.07 (2.47) **
Research cooperation	0.13 (3.43) ***	0.08 (1.03)	0.10 (1.64) *	0.08 (1.74) *
Young Innovative Company	0.08 (2.35) **	-0.01 (-0.12)	1.41 (8.33) ***	0.22 (1.36)
PhDs and civil engineers	0.07 (2.94) ***	0.13 (2.25) **	-0.02 (-0.50)	0.09 (2.14) **
Master	0.14 (5.50) ***	0.02 (0.40)	0.13 (2.97) ***	0.12 (2.78) ***
Tax credit R&D	0.10 (2.43) **	0.12 (0.65)	-0.02 (-0.37)	-0.08 (-2.15) **
Tax deduction 80% patent income	0.06 (1.47)	-0.04 (-0.85)	-0.07 (-1.34)	-0.06 (-1.41)
Control variables:				
Value added	-0.12 (-1.13)	0.03 (0.13)	-0.20 (-1.84) *	-0.09 (-0.35)
Number of employees	1.88 (7.58) ***	1.32 (1.13)	1.09 (1.15)	2.83 (3.22) ***
Age	-1.60 (-3.22) ***	1.16 (0.56)	0.25 (0.17)	-1.12 (-0.77)
Capital intensity	0.35 (3.26) ***	-0.12 (-0.37)	0.16 (0.43)	0.83 (2.02) **
R-squared (within)	0.16	0.31	0.39	0.38
Number of observations	9,555	2,293	2,200	2,232

Note: The table shows the results of fixed effects (within) estimation by size category. All variables are considered in logs. Industry-year dummies are included in all estimations. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

Table 15 shows the results of fixed effects panel estimation by age group. The age of a firm is defined by the date of incorporation. There are substantial differences between age group in estimates and statistical significance. There are more indications of input additionality for firms that exist for more than 10 years. The most troubling finding is the statistically significant positive coefficient for the partial exemption for Young Innovative Companies in the group of firms that are between 11 and 20 years old.

There is an obvious age condition for companies to be eligible for the partial exemption of the withholding tax for Young Innovative Companies. To be eligible, a company should exist for less than 10 years before the beginning of the year of application of the partial exemption.[27] So, in principle there should not be any company that benefits from this scheme in the group of firms between 11 and 20 years old. However, as graph 13 shows, according to the information on the date of incorporation, in every year since the introduction of this scheme in 2006, some firms appear to have existed for more than 10 years at the time that they benefitted from this specific tax incentive. The share of firms that benefit from the partial exemption for Young Innovative Companies, despite apparently not being eligible according to their age, increased gradually between 2008 and 2012, when it reached 18.75%. After 2012, the share decreased slightly although it was still 14% in 2015.

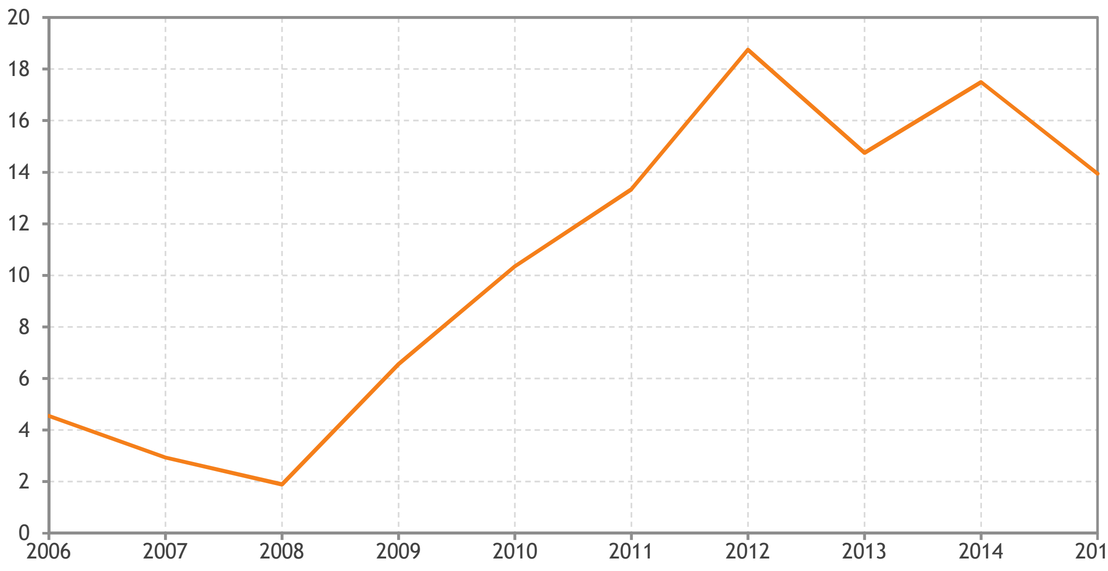
[27] Based on the date of incorporation.

Table 15 Results of fixed effects panel estimation by firm age (2003-2015)

	Age <= 5	5 < Age <= 10	10 < Age <= 20	Age > 20
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Regional subsidy	0.00 (0.05)	-0.01 (-0.36)	0.06 (3.02) ***	0.10 (5.60) ***
Research cooperation	0.03 (0.59)	0.05 (0.71)	0.01 (0.27)	0.12 (3.26) ***
Young Innovative Company	0.03 (0.53)	0.06 (0.79)	0.15 (3.32) ***	0.08 (0.79)
PhDs and civil engineers	0.08 (1.06)	0.20 (2.66) ***	-0.02 (-0.82)	0.07 (2.72) ***
Master	0.16 (1.95) **	0.11 (1.40)	0.20 (5.18) ***	0.12 (5.27) ***
Tax credit R&D	-0.01 (-0.11)	0.09 (1.04)	0.07 (0.95)	-0.01 (-0.18)
Tax deduction 80% patent income	0.04 (0.39)	0.07 (0.92)	0.01 (0.22)	-0.01 (-0.42)
Control variables:				
Value added	0.72 (5.83) ***	-0.31 (-1.89) **	-0.05 (-0.43)	0.04 (0.24)
Number of employees	1.43 (4.08) ***	2.10 (2.81) ***	1.23 (2.78) ***	2.14 (7.10) ***
Age	-0.98 (-2.03) **	-0.80 (-0.22)	-0.66 (-0.26)	-4.13 (-1.45)
Capital intensity	0.55 (2.48) **	0.45 (1.52)	0.31 (1.41)	0.24 (1.62)
R-squared (within)	0.59	0.40	0.22	0.15
Number of observations	1,165	1,447	4,004	9,664

Note: The table shows the results of fixed effects (within) estimation by firm age. All variables are considered in logs. Industry-year dummies are included in all estimations. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

Graph 13 Share of Young Innovative Companies that are older than 10 years (2006-2015)



Bodas Freitas et al. (2015) argue that public support to business R&D should be differentiated across industries given findings of substantial heterogeneity in the efficiency of public support. Considering the Pavitt taxonomy of industries, which categorizes industries by sources of technological knowledge and market structure, they report cross-country indications that R&D tax credits are more effective in science-based and specialized supplier industries than in supplier-dominated industries. Castellacci and Lie (2015) report somewhat diverging results. Table 16 shows the results of fixed effects panel estimation for each Pavitt category, as proposed by Bogliacino and Pianta (2015):

1. **Science-Based**: sectors in which innovation is based on advances in science and R&D,

2. **Specialized Suppliers**: sectors producing machinery and equipment that is used in new processes for other industries,

3. **Scale Intensive**: sectors in which scale economies are relevant and a certain rigidity of production processes exists, technological change is usually incremental,

4. **Supplier-dominated**: traditional sectors in which small firms are prevalent and technological change is introduced through the inputs and machinery provided by suppliers from other industries.

The estimates clearly differ across the four Pavitt industry groups. Except for the R&D tax credit and the tax deduction of 80% of patent income, all elasticity estimates are positive and statistically significant for all support schemes in science-based industries.

Table 16 Results of fixed effects panel estimation by Pavitt category (2003-2015)

	Science-based	Specialized Suppliers	Scale Intensive	Supplier-dominated
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Regional subsidy	0.03 (1.88) *	0.07 (3.31) ***	0.07 (2.79) ***	0.07 (2.84) ***
Research cooperation	0.10 (1.72) *	0.12 (1.80) *	0.07 (1.61) *	0.08 (1.65) *
Young Innovative Company	0.13 (2.72) ***	0.05 (0.95)	0.19 (0.90)	0.24 (1.72) *
PhDs and civil engineers	0.12 (2.81) ***	0.08 (1.90) *	0.07 (1.84) *	0.06 (1.69) *
Master	0.13 (4.63) ***	0.12 (2.93) ***	0.10 (2.59) ***	0.17 (4.75) ***
Tax credit R&D	0.02 (0.39)	0.02 (0.86)	0.01 (0.36)	0.17 (1.65) *
Tax deduction 80% patent income	-0.03 (-1.04)	0.02 (0.58)	-0.05 (-1.62) *	0.07 (1.48)
Control variables:				
Value added	0.17 (0.89)	0.13 (1.03)	0.38 (1.75) *	-0.14 (-0.81)
Number of employees	1.91 (4.64) ***	1.79 (5.32) ***	0.86 (1.36)	1.66 (4.44) ***
Age	-2.31 (-2.81) ***	-1.74 (-3.23) ***	-2.49 (-1.58)	-1.96 (-1.52)
Capital intensity	0.40 (2.25) **	0.37 (2.17) **	0.34 (1.09)	0.43 (2.10) **
R-squared (within)	0.08	0.13	0.16	0.12
Number of observations	3,296	3,832	2,700	5,336

Note: The table shows the results of fixed effects (within) estimation by Pavitt category, using the updated classification of industries provided by Bogliacino and Pianta (2015). All variables are considered in logs. Industry-year dummies are included in all estimations. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

For the three other Pavitt categories, the evidence is more mixed. For the R&D tax credit, the elasticity is positive in supplier-dominated industries which seems to be in contrast with the results reported by Bodas Freitas et al. (2015), although the estimate is only statistically significant at 10%.

Halpern and Muraközy (2015) offer a recent overview of the literature on the link between market competition and R&D investment. Table 17 shows the results of fixed effects estimation of specification (1) in which industries are grouped by average market concentration, as measured by the Herfindahl-Hirschman Index (HHI), which sums the squared market shares of firms in an industry. The HHI ranges from 1/N to 1, N being the number of active firms. The closer HHI is to 1, the more concentrated the market. Industries are grouped by quartile with the first quartile grouping the two-digit industries with the lowest average HHI over the period 2003-2015. The results in Table 17 indicate that the estimated elasticity tends to decrease with rising market concentration. In contrast with the estimates reported in table 10 up to table 16, the elasticity of the tax deduction of 80% of patent income is statistically significant positive for the first HHI quartile and the elasticity of the R&D tax credit is statistically significant positive for the second HHI quartile. Although the HHI is probably not the best indicator of competition (see Halpern and Muraközy 2015)[28], the results suggest that the efficiency of public support to business R&D may depend on the market structure and level of competition of industries. Industry-year dummies, included when possible in the estimations, account for time-variant differences between industries in R&D investment, such as changes in market competition, but do not permit to assess the specific role of these differences.

Table 17 Results of fixed effects panel estimation by Herfindahl-Hirschman Index quartile (2003-2015)

	1st quartile	2nd quartile	3rd quartile	4th quartile
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Regional subsidy	0.09 (2.49) **	0.05 (2.82) ***	0.07 (3.38) ***	0.07 (3.01) ***
Research cooperation	0.12 (1.36)	0.18 (3.14) ***	0.08 (2.09) **	0.09 (2.38) **
Young Innovative Company	0.17 (2.75) ***	0.13 (1.68) *	0.04 (0.81)	-0.04 (-0.58)
PhDs and civil engineers	0.08 (1.64) *	0.05 (1.59)	0.13 (2.94) ***	0.10 (2.59) ***
Master	0.18 (5.02) ***	0.16 (4.62) ***	0.11 (3.33) ***	0.06 (1.82) *
Tax credit R&D	0.02 (0.25)	0.10 (2.31) **	0.03 (0.54)	0.00 (0.00)
Tax deduction 80% patent income	0.13 (2.03) **	0.02 (0.63)	-0.00 (-0.10)	-0.03 (-0.95)
Control variables:				
Value added	0.35 (0.72)	-0.28 (-1.41)	0.02 (0.19)	0.25 (1.29)
Number of employees	1.72 (2.99) ***	1.48 (4.01) ***	1.74 (4.74) ***	0.95 (2.48) **
Age	-1.86 (-1.89) *	-2.19 (-3.61) ***	-0.18 (-0.28)	-1.68 (-1.62)
Capital intensity	0.41 (1.81) *	0.56 (3.20) ***	0.38 (2.32) **	0.05 (0.21)
R-squared (within)	0.07	0.08	0.10	0.22
Number of observations	2,804	4,318	4,720	4,438

Note: The table shows the results of fixed effects (within) estimation of specification (1) on p.27, by industry category. Industries are grouped by average Herfindahl-Hirschman Index, which provides an indication of market concentration (computed as the sum of the squared market shares of firms within the industry). Industries are grouped by HHI quartile with the 1st quartile grouping the industries with the lowest average market concentration. All variables are considered in logs. Industry-year dummies are included in all estimations. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

Across different sub-groups of firms (categorized by size, age or industry) the most robust evidence of input additionality is found for the partial exemption of the withholding tax for R&D employees with a master's degree.

Zúñiga-Vicente et al. (2014) point out that as R&D projects take time to implement and are subject to adjustment costs. Money saved through public support to R&D may be used by companies to invest in R&D in the following years. Corporate research projects run over several years. Cincera and Fombasso Toyem (2018) find that more than half of the EUREKA[29] projects have a duration of 4 up to 7 years. Public support may therefore impact R&D expenditures for several years. Cerulli (2010) considers a

[28] The available data do not permit the calculation or estimation of other indicators of market competition.

[29] EUREKA Network Projects are transnational, market-driven innovative research and development projects, labelled by EUREKA and supported by the public administrations and public funding agencies that represent EUREKA in each of its member countries (https://www.eurekanetwork.org/content/eureka-network-projects).

specification to which lags of public support are added. For the two tax incentives that operate through corporate income taxation, the R&D tax credit and the tax deduction of 80% of patent income there is a discrepancy between the income year and the tax year. The tax incentives apply to income, and expenditures, in the previous year. In the baseline specification, the tax incentives based on corporate income taxation are linked to the previous year (income year) as that is the year for which the tax incentives are applied for. If a lag is considered for public support, this implies that these tax incentives are linked to the tax year.

Table 18 presents the results of fixed effects panel estimation of the baseline specification in which the variables that reflect the amount of public support received by firms are lagged, by one and two years, respectively. In the last two columns, a lag of the dependent variable is also included. This lag captures the substantial persistence that can be found in R&D expenditures (see for recent evidence, Arqué-Castells and Mohnen 2015 and Busom, Corchuelo and Martínez-Ros 2017). The inclusion of a lagged dependent variable may pose some problems (see discussion in Dumont 2015) so the results of these estimations should be taken with caution.

Table 18 Results of fixed effects panel estimation with lags (2003-2015)

	One-year lag	Two-year lag	Lagged dependent	Lagged dependent + Lagged support
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Net R&D expenditures (t-1)			0.56 (45.48) ***	0.56 (45.84) ***
Regional subsidy	0.03 (2.89) ***	0.01 (1.12)	0.02 (2.15) **	0.02 (2.27) **
Research cooperation	0.07 (3.12) ***	0.03 (1.32)	0.04 (2.74) ***	0.01 (0.62)
Young Innovative Company	0.08 (2.16) **	0.05 (1.69) *	0.05 (1.35)	0.01 (0.19)
PhDs and civil engineers	0.05 (2.99) ***	0.02 (1.45)	0.05 (3.98) ***	0.01 (1.41)
Master	0.08 (4.75) ***	0.04 (2.55) **	0.06 (5.14) ***	0.03 (3.55) ***
Tax credit R&D	0.00 (0.17)	0.01 (0.69)	-0.01 (-0.69)	-0.01 (-0.47)
Tax deduction 80% patent income	-0.02 (-0.82)	-0.01 (-0.54)	0.01 (0.82)	-0.00 (-0.25)
Control variables:				
Value added	0.13 (1.71) *	0.13 (1.95) *	0.02 (0.23)	0.03 (0.26)
Number of employees	1.67 (7.33) ***	1.30 (4.63) ***	0.75 (5.06) ***	0.81 (5.33) ***
Age	-1.29 (-2.55) ***	-0.90 (-1.37)	-0.47 (-1.45)	-0.49 (-1.52)
Capital intensity	0.30 (2.84) ***	0.13 (1.08)	0.17 (2.34) **	0.18 (2.50) **
R-squared (within)	0.13	0.17	0.42	0.42
Number of observations	11,267	7,010	10,967	10,967

Note: The table shows the results of fixed effects panel estimation in which lags of the explanatory variables and the dependent variable are included. All variables are considered in logs and industry-year dummies are included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

A more acceptable way to account for the persistence of R&D expenditures is dynamic panel estimation (see section 5.1.4). The results with different lags, reported in table 18, are to large extent in line with the results of the baseline panel estimation reported in table 10.

As can be seen in table 8, firms combine different instruments of direct and indirect public support to R&D. Busom, Corchuelo and Martínez-Ros (2015) and Guerzoni and Raiteri (2015) argue that estimates for single policy instruments, without controlling for other available instruments, are subject to hidden treatment bias. The baseline specification (1) considers the impact of each individual support scheme, controlling for the support provided through other support schemes. This precludes the hidden treatment bias but does not provide indications on the possible complementarity or substitution between different policy instruments. Guellec and van Pottelsberghe de La Potterie (2003) report cross-country macroeconomic evidence that direct and indirect public support to R&D are effective but that the efficiency is reduced if one form of support is combined with other forms of support. There are relatively few firm-level studies on the complementarity of different public support schemes for business R&D and the results are rather mixed (Hægeland and Møen 2007; Czarnitzki and Lopes-Bento 2014; Guerzoni and Raiteri 2015; Marino et al. 2016; Dumont 2017; Montmartin, Herrera and Massard 2018).

Table 19 shows the results of an estimation of the baseline specification to which variables have been added that reflect the support received by firms that combine different support schemes. Only the combinations for which the coefficient is statistically significant are shown.

Table 19 Results of the estimation of the policy mix of public support for R&D (2003-2015)

Dependent variable (R&D expenditures net of public support)	
Explanatory variables (individual support scheme):	
Regional subsidy	0.18 (11.26) ***
Research cooperation	0.18 (5.94) ***
Young Innovative Company	0.20 (4.95) ***
PhDs and civil engineers	0.13 (7.51) ***
Master	0.18 (9.73) ***
Tax credit R&D	0.02 (1.00)
Tax deduction 80% patent income	0.02 (1.03)
Explanatory variables (combination support):	
Regional subsidy + Research cooperation	-0.16 (-3.57) ***
Regional subsidy + Young Innovative Company	-0.15 (-4.25) ***
Regional subsidy + PhDs and civil engineers	-0.12 (-3.92) ***
Regional subsidy + Master	-0.14 (-4.43) ***
Research cooperation + PhDs and civil engineers	-0.07 (-2.00) **
Research cooperation + Tax deduction 80% patent income	-0.19 (-8.00) ***
Young Innovative Company + Master	-0.09 (-2.19) **
PhDs and civil engineers + Master	-0.05 (-2.17) **
Subsidy and at least two tax incentives	-0.18 (-9.28) ***
More than two tax incentives	-0.03 (-1.48)
R-squared (within)	0.06
Number of observations	16,280

Note: The table shows the results of an estimation of the baseline specification to which terms are added which reflect the amount received by firms that combine support schemes. Only combinations for which the coefficient is statistically significant are shown. The four control variables that are considered in the previous estimations are also included in the estimation but not reported. All estimations use fixed effect (within) with industry and year dummies. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

The coefficients of the combination of support variables should be interpreted as additional effects of combining two schemes relative to the individual schemes. A positive coefficient implies that combining the two schemes provides a complementary impact and a negative coefficient would indicate that the combination results in some crowding out of R&D expenditures. The last two variables reflect the effect of firms that combine direct support (subsidies) with at least two tax incentives and firms that combine at least three different tax incentives, respectively.

The statistical significance of the coefficients of the individual support schemes are in line with the results from the baseline estimation reported in table 10 but the estimated elasticity is higher. This indicates that the single use of support schemes results in higher additionality than when the schemes are combined with other forms of support. This is further corroborated by the coefficients of the variables that reflect the combination of different support schemes, which are all negative. The coefficients of these variables support the results of the two previous evaluations of decreased efficiency of direct and indirect support when different support measures are combined. The negative impact of combining support schemes is even more substantial as the elasticity estimates are much larger.

Raising the R&D intensity of a country can be achieved by raising the R&D intensity of R&D active firms (intensive margin) but also by inciting non-R&D active firms to start doing R&D. Estimations of the impact of public support on the probability to start R&D, using alternative definitions of R&D starters, provide mostly non-significant estimates, except for a rather improbable statistically significant negative impact of the partial exemption for PhDs and civil engineers in one of the estimations. The results of these estimations are not reported but available upon request.[30]

5.1.2. Robustness of estimates

a. Selection model

This section reports the results of the estimation of a two-step selection model, as proposed by Heckman (1979) and used for the evaluation of public support for R&D by Busom (2000) and Hussinger (2008). The first-step estimation considers variables that may explain whether a firm receives support for its R&D activities. From this estimation inverse Mills ratios can be computed which are then included in the second-step estimation, which is the actual estimation of the impact of public support on R&D expenditures (baseline specification (1) on p.27). The statistical significance of the inverse Mills variables in the second-step estimation provides an indication on the relevance of the selection bias.

The selection and self-selection by firms in the application for and obtaining of regional subsidies or tax incentives is likely to be explained by different firm and industry characteristics. Rather than using a bivariate selection, five possible categories of public support are considered:

1) Firm receives no support for R&D,
2) Firm receives a subsidy but no tax benefit,
3) Firm receives a wage-based tax benefit (partial exemption) but no subsidy and no tax incentives through corporate income taxation (R&D tax credit and tax deduction 80% of patent income),
4) Firm receives a tax benefit through corporate income taxation but no subsidy and no wage-based tax benefit,
5) Firm receives a subsidy, a wage-based tax benefit and a tax benefit through corporate income taxation.

A two-step selection model estimation requires at least one variable that explains selection but not the actual dependent variable of interest, which in this paper is R&D expenditures. As some subsidy

[30] As the dependent variable is binary (start R&D or not) a logit estimation is considered. Inclusion of industry dummies results in non-convergence of the iterative estimation procedure.

programmes explicitly target SMEs whereas the SME criterion is not relevant for the level of R&D expenditures, a binary SME variable is considered in the first-step estimation but not in the second step. The lags of public support and R&D expenditures are also included in the first-step but not in the second-step estimation so there are five exclusion variables.

The results of the estimation of the selection model are reported in table 20. The coefficients in the table are the relative risk ratios which denote the change in probability to belong to a group, relative to the benchmark group (firms that receive no support), for a unit change in the explanatory variable, with the other variables held constant. A coefficient below 1 indicates that an increase in that explanatory variable reduces the probability to belong to that group relative to the group of firms that receive no support. A relative risk ratio below 1 implies a negative t-value. Past R&D expenditures and past public support very significantly explain group membership of firms. For example, a firm that received direct support in the previous year will much more likely also receive direct support but no tax support in this year than to receive no support at all. If a firm had R&D activities in the previous year, this increases the probability that it will receive support for its current R&D.

Table 20 Determinants of receiving public support for R&D (2003-2015) – first step of selection model

Dependent variable: category of public support	Subsidy no tax benefit	No subsidy Tax emption no CIT benefit	No subsidy No tax exemption CIT benefit	Subsidy Tax exemption CIT benefit
Explanatory variables:				
Lag R&D expenditures	1.07(5.79) ***	1.11 (9.47) ***	1.08 (2.13) **	1.01 (0.33)
Lag regional subsidy	1.24 (23.80) ***	0.79 (-23.02) ***	0.77 (-4.17) ***	1.20 (9.92) ***
Lag partial exemption	0.72 (-12.67) ***	1.39 (39.32) ***	0.54 (-5.86) ***	1.22 (7.04) ***
Lag CIT-based benefit	0.78 (-3.54) ***	0.69 (-16.80) ***	1.64 (14.08) ***	1.26 (13.66) ***
Value added	0.93 (-1.04)	1.01 (0.14)	1.06 (0.21)	0.97 (-0.38)
Age	0.72 (-5.94) ***	0.94 (-1.39)	1.15 (0.72)	0.86 (-1.41)
Capital intensity	1.09 (2.67) ***	0.99 (-0.53)	1.22 (2.06) **	1.02 (0.31)
SME (0/1)	1.01 (0.03)	0.89 (-0.96)	1.18 (0.27)	0.92 (-0.33)
Mc Fadden pseudo R-squared: 0.42				
Number of observations: 11,362				

Note: The table shows the results of multinomial logistic regression. The dependent variable is a categorical variable reflecting five possible situations in terms of public support for R&D: 1 (firm receives no support for R&D); 2 (firm receives a subsidy but no tax benefit); 3 (firm receives partial exemption of the withholding tax but no subsidy and no tax benefit through corporate income taxation); 4 (firm receives no subsidy and no partial exemption but a tax benefit through corporate income taxation) and 5 (firm receive subsidies, partial exemption and tax benefits through corporate income taxation (CIT)). The table shows the results for the latter four categories relative to the benchmark group of no support. The coefficients denote the relative risk ratio which reflects the change in probability to belong to a group, relative to the benchmark group, for a unit change in the explanatory variable, with the other variables held constant. The SME dummy equals 1 for SMEs (employees<=250) and 0 for large firms. The estimation considers region and year dummies (not reported). *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%.

From the estimation of the selection model reported in table 20, four inverse Mills variables can be computed which are included in the second-step estimation, the results of which are reported in table 21. The coefficient estimates of all inverse Mills variables are statistically significant, which indicates the need to account for selection in public support. However, the five exclusion variables included in the first-step estimation are rather problematic. The coefficient of the binary SME variable is not statistically significant for any public support group, so it does not appear to explain whether a firm receives support, even not whether a firm receives a subsidy. The four lag variables in the first step on the other hand are very significant but as the estimates reported in table 18 suggest, they also have statistically significant coefficients when included as explanatory variables of R&D expenditures so their use as exclusion variables is equally questionable.[31]

In contrast with the fixed effects estimation, the coefficients of all support schemes, including the coefficients of the R&D tax credit and the tax deduction of 80%, of patent income, are positive and statistically significant in the second-step estimation of the two-step selection model.

Table 21 Results of panel estimation accounting for (self-) selection (2003-2015) - second step of selection model

Dependent variable: (R&D expenditures net of public support)	
Explanatory variables:	
Regional subsidy	0.07 (5.62) ***
Research cooperation	0.06 (2.12) **
Young Innovative Company	0.13 (2.50) **
PhDs and civil engineers	0.06 (3.16) ***
Master	0.13 (7.11) ***
Tax credit R&D	0.18 (5.50) ***
Tax deduction - 80% patent income	0.12 (4.29) ***
Variables from selection model (derived from first step):	
Inverse Mills (subsidy, no tax benefit)	0.11 (9.68) ***
Inverse Mills (partial exemption, no subsidy, no CIT benefit)	0.22 (12.33) ***
Inverse Mills (CIT benefit, no subsidy, no partial exemption)	0.02 (2.89) ***
Inverse Mills (subsidy, partial exemption and CIT benefit)	0.08 (3.37) ***
Control variables:	
Value added	0.08 (0.72)
Number of employees	1.36 (6.09) ***
Age	-1.22 (-2.34) **
Capital intensity	0.18 (1.69) *
R-squared (within)	0.19
Number of observations	10,967

Note: The table shows the results of a fixed effects (within) estimation of the baseline panel specification (1) in which four inverse Mills ratios, computed from the first-step estimation of the selection model, reported in table 20, are included to account for (self-) selection. The estimation includes industry-year dummies. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

If the four lag variables of the first-step estimation are also included in the second step, the coefficient of lagged R&D expenditures is highly significant, whereas the coefficients of the lagged support variables are not statistically significant. In this estimation the coefficient of the partial exemption for Young Innovative Companies, the R&D tax credit and the tax deduction for 80% of patent income are not statistically significant.

b. Instrumental variables

In the baseline specification, endogeneity of the support variables on the right-hand side is likely as firms decide autonomously whether to apply for public support and for which amount of R&D support is requested. Endogeneity may result in biased estimates of input additionality. The most common econometric approach that is used to tackle endogeneity is instrumental variables (IV) estimation. A valid

[31] Sartori (2003) points out that in the absence of exclusion variables, identification in a two-step Heckman model depends on the assumptions oh the distribution of the residuals alone. She proposes a maximum-likelihood estimator that is based on the additional identifying assumption that the error term for an observation is the same in both steps.

instrument is a variable that is exogenous (not correlated with the residual term) but that is correlated with the assumed endogenous variable. This section reports the results of two alternative IV estimations. Table 22 shows the two alternative lists of instruments. For example, the changes in the rate of exemption of the partial exemption of the withholding tax are used to construct some instruments. In 2008, the rate of exemption was raised to 65%, from 50% for the first two schemes of partial exemption and from 25% for the two schemes based on the education degree of R&D employees. For all four schemes the rate was further raised to 75% in 2009 and to 80% in 2013.

Table 22 List of instruments

	Instruments 1	Instruments 2
Regional subsidy	Average subsidization rate by three-digit industry	Total amount of support (net of support firm) by three-digit industry
Research cooperation	Share of firms that cooperate in three-digit industry * (rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year)	Rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year
Young Innovative Company	Share of young firms (age<=10 years) in three-digit industry * (rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year)	Rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year
PhDs and civil engineers	Average share of researchers with a PhD in total number of employees by three-digit industry * (rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year)	Rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year
Master	Average share of researchers with a university degree in total number of employees by three-digit industry * (rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year)	Rate of partial exemption if firm did not receive same benefit in previous year OR change in rate of partial exemption if firm also received this benefit in previous year
Tax credit R&D	Total amount of tax credit by three-digit industry	Applicable rate of deduction if firm did not receive a tax credit in previous year OR change in the rate of deduction if firm also received tax credit in previous year
Tax deduction 80% patent income	Total amount of tax deduction by three-digit industry	Applicable rate of deduction if firm did not receive a tax deduction in previous year OR change in the rate of deduction if firm also received tax deduction in previous year

Table 23 shows the results of a fixed effects IV estimation using the first and the second list of instruments, respectively, and a random effects estimation using the second list of instruments.[32] Lags of the support variables are also included as instruments. The table shows the results of several tests of the validity of the instruments.

The Sargan test of over-identifying restrictions tests the crucial assumption that the instruments are not correlated with the residual term of the second-stage regression.[33]

32 Lichtenberg (1988) points out that IV estimation with fixed effects will only provide good results if instruments are endogenous with respect to omitted time-invariant characteristics.

33 The IV estimation consists in two stages (two-stage least squares). In a first-stage estimation, all potentially endogenous variables are regressed, separately, on the explanatory variables that are included in the second-stage estimation and the list of instrumental variables. In the second-stage estimation, the actual dependent variable (R&D expenditures) is regressed on the exogenous variables and the fitted values, from the first-stage estimation. of the potentially endogenous variables.

Table 23 Results of instrumental variables estimation (2003-2015)

	Instruments 1	Instruments 2	Random Effects
Dependent variable:			
(R&D expenditures net of public support)			
Explanatory variables:			
Regional subsidy	0.05 (0.92)	0.16 (1.99) **	0.26 (8.37) ***
Research cooperation	0.10 (1.75) *	0.11 (1.70) *	0.14 (3.79) ***
Young Innovative Company	0.04 (0.38)	0.16 (1.49)	0.24 (6.16) ***
PhDs and civil engineers	0.02 (0.62)	0.06 (1.74) *	0.17 (8.19) ***
Master	0.17 (5.47) ***	0.13 (4.05) ***	0.17 (8.32) ***
Tax credit R&D	0.03 (0.76)	-0.00 (-0.08)	-0.01 (-0.26)
Tax deduction 80% patent income	0.03 (0.63)	-0.04 (-0.79)	-0.01 (-0.27)
Control variables:			
Value added	0.09 (1.04)	0.14 (1.66) *	0.18 (2.54) ***
Number of employees	1.29 (7.46) ***	1.48 (8.87) ***	0.46 (8.93) ***
Age	-0.45 (-1.10)	-1.16 (-2.88) ***	-0.44 (-4.96) ***
Capital intensity	0.21 (2.36) **	0.23 (2.87) ***	0.11 (2.83) ***
Sargan (over-identification)	142.33 (0.00) ***	10.46 (0.21)	
Anderson (under-identification)	336.39 (0.00) ***	274.97 (0.00) ***	
Weak instrument (robust):			
Anderson-Rubin F	14.24 (0.00) ***	4.18 (0.00) ***	
Anderson-Rubin Chi2	202.92 (0.00) ***	59.34 (0.00) ***	
Stock-Wright	195.03 (0.00) ***	58.88 (0.00) ***	
Angrist-Pishke (under-identification):			
Regional subsidy	27.40 (0.00) ***	22.76 (0.00) ***	
Research cooperation	109.09 (0.00) ***	154.15 (0.00) ***	
Young Innovative Company	134.09 (0.00) ***	176.47 (0.00) ***	
PhDs and civil engineers	227.16 (0.00) ***	338.76 (0.00) ***	
Master	203.79 (0.00) ***	300.49 (0.00) ***	
Tax credit R&D	321.83 (0.00) ***	430.99 (0.00) ***	
Tax deduction - 80% patent income	146.67 (0.00) ***	235.46 (0.00) ***	
R-squared	0.09	0.06	0.04
Number of observations	6,894	9,997	11,250

Note: The table shows the results of the second step of an instrumental variables estimation. The second column shows the results of an estimation in which instruments 1, listed in Table 22 are used in addition to lags of the support variables. The third column shows the results of an estimation in which instruments 2 are used in addition to lags of the support variables. The last column shows the results of an IV estimation with random effects, using the second list of instruments. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

As the null hypothesis is zero correlation, rejection provides an indication that (some) instruments are not valid or more generally that the model is not correctly specified. The relevance of instruments is tested with under-identification or weak instruments tests. The null hypothesis is zero correlation between the instrument(s) and the instrumented (endogenous) variable so that failure to reject would indicate that the instruments are not relevant or weak. Both under-identification and weak identification tests for all instruments and tests for each instrumented support variable separately are reported. The tests appear to favour Instruments 2 over Instruments 1.

The estimates of the fixed effects estimation with Instruments 2 corroborate the results of the plain fixed effects estimation reported in table 10 although the coefficient for Young Innovative Companies is not statistically significant and the coefficients of the partial exemption for research cooperation and for R&D employees with a PhD or civil engineering degree are only significant at 10%. In contrast with the results of the selection model but in line with the results of the baseline panel estimation, the (negative) coefficient of the R&D tax credit and the tax deduction for 80% of patent income is not statistically significant

c. Dynamic panel

In this section the results of dynamic panel estimation are reported. Dynamic panel estimation permits to account for the persistence in the dependent variable which seems appropriate given the evidence of high persistence in R&D activities (see Arqué-Castells and Mohnen 2015; Busom, Corchuelo and Martínez-Ros 2017). Table 24 shows the results of a two-step system Generalized Method of Moments (GMM) estimation. Short-term effects can be distinguished from the long-term impact of public support. Long-term coefficients are computed as non-linear combinations of short-term estimates.

The large statistically significant positive coefficient of the first lag of R&D expenditures reflects the substantial persistence in R&D expenditures. Due to the inclusion of three lags, necessary to ensure that the residuals are not serially correlated, the number of observations is only 4,402 compared to 16,280 in the baseline fixed effects panel estimation. The dynamic panel estimation provides indications of input additionality for the four partial exemption schemes. The long-term elasticity for these schemes is substantially larger than the short-term elasticity which may be explained by the adaptation costs involved in R&D activities and the fact that investment in R&D is often decided for the medium-term.

The Arellano-Bond tests indicate first-order serial correlation of residuals, but no higher-order serial correlation, as expected in system GMM. The null hypothesis of the Sargan and Hansen test, that instruments are uncorrelated with residuals, is clearly rejected, suggesting that the instruments are not valid. This result is in line with the poor performance of GMM estimation for the French R&D tax credit, reported by Mulkay and Mairesse (2013).

An alternative specification that permits to distinguish short-term from long-term effects is an error-correction model (ECM). Estimation of such a model provides no statistically significant coefficient estimates.[34] A possible explanation for the poor results of the ECM estimation may be the difference in order of integration of the variables as suggested by the panel unit root tests reported in table 25. Unit root tests assess the stationarity of time series. If a time series of a variable is stationary in level, the order of integration is said to be zero, labelled as I(0). If the time series is not stationary in level but in first difference, the order of integration is one, labelled as I(1). If the variable is only stationary after twice differencing its order of integration is two, labelled I(2).

34 The results of the estimation of two ECM are not reported but available upon request.

Table 24 Results of dynamic panel estimation (2003-2015)

	Short-term		Long-term
Dependent variable:			
(R&D expenditures net of public support)			
Public support variables:			
Regional subsidy	0.01 (1.00)		0.06 (1.05)
Research cooperation	0.04 (2.15) **		0.21 (2.10) **
Young Innovative Company	0.11 (4.28) ***		0.61 (3.84) ***
PhDs and civil engineers	0.08 (5.99) ***		0.43 (6.16) ***
Master	0.05 (4.43) ***		0.28 (4.32) ***
Tax credit R&D	-0.01 (-0.47)		-0.03 (-0.47)
Tax deduction 80% patent income	0.02 (1.59)		0.13 (1.59)
Lags of dependent variable			
Net R&D expenditures (t-1)		0.88 (63.23) ***	
Net R&D expenditures (t-2)		-0.23 (-7.50) ***	
Net R&D expenditures (t-3)		0.17 (6.64) ***	
Control variables:			
Value added		-0.02 (-0.32)	
Number of employees		0.10 (1.61)	
Age		-0.25 (-2.58) ***	
Capital intensity		0.28 (3.10) ***	
Arellano-Bond test AR (1) -10.76 (0.00) ***			
Arellano-Bond test AR (2) -0.80 (0.43)			
Arellano-Bond test AR (3) 1.45 (0.15)			
Arellano-Bond test AR (4) -0.56 (0.58)			
Sargan (over-identification) 1693.47 (0.00) ***			
Hansen (over-identification) 922.77 (0.01) ***			
Hansen test excluding group 908.74 (0.01) ***			
Difference (H_0=exogeneity) 14.03 (0.17)			
Number of observations 4,402			

Note: The table shows the results of a two-step system GMM with orthogonal deviations. For lags of the dependent variable GMM-style instruments are used and for the public support variables lags are used as instruments. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity and are corrected for the finite-sample bias of a two-step estimation.

Table 25 reports the results of a Fisher panel unit root test (XTFISHER procedure in STATA) which has a null hypothesis of non-stationarity.[35] To be stationary the null hypothesis should therefore be rejected.

As can be seen, none of the main variables used in the baseline specification are stationary in level. For the partial exemption of the withholding tax for PhDs and civil engineers, the order of integration appears to be 1. Even after twice differencing, only three variables are stationary, in effect, R&D expenditures and the two partial exemption schemes based on the educational degree of R&D employees.

[35] Given that the panel is highly unbalanced, the Fisher test is appropriate.

Table 25 Panel unit root tests (2003-2015)

	Level test I(0)	First difference test I(1)	Second difference test I(2)
R&D expenditures (net of support)	1557.18 (1.00)	1123.72 (1.00)	1261.61 (0.00) ***
Regional subsidy	969.41 (1.00)	636.65(1.00)	789.84 (1.00)
Research cooperation	445.11 (1.00)	501.68 (1.00)	341.03 (1.00)
Young Innovative Company	29.62 (1.00)	151.15 (1.00)	60.74 (1.00)
PhDs and civil engineers	1399.96 (1.00)	2062.54 (0.03) **	1367.38 (0.00) ***
Master	856.41 (1.00)	1276.70 (1.00)	1752.06 (0.00) ***
Tax credit R&D	205.31 (1.00)	179.65 (1.00)	366.37 (1.00)
Tax deduction 80% patent income	87.35 (1.00)	130.68 (1.00)	368.76 (1.00)

Note: The table shows the results of panel unit root tests on the level, the first and second difference of R&D expenditures and the public support variables. The test has been performed using the Stata procedure XTFISHER which allows for unbalanced panels. The reported test is a Fisher panel augmented Dickey-Fuller unit root test. The null hypothesis is that the variable contains a unit root, in effect, is not stationary. The *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The reported values are the Fisher Chi-squares values with p-values in brackets.

In line with the previous evaluation of the federal tax incentives, the results of the unit root test are problematic as they suggest that there cannot exist a long-term (cointegration) relationship between R&D expenditures and the amount of direct and indirect public support that firms receive. The panel is still not very long, in effect ten years at most for the tax incentives, so stationarity and unit root tests should be considered with caution, but the results suggest that caution may also be warranted in the interpretation of the previous results in this paper as the possibility of spurious correlation cannot be excluded.[36] Another issue is that there are not many firms with long consecutive observations as indicated by table 26 which shows the ten most common patterns of real responses by firms. Only 4% of observations result from firms for which R&D expenditures are reported for every year over the period 2003-2015.

Table 26 Time pattern of real responses R&D survey (internal R&D Expenditures)

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
											1	1
									1	1	1	1
							1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1
					1	1	1	1	1	1	1	1
							1	1			1	1
			1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1
					1	1	1	1				
							1	1	1	1		

[36] Spurious correlation denotes apparent high correlation between time series variables that is explained by a common time trend rather than by an actual 'causal' link between the variables.

5.1.3. Bang for the Buck

The coefficient estimates of a specification with all variables expressed in logs can be interpreted in elasticity terms. For example, an estimate of 1 implies that an increase by 10% in the explanatory variable results in a 10% increase of the dependent variable. Input additionality is often denoted in terms of the Bang for the Buck (BFTB) which denotes how much euro in additional R&D expenditures results from one euro in public support. The BFTB can be computed from the elasticity estimates and the average R&D expenditures and the average amount of support received by firms. Based on the elasticity estimates from the different alternative procedures reported in this paper, table 27 shows the BFTB computed with averages. The BFTB is only reported for the elasticity estimates that are statistically significant. The average amount of support is strongly influenced by large firms. As the results in table 14 show, coefficient estimates are generally higher for small firms than for large firms. Applying coefficient estimates that reflect average effects to the average amount of support may therefore overestimate the BFTB. Table 27 therefore also shows an alternative BFTB computed with the median of R&D expenditures and support.

Table 27 Bang for the Buck based on alternative estimates (2003-2015)

	Fixed Effects 1	Fixed Effects 2	Selection	IV List 1	IV List 2	GMM ST	GMM LT
	(Table 10)	(Table 10)	(Table 21)	(Table 23)	(Table 23)	(Table 24)	(Table 24)
Based on the mean							
Regional subsidy	0.68	0.68	0.51		1.27		
Research cooperation	2.85	2.85	1.38	2.62	2.92	1.53	8.02
Young Innovative Company	4.23	4.94	4.44			5.35	29.67
PhDs and civil engineers	0.59	0.59	0.43		0.48	0.78	4.17
Master	1.64	1.64	1.47	2.31	1.71	0.86	4.83
Tax credit R&D			0.14				
Tax deduction 80% patent income			0.07				
Based on the median							
Regional subsidy	0.16	0.16	0.13		0.31		
Research cooperation	0.96	0.96	0.48	0.95	0.92	0.32	1.67
Young Innovative Company	0.59	0.69	0.63			0.54	3.00
PhDs and civil engineers	0.26	0.26	0.19		0.21	0.26	1.40
Master	0.54	0.54	0.50	0.76	0.54	0.19	1.08
Tax credit R&D			0.22				
Tax deduction 80% patent income			0.23				

Note: The table shows the Bang for the Buck (BFTB), an estimate of how much additional R&D expenditures result from one euro in public support received by companies. The BFTB is calculated at the mean and median, respectively, of net R&D expenditures and public support for non-missing observations in the given specification and the estimates of elasticity as reported (reference to table in brackets). Only estimates of elasticity that are statistically significant (at least at 10%) are considered.

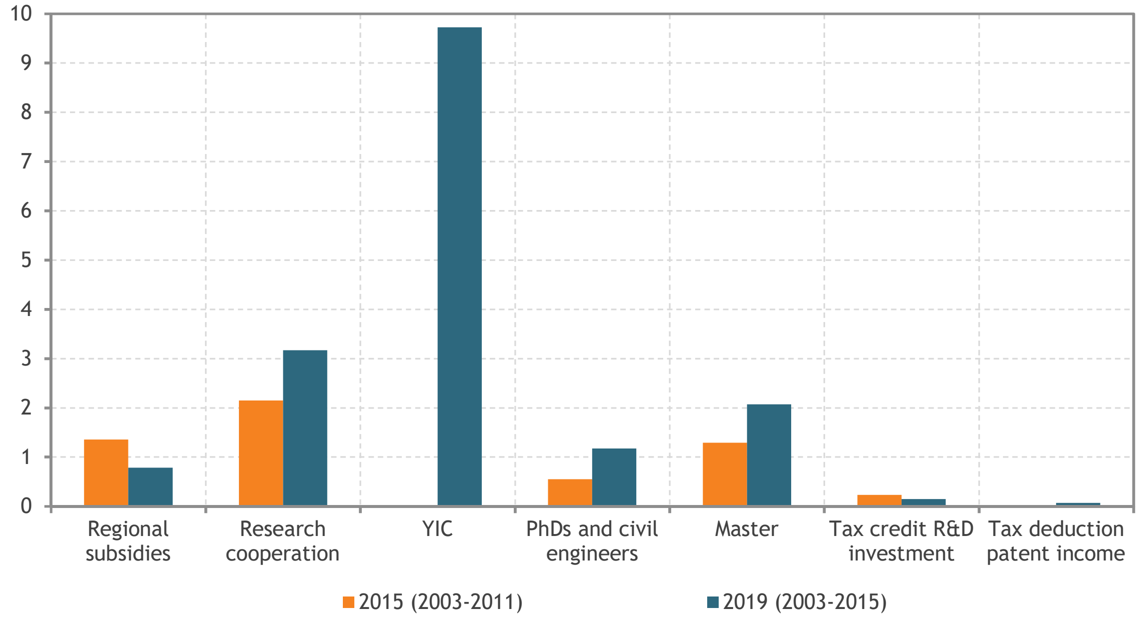
As R&D expenditures are denoted net of public support, the BFTB reported should be interpreted in net terms. For example, the BFTB of 0.68 for regional subsidies in the Fixed Effects 1 estimation implies that one euro results in 0.68-euro additional R&D, in addition to the one euro received in support. Indications of additionality are most robust for the partial exemption for research cooperation and – as in the previous evaluation – for R&D employees with a master's degree.

For the other support schemes, not all estimation procedures provide statistically significant estimates. For the R&D tax credit and the tax deduction of 80% of patent income, the selection model is the only procedure to provide statistically significant indications of input additionality and even in this estimation the BFTB is relatively low.

Some of the BFTB estimates are unreliable, especially for the tax incentives with relatively few beneficiaries such as the partial exemption of the withholding tax for research cooperation and for Young Innovative Companies. This indicates the difficulty of identification with relatively few observations. The BFTB based on the median rather than on the average seems to provide more reliable results.

Graph 14 compares the average BFTB for each support scheme, over all statistically significant estimates in the third evaluation (2019), which covers the period 2003-2015, with the average BFTB over all statistically significant estimates in the second evaluation (2015), which covers the period 2003-2011. As both evaluations do not cover the same period and as there are also differences in the estimation procedures the comparison is indicative at best.

Graph 14 Average BFTB of second evaluation (2003-2011) and third evaluation (2003-2015)



Given this caveat, the graph shows that the average estimate of the BFTB for the four partial exemption schemes is higher in the third evaluation than in the second evaluation. For the first three partial exemption schemes the indications of additionality are moreover based on more robust estimates in the recent evaluation.

As mentioned before, the average BFTB for the partial exemption for Young Innovative Companies is extremely high in the third evaluation and should be taken with considerable caution.

The average BFTB for regional subsidies is, although still relatively high, lower in the third evaluation compared to the results from the previous evaluation. As (changes in) the policy mix of regional subsidies is not adequately accounted for in the evaluation of the tax incentives, the variable on direct support should be considered more as a control variable than as a variable that provides a reliable assessment of the efficiency of regional subsidies.

The average BFTB for the R&D tax credit, based on a single statistically significant estimate, is even lower in the recent evaluation than in the previous evaluation. Whereas there were no statistically significant estimates for the tax deduction for patent income in the previous evaluation, the only significant estimate results in a very low average BFTB of 0.07 in the third evaluation.

5.2. Behavioural additionality

The tax incentives introduced by the federal government aim at raising additional R&D expenditures. They may however also affect the characteristics of R&D activities such as the orientation of R&D (basic research, applied research or experimental development) or the educational composition of R&D employees. This chapter reports the results of a panel estimation of the impact of public support on these characteristics of R&D activities.

Table 28 shows the results of an estimation of the effects of subsidies and tax benefits on the orientation of R&D activities. In the R&D Survey, companies are asked to provide the distribution of their R&D expenditures over three categories: basic research, applied research and experimental development. The response to this question only applies to one of the two years that the survey covers.

As such observations are only available for odd years, which explains the lower number of observations, in addition to the fact that less firms respond to the question on orientation than on R&D expenditures.

Table 28 Results of panel estimation of the impact on the orientation of R&D activities (2003-2015)

Dependent variable: share in R&D expenditures	Basic research	Applied research	Experimental development
Explanatory variables:			
Regional subsidy	0.01 (1.31)	-0.00 (-0.01)	0.00 (0.19)
Research cooperation	0.01 (0.83)	0.00 (0.10)	0.03 (1.52)
Young Innovative Company	0.02 (0.78)	-0.05 (-2.08) **	0.05 (1.94) **
PhDs and civil engineers	-0.00 (-0.42)	0.00 (0.39)	0.02 (1.65) *
Master	0.01 (0.60)	-0.01 (-1.12)	0.03 (2.26) **
Tax credit R&D	-0.01 (-0.51)	0.02 (1.06)	0.03 (1.57)
Tax deduction 80% patent income	-0.01 (-0.87)	0.02 (1.35)	0.03 (1.62)
Control variables:			
Value added	0.08 (1.64) *	0.09 (1.63) *	-0.20 (-3.38) ***
Number of employees	-0.03 (-0.21)	-0.17 (-1.95) **	0.21 (2.04) **
Age	-0.53 (-2.20) **	0.05 (0.29)	-0.10 (-0.50)
Capital intensity	0.12 (1.69) *	0.11 (2.37) **	-0.10 (-1.82) *
R-squared (within)	0.27	0.14	0.34
Number of observations	2,611	4,599	4,430

Note: The table shows the results of fixed effects (within) estimation of the baseline panel specification (1) by category of R&D orientation. The dependent variables are the shares of the three categories in total R&D expenditures. As these range between 0 and 1 the variables are logit-transformed. All estimations include industry-year dummies. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

For three out of the four schemes of partial exemption there are statistically significant indications that they raise the share of R&D expenditures oriented towards experimental development, in line with the US evidence reported by Arora et al. (2018) that (especially large) firms tend to shift the focus of their R&D activities to product development and commercialization, away from basic research.

Table 29 shows the results of an estimation of the impact of public support on the composition of R&D employment in terms of educational degree. The coefficient estimates are mostly not significant. The partial exemption for R&D employees with a master's degree somewhat surprisingly appear to raise the share of PhDs and civil engineers whereas the partial exemption for research cooperation increases the share of R&D employees with a qualification below 1st stage tertiary education.

Table 29 Results of panel estimation of the impact on the composition of R&D personnel (2003-2015)

Dependent variable: share in R&D employment	PhD	University - Tertiary (2nd stage)	Tertiary 1st stage	Other qualifications
Explanatory variables:				
Regional subsidy	-0.00 (-0.11)	0.01(1.12)	-0.02 (-1.83) *	-0.01 (-0.97)
Research cooperation	-0.01 (-0.83)	-0.00 (-0.14)	-0.01 (-0.59)	0.03 (2.34) **
Young Innovative Company	-0.03 (-1.07)	0.01 (0.55)	0.01 (0.32)	-0.00 (-0.20)
PhDs and civil engineers	-0.00 (-0.07)	0.01 (1.18)	-0.00 (-0.28)	0.00 (0.05)
Master	0.03 (2.48) **	-0.01 (-1.31)	-0.01 (-1.31)	0.01 (0.62)
Tax credit R&D	0.00 (0.45)	-0.00 (-0.38)	0.00 (0.47)	-0.00 (-0.18)
Tax deduction 80% patent income	0.01 (0.78)	-0.00 (-0.44)	-0.00 (-0.16)	-0.01 (-0.54)
Control variables:				
Value added	0.03 (1.04)	0.02 (0.51)	-0.02 (-0.81)	-0.03 (-1.35)
Number of employees	-0.04 (-0.37)	0.15 (2.07) **	-0.17 (-1.71) *	-0.27 (-2.14) **
Age	0.01 (0.06)	-0.06 (-0.37)	0.01 (0.08)	-0.21 (-0.69)
Capital intensity	-0.05 (-0.76)	-0.00 (-0.03)	-0.04 (-0.81)	-0.02 (-0.31)
R-squared	0.24	0.34	0.17	0.20
Number of observations	1,887	3,608	2,667	1,674

Note: The table shows the results of fixed effects panel regression, using the logit of the shares of specific groups of R&D personnel, grouped by educational degree. All estimations include industry-year dummies. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

5.3. Output additionality

This chapter reports the results of estimations of the impact of public support to business R&D on productivity, profitability and the number of patents granted to firms in Belgium.

Business R&D is generally perceived as an important determinant of innovation, technological progress and productivity growth. The potential impact results from the direct contribution to the performance of R&D active companies but also from spillovers of these R&D activities to the rest of the economy. Spillovers are at the core of the argument for public support to business R&D as they imply that the social return to R&D exceeds the private return to R&D active firms. Given that the return to firms is uncertain and highly skewed, they may invest less in R&D than optimal from a social point of view. Although the aim of the tax incentives introduced by the federal government is to raise the input of the

R&D process, it is therefore also of interest to assess the potential impact of public support on the output of R&D.

Bloom et al. (2017) provide product-, firm- and industry-level evidence that the productivity of research activities has been falling for decades. To sustain growth, research effort needs to be raised to offset the decline in research productivity. The fact that productivity growth in Belgium has not increased substantially since 2005 despite the relatively strong increase in R&D intensity seems to corroborate these findings.

The main difficulty in assessing the output of R&D activities is the low success rate of R&D projects. Stevens and Burley (1997) report evidence that only about 1% of small R&D projects that are initiated can be considered successful. For projects closer to the actual development of products they consider odds between 1 in 7 up to 1 in 10. Estimates of the average return to R&D may fail to reflect the disproportionate positive contribution of the small number of very successful projects. Ugur et al. (2016) conclude, from a recent meta-regression based on 65 studies, that the private and social return to R&D is very heterogenous across studies and is smaller than what is reported in previous reviews. They recommend more attention to the lag structure of R&D investment, to assess the long-term impact and spillovers. Although spillovers are more likely to be captured at the industry-level or the economywide level, some of the estimations reported in this chapter include variables reflecting intra- and inter-industry spillovers.

Corredoira et al. (2018) find that research funded by the US federal government is associated with more active and diverse technological trajectories and appears to be linked to breakthrough inventions. Torregrosa-Hetland et al. (2019) report evidence for Finland and Sweden that public funding of research projects and research cooperation plays an increasingly prominent role in significant innovations.

In their seminal paper, Crépon, Duguet and Mairesse (1998) propose a model to estimate the link between R&D, innovation and productivity. Lööf, Mairesse and Mohnen (2017) offer a recent review of what is generally labelled as the CDM model. Crépon, Duguet and Mairesse (1998) acknowledge that firms do not necessarily have to do R&D to innovate or to be productive. As such, firms without R&D activities can also be included in the estimation. As the evaluation of the Belgian R&D tax incentives focuses on R&D active firms, the estimations reported in this chapter only consider the impact of R&D and distinguishes R&D active firms by the type of public support that they receive.

Table 30 shows the results of a panel regression of the impact of R&D expenditures on labour productivity (value added per employee) with firms grouped by the type of public support that they receive. Following Lehto (2007), the spillover variables denote the sum of R&D expenditures of all firms within the same industry (intra-industry) or the sum of R&D expenditures of all firms in other industries (inter-industry). R&D expenditures of firms are subtracted from the intra-industry sum of R&D expenditures. For the spillover variables a distinction is also made between firms that receive public support and firms that do not. To control for a potential selection bias, a first-step estimation of the probability to receive public support is considered, as in section 5.1.2, with the lag of labour productivity as one of the explanatory variables.

Table 30 Results of panel estimation of the impact on labour productivity (2003-2015)

Dependent variable: Labour productivity	No spillover variables	Spillover variables included
Explanatory variables (R&D expenditures):		
One-year lag labour productivity	0.25 (2.86) ***	0.17 (1.31)
No public support	-0.01 (-2.10) **	-0.02 (-2.03) **
Direct support only	0.16 (2.84) ***	0.21 (2.47) ***
Partial exemption only	-0.05 (-3.06) ***	-0.05 (-2.18) **
CIT incentives only	-0.09 (-2.47) ***	-0.09 (-1.90) *
Direct support and partial exemption	0.15 (2.26) **	0.24 (2.24) **
Direct support and CIT incentives	0.10 (2.38) **	0.19 (2.46) **
Partial exemption and CIT incentives	-0.08 (-2.92) ***	-0.05 (-1.32)
Direct, partial exemption and CIT	0.08 (1.87)	0.19 (2.17) ***
Spillovers		
Intra-industry no support		-0.05 (-1.16)
Intra-industry only subsidies		-0.01 (-1.33)
Intra-industry only tax incentives		0.04 (2.62) ***
Intra-industry subsidies and tax incentives		0.04 (3.81) ***
Inter-industry no support		-0.03 (-0.14)
Inter-industry only subsidies		-0.26 (-3.00) ***
Inter-industry only tax incentives		0.14 (2.46) ***
Inter-industry subsidies and tax incentives		0.24 (2.19) **
R-squared	0.50	0.52
Number of observations	11,116	7,042

Note: The table shows the results of a fixed effects panel regression, using labour productivity defined as value added per full-time equivalent employee as dependent variable and R&D expenditures of firms by group according to which type of public support that they receive, as explanatory variables. CIT: corporate income taxation (R&D tax credit and tax deduction for 80% of patent income). All variables are considered in logs. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of labour productivity is included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

The estimation reported in table 30 includes four inverse Mills ratios computed from this first-step estimation. Acknowledging the well-known persistence of productivity (see, for example, Raymond et al. 2010), the lag of labour productivity is also included. The statistically significant positive coefficient of lagged productivity confirms persistence. All variables on R&D expenditures by support group are included with a one-year lag, reflecting the delay in the impact of R&D activities. Estimations with longer lags tend to provide less significant results.[37]

Results suggest substantial differences in the impact of R&D on labour productivity, depending on which type of public support that firms receive. Most statistically significant positive coefficients fall within the 0.01-0.25 range reported for research productivity by Hall, Mairesse and Mohnen (2010). The strongest positive impact on productivity is found for firms that receive subsidies, whether they only benefit from subsidies or combine subsidies with partial exemption from payment of the withholding tax. Apparently, for firms that receive tax incentives through (CIT) corporate income taxation (R&D tax credit and tax deduction for 80% of patent income) the impact of R&D is negative, for single use and if combined with support through partial exemption.

[37] These results are not reported but available upon request.

The relatively strong negative coefficients of R&D expenditures of firms that benefit from tax incentives through corporate income taxation are hard to explain. This result seems to hint at the impact of profit shifting by multinational enterprises on measured productivity. Guvenen et al. (2017) provide evidence for the U.S. that productivity of domestic firms is underestimated as multinationals attribute part of economic activity to foreign affiliates.

Profit-shifting by US multinationals results in a considerable undermeasurement of aggregate productivity growth. Undermeasurement appears to be notable in R&D-intensive industries, as they produce intangible assets that can swiftly be moved across borders. Guvenen et al. (2017) find that value added in R&D-intensive industries increases by up to 8 percent annually in the mid-2000s if corrected for profit-shifting. The Belgian Policy Mix database so far does not contain a variable that reflects possible affiliation of firms to a domestic or foreign multinational group. This information may be a worthwhile addition to the data for future analysis.

The opposite signs of the impact of R&D and productivity may explain why if only a single variable for R&D expenditures is considered, the estimate of its impact on productivity is very small (negative) and not statistically significant.[38] The results indicate the need to account for firm heterogeneity in the impact of R&D expenditures and suggest that the type of public support that firms receive may be informative although caution in the interpretation of the results is warranted given the caveat of the potential impact of profit-shifting.

The estimation that includes spillover variables, reported in the third column in table 30, confirms the results for the effects of R&D by type of support group in the second column. Whereas a positive impact of own R&D is mainly found for firms that receive direct support (subsidies), spillovers result more from firms that benefit from tax incentives, with indications of substantial inter-industry spillovers. Estimates suggest negative inter-industry spillovers from firms that only receive direct support. On the other hand, for firms that combine subsidies with tax incentives, inter-industry spillovers are positive and substantial.

The coefficient of the lag of productivity is not statistically significant when spillover variables are included. This could indicate that the lag to some extent reflects the capacity of firms to absorb the knowledge that results from the R&D activities of other firms.

The impact of R&D on productivity may differ according to the orientation of R&D activities. The following three tables (table 31 up to table 33) show the results of a panel estimation of the impact of R&D on productivity, by type of support group, in which firms are split into two groups depending on whether they belong to the bottom or the upper half of the distribution in terms of the average share of R&D expenditures oriented towards respectively, basic research, applied research and experimental development. The results are to a large extent in line with the results reported in the second column of table 30 but reveal substantial differences between firms depending on which group they belong to. For example, the positive effects of R&D for firms that receive direct support, above all apply to firms with a share oriented towards basic research or applied research below the median and a share oriented towards experimental development above the median.

38 Results are not reported but available upon request.

Table 31 Results of panel estimation of the impact on labour productivity by share basic research (2003-2015)

	Bottom 50% basic research	Top 50% basic research
Dependent variable: Labour productivity		
Explanatory variables (R&D expenditures):		
One-year lag labour productivity	0.13 (1.25)	0.31 (3.34) ***
No public support	-0.02 (-2.03) **	-0.01 (-1.42)
Direct support only	0.24 (2.44) **	0.13 (1.97) **
Partial exemption only	-0.08 (-2.48) **	-0.03 (-2.50) **
CIT incentives only	-0.10 (-2.33) **	-0.08 (-1.64) *
Direct support and partial exemption	0.22 (2.22) **	0.13 (1.54)
Direct support and CIT incentives	0.22 (2.26) **	0.06 (1.44)
Partial exemption and CIT incentives	-0.07 (-1.66) *	-0.09 (-2.40) **
Direct, partial exemption and CIT	0.18 (1.89) *	0.05 (1.06)
R-squared	0.54	0.49
Number of observations	4,589	5,215

Note: The table shows the results of fixed effects panel regression, using labour productivity defined as value added per full-time equivalent employee as dependent variable and a one-year lag of R&D expenditures of firms by group according to which type of public support that they receive. CIT: corporate income taxation (R&D tax credit and tax deduction for 80% of patent income). The second (third) column shows the results for the 50% of firms with the lowest (highest) share of R&D expenditures oriented towards basic research. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of labour productivity is included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

Table 32 Results of panel estimation of the impact on labour productivity by share applied research (2003-2015)

	Bottom 50% applied research	Top 50% applied research
Dependent variable: Labour productivity		
Explanatory variables (R&D expenditures):		
One-year lag labour productivity	0.28 (2.88) ***	0.15 (0.89)
No public support	-0.02 (-1.73) *	-0.00 (-0.22)
Direct support only	0.23 (2.35) **	0.08 (2.22) **
Partial exemption only	-0.06 (-1.89) *	-0.03 (-2.24) **
CIT incentives only	-0.11 (-1.79) *	-0.06 (-2.55) ***
Direct support and partial exemption	0.23 (1.80) *	0.07 (1.78) *
Direct support and CIT incentives	0.12 (1.67) *	0.05 (1.39)
Partial exemption and CIT incentives	-0.11 (-2.64) ***	-0.04 (-1.89) *
Direct, partial exemption and CIT	0.13 (1.60)	0.04 (0.91)
R-squared	0.42	0.63
Number of observations	4,962	4,860

Note: The table shows the results of fixed effects panel regression, using labour productivity defined as value added per full-time equivalent employee as dependent variable and a one-year lag of R&D expenditures of firms by group according to which type of public support that they receive, as explanatory variables. CIT: corporate income taxation (R&D tax credit and tax deduction for 80% of patent income). The second (third) column shows the results for the 50% of firms with the lowest (highest) share of R&D expenditures oriented towards applied research. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of labour productivity is included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

Table 33 Results of panel estimation of the impact on labour productivity by share experimental development (2003-2015)

	Bottom 50% experimental development	Top 50% experimental development
Dependent variable: Labour productivity		
Explanatory variables (R&D expenditures):		
One-year lag labour productivity	0.42 (10.28) ***	0.08 (0.97)
No public support	-0.01 (-1.14)	-0.01 (-1.37)
Direct support only	0.12 (1.78) *	0.18 (2.43) ***
Partial exemption only	-0.02 (-1.73) *	-0.06 (-2.15) **
CIT incentives only	-0.08 (-2.11) **	-0.08 (-1.58)
Direct support and partial exemption	0.13 (1.52) *	0.17 (1.70) *
Direct support and CIT incentives	0.06 (1.16)	0.13 (2.11) **
Partial exemption and CIT incentives	-0.08 (-2.38) **	-0.07 (-2.13) **
Direct, partial exemption and CIT	0.06 (0.99)	0.11 (1.64) *
R-squared	0.63	0.44
Number of observations	4,825	4,993

Note: The table shows the results of fixed effects panel regression, using labour productivity defined as value added per full-time equivalent employee as dependent variable and a one-year lag of R&D expenditures of firms by groups according to which type of public support that they receive, as explanatory variables. CIT: corporate income taxation (R&D tax credit and tax deduction for 80% of patent income). The second (third) column shows the results for the 50% of firms with the lowest (highest) share of R&D expenditures oriented towards experimental development. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of labour productivity is included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

The estimates suggest that experimental development has a more positive impact on productivity than basic and applied research although for the latter longer lags may be more appropriate.[39] Knott (2017) argues that although radical innovation, which more likely results from basic research than from experimental development, may benefit the whole economy, it tends to have a lower return to firms than incremental innovation. An alternative explanation may be that estimates of the average private return to firms fail to capture the potentially disproportionate positive outcome of a small number of successful basic and applied research activities.

Table 34 shows the results of an estimation of the impact of R&D on net profitability, using the same explanatory variables as in table 30. However, instead of using one-year lags for the right-hand side variables, the support group variables are included contemporaneously and the spillover variables with a one-year lag.

Specifications with alternative lags provide few statistically significant estimates or negative estimates.[40] In contrast with the results for labour productivity, R&D has a positive impact on profitability for firms that benefit from tax incentives through corporate income taxation if combined with subsidies or partial exemption whereas statistically significant positive spillovers are now found for firms that receive subsidies, used without other forms of public support or combined with tax incentives.

39 Estimations with two-year and three-year lags do not provide evidence of higher returns for firms with a high share of basis or applied research. These estimations are not reported but available upon request.

40 Results not reported but available upon request.

Table 34 Results of panel estimation of the impact on net profitability (2003-2015)

	No spillover variables	Spillover variables included
Dependent variable: Net profitability		
Explanatory variables (R&D expenditures):		
Lag net profitability	0.19 (8.20) ***	0.11 (4.06) ***
No public support	0.00 (1.12)	0.00 (0.62)
Direct support only	0.01 (1.13)	0.02 (1.48)
Partial exemption only	0.01 (1.42)	0.00 (1.34)
CIT incentives only	0.01 (0.73)	0.00 (0.02)
Direct support and partial exemption	0.01 (0.90)	0.01 (0.76)
Direct support and CIT incentives	0.03 (2.62) ***	0.04 (2.97) ***
Partial exemption and CIT incentives	0.02 (2.25) **	0.02 (1.44)
Direct, partial exemption and CIT	0.01 (0.97)	0.01 (0.68)
Spillovers		
Intra-industry no support		-0.04 (-1.01)
Intra-industry only subsidies		0.05 (2.93) ***
Intra-industry only tax incentives		-0.03 (-1.32)
Intra-industry subsidies and tax incentives		0.05 (1.81) *
Inter-industry no support		-0.27 (-0.58)
Inter-industry only subsidies		0.19 (1.44)
Inter-industry only tax incentives		-0.09 (-0.92)
Inter-industry subsidies and tax incentives		0.54 (1.73) *
R-squared (overall)	0.11	0.08
Number of observations	6,873	4,431

Note: The table shows the results of fixed effects panel regression, using net profitability as dependent variable and R&D expenditures of firms by group according to which type of public support that they receive, as explanatory variables. CIT: corporate income taxation (R&D tax credit and tax deduction for 80% of patent income). Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of net profitability is included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

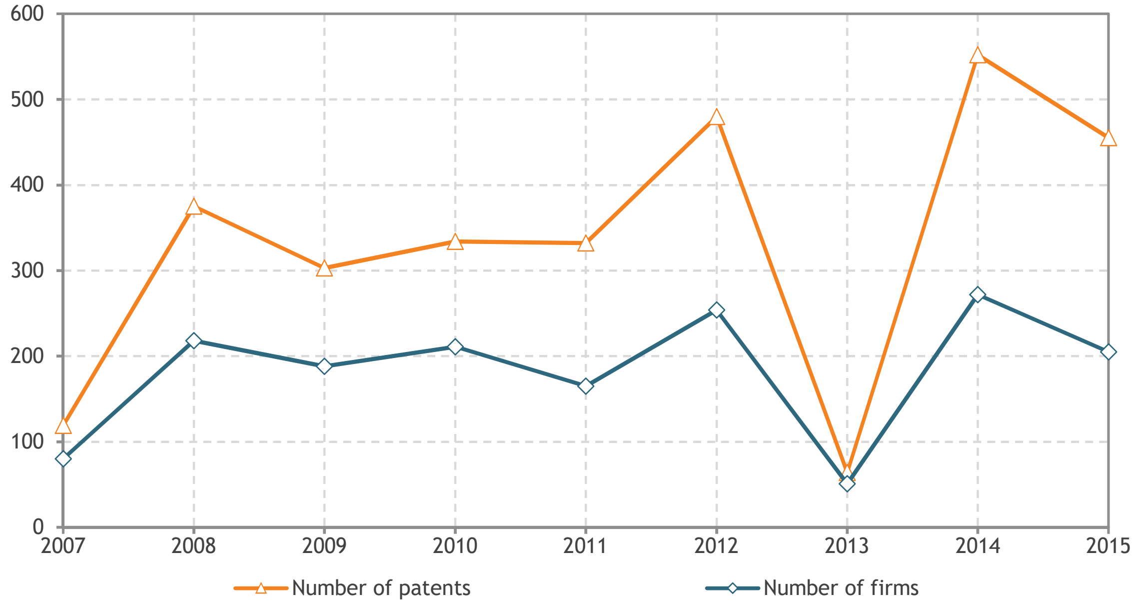
Patents provide an indication of the intermediate output of research activities. The use of patents in protecting industrial applicability of inventions that result from R&D activities is very industry-specific. They are very important for pharmaceuticals and chemicals but not for office equipment. The benefits of patents to foster innovation are much debated. Sampat (2018) provides a recent review of the empirical evidence on patents and their role in innovation.

Bornemann, Laplante and Osswald (2018) investigate the impact of the Belgian tax deduction for patent income. Comparing Belgian firms to German firms, which do not benefit from any tax incentive for patent income, they conclude that the Belgian patent box increases the number of patents granted by the European Patent Office to Belgian firms but has a negative impact on the average quality of patents. They also consider the impact on the effective tax rate due to the patent box. Belgian multinationals that do not have an opportunity to shift income abroad would have the highest tax rate savings, followed by domestic firms. Multinationals with the opportunity to shift income abroad do not experience a significant reduction in their effective tax rate due to the Belgian patent box.[41] Cantner and Kösters (2015) report a positive impact of R&D subsidies on patent application by East German high-tech start-ups.

[41] The potential to shift income abroad is denoted by an indicator variable that takes a value of one if the statutory tax rate of a foreign subsidiary or parent is lower than the Belgian statutory tax rate, and zero otherwise (Bornemann, Laplante and Osswald 2018: p. 39).

Using the data on the number of patents granted in Belgium in the R&D Policy Mix database, table 35 shows the results of an estimation of the impact of public support on the number of patents granted to firms by the Belgian Office for Intellectual Property. Graph 15 shows the number of granted Belgian patents and the number of firms with granted patents for the period 2007-2015.

Graph 15 Number of Belgian patents granted and number of firms with granted patents (2007-2015)



As the dependent variable is a count variable with many zero values, a zero-inflated Poisson regression is used (see Lambert 1992, Cameron and Trivedi 2010).[42] The Vuong test compares a zero-inflated Poisson specification to a standard Poisson specification. Rejection of the null hypothesis favours a zero-inflated Poisson specification.

There are rather robust indications of a positive impact of R&D expenditures on the number of patents for firms that receive direct support or that benefit from one of the four partial exemption schemes.

The estimation includes four inverse Mills variables from a first-step estimation of a selection model in which the lag of the number of patents granted is included as one of the explanatory variables. The results of a specification with respectively a one- year and a two-year lag for R&D expenditures are reported.

Contrary to the finding by Bornemann, Laplante and Osswald (2018), R&D expenditures of firms that benefit from tax incentives based on corporate income taxation, such as the tax deduction of 80% of patent income, do not appear to have a statistically significant impact on the number of granted patents, except if combined with subsidies or partial exemption. The estimation only considers Belgian patents and not patents granted by the European Patent Office or the United States Patent and Trademark Office.

[42] As can be seen on the last line of Table 35, there are relatively few non-zero observations as not many Belgian patents appear to be granted.

Table 35 Results of panel estimation of the impact on the number of Belgian patents (2003-2015)

	One-year lag	One-year lag	Two-year lag	Two-year lag
Dependent variable: Number of patents				
Explanatory variables (R&D expenditures):				
No public support	0.09 (3.98) ***	0.09 (2.39) **	-0.01 (-0.24)	0.02 (0.56)
Direct support only	0.20 (6.39) ***	0.33 (5.52) ***	0.05 (2.23) **	0.03 (0.87)
Partial exemption only	0.25 (4.52) ***	0.16 (1.39)	0.13 (4.88) ***	0.10 (2.39) **
CIT incentives only	0.03 (0.63)	0.02 (0.38)	-0.05 (-0.70)	-0.01 (-0.29)
Direct support and partial exemption	0.22 (4.13) ***	0.21 (1.94) *	0.11 (4.10) ***	0.09 (2.15) **
Direct support and CIT incentives	0.04 (1.04)	0.10 (2.19) **	0.00 (0.19)	0.06 (1.14)
Partial exemption and CIT incentives	0.06 (0.89)	-0.11 (-0.89)	0.10 (3.59) ***	0.10 (2.22) **
Direct, partial exemption and CIT	0.15 (2.66) ***	0.13 (1.16)	0.11 (3.89) ***	0.13 (2.73) ***
Spillovers:				
Intra-industry no support		0.39 (2.69) ***		-0.15 (-0.63)
Intra-industry only subsidies		0.05 (0.82)		0.07 (1.01)
Intra-industry only tax incentives		-0.12 (-1.21)		0.24 (2.09) **
Intra-industry subsidies and tax incentives		0.09 (0.99)		-0.11 (-1.18)
Inter-industry no support		7.61 (2.56) ***		0.15 (0.04)
Inter-industry only subsidies		0.31 (1.09)		-0.21 (-0.93)
Inter-industry only tax incentives		2.20 (1.32)		4.99 (2.97) ***
Inter-industry subsidies and tax incentives		5.19 (2.02) **		2.31 (1.02)
Vuong test zero-inflated Poisson	6.38 (0.00) ***	6.32 (0.00) ***	6.01 (0.00) ***	4.89 (0.00) ***
Number of observations (non-zero)	11,362 (279)	7,172 (209)	6,851 (213)	4,181 (156)

Note: The table shows the results of a zero-inflated Poisson regression, using the number of patents granted to firms in Belgium as dependent variable and R&D expenditures of firms by group according to which type of public support that they receive, as explanatory variables. CIT: corporate income taxation (R&D tax credit and tax deduction for 80% of patent income). Estimations include year dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of the number of granted patents is included. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity. The Vuong test compares a zero-inflated Poisson to a standard Poisson regression. Rejection of the null hypothesis favours zero-inflated Poisson.

The different results may indicate that the tax deduction for patent income results in the shifting of international patents by multinationals and not necessarily in an increase of patents granted as a result of domestic R&D activities.

Although the estimations reported in this chapter ought to be considered with caution, the results indicating that R&D investment by firms that receive public support has a stronger impact on the output of firms and also results in more spillovers than R&D performed by firms that do not receive public support, suggests that subsidies and tax incentives not only increase the input but also positively affects the output of business R&D.

Profit shifting may affect most output indicators such as profits, value added and productivity. For future evaluation it would be worthwhile to include information on the potential of profit shifting such as affiliation of a firm to a multinational group.

6. Conclusions

The third evaluation of the tax incentives in support of business R&D in Belgium, presented in this paper, provides relatively robust indications that the four schemes of partial exemption from payment of the withholding tax on the wages of R&D employees succeed in raising additional R&D activities. As in the previous evaluation, this applies especially to the partial exemption for R&D employees with a master's degree whereas for the three other schemes (research cooperation, Young Innovative Companies and R&D employees with a PhD or civil engineering degree), more robust evidence of additionality is found than in the previous evaluation.

On the other hand, the lack of evidence on the efficiency of the tax credit for R&D investment and the tax deduction for 80% of gross qualifying patent income reported in the previous evaluation is confirmed. Equally in line with previous evaluations, the third evaluation finds that additionality of public support is reduced if firms combine different support schemes, especially if firms combine direct support (subsidies) with several tax incentives.

The rate of partial exemption from payment of the withholding tax is the same for PhDs or civil engineers and masters. As PhDs and civil engineers, by definition, have a master's degree, the usefulness of the distinction between the two partial exemption schemes based on the educational degree of R&D employees is not clear. The partial exemption from payment of the withholding tax on the wages of R&D employees with a bachelor's degree in qualifying study fields was introduced too recently (January 2018) to be included in this evaluation as is the tax deduction for innovation income which replaced the tax deduction for patent income in 2016.

The efficiency of public support seems to decrease with firm size and with the level of public support. For the R&D tax credit the coefficient is positive for firms with not more than 50 employees whereas the coefficient is negative for firms with more than 250 employees. There are also indications that the additionality of support decreases with the degree of market concentration of industries, especially for the R&D tax credit, the tax deduction for 80% of patent income and the partial exemption from payment of the withholding tax for Young Innovative Companies. These findings indicate that some differentiation in public support across industries - for example, according to the level of market competition – may be considered although it may be challenging to ensure that this complies with EU rules on state aid. It certainly indicates that further investigation of the link between R&D investment and market competition is warranted, from a static as well as from a dynamic perspective.

Three of the four partial exemption schemes appear to result in a relative shift in R&D investment towards experimental development at the expense of basic and applied research which lends support to concerns that especially large firms increasingly shy away from basic and applied research which are probably more vital to long-term technological progress and economic growth than experimental development.

Estimation of the impact of public support on the output of firms suggests relatively strong positive effects of R&D activities of firms that receive direct support (regional subsidies). The large negative coefficients found for firms that receive tax benefits though corporate income taxation are difficult to explain and may hint at a bias in output indicators due to profit shifting, as reported in some studies. Future evaluation may consider information on the profit shifting potential of firms, such as the affiliation of a firm to a multinational group.

Although the impact of the recent reform of Belgian corporate income taxation (for example, reduction in the tax rate) remains uncertain, the strong increase in the budgetary cost of the R&D tax incentives in Belgium calls for reflection on possible ways to slow down the rise in government support through tax incentives as a percentage of GDP. The two tax incentives for which few indications of efficiency can be found account for the bulk of the budgetary cost of tax incentives in support of business R&D. The tax deduction for patent income was replaced in 2016 by a tax deduction for innovation income, in accordance with the OECD Base Erosion Profit Shifting (BEPS) guidelines. The R&D tax credit therefore seems the most obvious support scheme for adjustment, in a way that constrains the increase in the budgetary cost without hindering the potential of tax incentives to raise additional R&D activities. Recent reforms of the French R&D tax credit, which appear to have contained the rise in the budgetary cost as a percentage of GDP, offer an interesting benchmark.

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Annexes

Annex 1: List of NACE REV.2 industries

1	Crop and animal production, hunting and related service activities
2	Forestry and logging
3	Fishing and aquaculture
5	Mining of coal and lignite
6	Extraction of crude petroleum and natural gas
7	Mining of metal ores
8	Other mining and quarrying
9	Mining support service activities
10	Manufacture of food products
11	Manufacture of beverages
12	Manufacture of tobacco products
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17	Manufacture of paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31	Manufacture of furniture
32	Other manufacturing
33	Repair and installation of machinery and equipment
35	Electricity, gas, steam and air conditioning supply
36	Water collection, treatment and supply
37	Sewerage
38	Waste collection, treatment and disposal activities; materials recovery
39	Remediation activities and other waste management services
41	Construction of buildings
42	Civil engineering
43	Specialised construction activities
45	Wholesale and retail trade and repair of motor vehicles and motorcycles
46	Wholesale trade, except of motor vehicles and motorcycles
47	Retail trade, except of motor vehicles and motorcycles
49	Land transport and transport via pipelines

50	Water transport
51	Air transport
52	Warehousing and support activities for transportation
53	Postal and courier activities
55	Accommodation
56	Food and beverage service activities
58	Publishing activities
59	Motion picture, video and television programme production, sound recording and music publishing activities
60	Programming and broadcasting activities
61	Telecommunications
62	Computer programming, consultancy and related activities
63	Information service activities
64	Financial service activities, except insurance and pension funding
65	Insurance, reinsurance and pension funding, except compulsory social security
66	Activities auxiliary to financial services and insurance activities
68	Real estate activities
69	Legal and accounting activities
70	Activities of head offices; management consultancy activities
71	Architectural and engineering activities; technical testing and analysis
72	Scientific research and development
73	Advertising and market research
74	Other professional, scientific and technical activities
75	Veterinary activities
77	Rental and leasing activities
78	Employment activities
79	Travel agency, tour operator and other reservation service and related activities
80	Security and investigation activities
81	Services to buildings and landscape activities
82	Office administrative, office support and other business support activities
84	Public administration and defence; compulsory social security
85	Education
86	Human health activities
87	Residential care activities
88	Social work activities without accommodation
90	Creative, arts and entertainment activities
91	Libraries, archives, museums and other cultural activities
92	Gambling and betting activities
93	Sports activities and amusement and recreation activities
94	Activities of membership organisations
95	Repair of computers and personal and household goods
96	Other personal service activities
97	Activities of households as employers of domestic personnel
98	Undifferentiated goods- and services-producing activities of private households for own use
99	Activities of extraterritorial organisations and bodies

Annex 2: Comparison of joint estimation of all support schemes with separate estimation

Table A.1 Results of fixed effects panel estimation (2003-2015) – Joint versus separate estimation

	Joint	Separate
Dependent variable (R&D expenditures net of public support)		
Explanatory variables (public support):		
Regional subsidy	0.09 (7.90) ***	0.10 (8.83) ***
Research cooperation	0.12 (4.58) ***	0.14 (5.69) ***
Young Innovative Company	0.12 (3.25) ***	0.10 (2.57) **
PhDs and civil engineers	0.08 (4.76) ***	0.14 (7.99) ***
Master	0.14 (8.67) ***	0.17 (10.15) ***
Tax credit R&D	0.01 (0.24)	0.06 (2.33) **
Tax deduction 80% patent income	-0.02 (-1.14)	0.03 (1.45)

Note: The table compares the results of Log1 as reported in the second column of table 10 in which the impact of all support schemes is estimated jointly to a fixed effects panel estimation in which each support scheme is considered separately, in effect, without controlling for the public support that firms receive through other schemes. All estimations include industry and year dummies. All variables are considered in logs. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity.

The results show that ignoring support received through other schemes results in overestimation of the efficiency and statistical significance of individual schemes, except for the partial exemption for Young Innovative Companies. This is especially true for the R&D tax credit for which separate estimation provides a statistically significant positive coefficient which is not the case if support through other schemes is controlled for. For the tax deduction of 80% of patent income, separate estimation results in a positive , though not statistically significant, coefficient whereas in the joint estimation the coefficient is negative (also not statistically significant).

Annex 3: Revised Pavitt taxonomy for manufacturing and services (Bogliacino and Pianta 2015)

	Nace REV.2	Pavitt
SCIENCE BASED		
Manufacture of chemicals and chemical products	20	1
Manufacture of basic pharmaceutical products and pharmaceutical prep.	21	1
Manufacture of computer, electronic and optical products	26	1
Telecommunications	61	1
Computer programming, consultancy and related activities	62	1
Scientific research and development	72	1
SPECIALISED SUPPLIERS		
Manufacture of electrical equipment	27	2
Manufacture of machinery and equipment n.e.c.	28	2
Manufacture of other transport equipment	30	2
Repair and installation of machinery and equipment	33	2
Real estate activities	68	2
Legal and accounting activities	69	2
Management consultancy activities	70	2
Architectural and engineering activities; technical testing and analysis	71	2
Advertising and market research	73	2
Other professional, scientific and technical activities	74	2
Rental and leasing activities	77	2
Office administrative, office support and other business support activities	82	2
SCALE AND INFORMATION INTENSIVE		
Manufacture of paper and paper products	17	3
Printing and reproduction of recorded media	18	3
Manufacture of coke and refined petroleum products	19	3
Manufacture of rubber and plastic products	22	3
Manufacture of other non-metallic mineral products	23	3
Manufacture of basic metals	24	3
Manufacture of motor vehicles, trailers and semi-trailers	29	3
Publishing activities	58	3
Audiovisual activities	59	3
Broadcasting activities	60	3
Information service activities	63	3
Financial service activities, except insurance and pension funding	64	3
Insurance, reinsurance and pension funding, except compulsory social security	65	3
Activities auxiliary to financial services and insurance activities	66	3

SUPPLIERS DOMINATED	Nace REV.2	Pavitt
Manufacture of food products	10	4
Manufacture of beverages	11	4
Manufacture of tobacco products	12	4
Manufacture of textiles	13	4
Manufacture of wearing apparel	14	4
Manufacture of leather and related products	15	4
Manufacture of wood and of products of wood and cork, except furniture	16	4
Manufacture of fabricated metal products, except machinery and equipment	25	4
Manufacture of furniture	31	4
Other manufacturing	32	4
Wholesale and retail trade and repair of motor vehicles and motorcycles	45	4
Wholesale trade, except of motor vehicles and motorcycles	46	4
Retail trade, except of motor vehicles and motorcycles	47	4
Land transport and transport via pipelines	49	4
Water transport	50	4
Air transport	51	4
Warehousing and support activities for transportation	52	4
Postal and courier activities	53	4
Accommodation and food service activities	55	4
Accommodation and food service activities	56	4
Veterinary activities	75	4
Employment activities	78	4
Travel agency, tour operator reservation service and related activities	79	4
Security and investigation activities	80	4
Services to buildings and landscape activities	81	4