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Public Support to Business Research and Development in Belgium

Fourth evaluation

November 2022

Michel Dumont, dm@plan.be

Rue Belliard 14-18 – Belliardstraat 14-18
1040 Brussels

e-mail: contact@plan.be
https://www.plan.be

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https://www.plan.be
e-mail: contact@plan.be

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Federal Planning Bureau
Rue Belliard – Belliardstraat 14-18, 1040 Brussels
phone: +32-2-5077311
e-mail: contact@plan.be
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Abstract - Belgium met its Europe 2020 target that Research and Development (R&D) expenditures should equal 3% of Gross Domestic Product. This report presents the results of an evaluation of the extent to which public support to business R&D has been instrumental in reaching this target, by stimulating additional R&D expenditures of firms. Regional direct support (subsidies), and the federal partial exemption from payment of the withholding tax on the wages of R&D personnel, appear to encourage firms to increase their investment in R&D activities, in addition to the amount of public support that they receive. By contrast, some incentives provided through corporate income taxation (CIT) seem to have no additionality effect or even result in the crowding out of firms' own R&D expenditures. As the CIT incentives claim the lion's share of the rapidly rising budgetary cost of public support to business R&D, the efficiency of tax incentives for R&D activities could be increased by introducing a cap on the total amount of public support that companies can receive, as suggested by the findings of a cross-country OECD study.

Jel Classification - H32, L10, L26, O32, O38
Keywords - Business R&D, tax incentives, subsidies, policy mix, evaluation, spillovers

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Executive summary

Belgium was one of only seven EU countries to reach its Europe 2020 Research and Development (R&D) investment target in 2020. With R&D expenditures equal to 3.48% of Gross Domestic Product (GDP), Belgium amply exceeded its 3% R&D intensity target and took second place, narrowly behind Sweden. The high R&D intensity in 2020 is partially explained by a Covid-19-induced drop in GDP (the denominator of R&D intensity), but Belgium is nevertheless one of the EU countries with the highest increase in R&D intensity since 2010.

In fulfilment of its commitment to the 3% target, set at the 2002 Barcelona European Council meeting, the Belgian federal government introduced several tax incentives in support of business R&D, starting from 2005. This indirect support through tax benefits supplemented the existing substantial direct support (subsidies), provided by the three Belgian regions. The R&D tax incentives were provided through personal income taxation, such as a partial exemption from payment of the withholding tax on the wages of R&D personnel, or through corporate income taxation, such as a tax credit for R&D investment and a patent income deduction. In 2018 a partial exemption for R&D personnel with a bachelor's degree was added to the four existing partial exemption schemes. The patent income deduction, introduced in 2008, was replaced in 2016 (phased out in 2021) by an innovation income deduction, developed according to the Base Erosion and Profit Shifting (BEPS) guidelines of the OECD, which aim to tackle harmful tax avoidance by multinational enterprises. The tax incentives for business R&D have gradually gained popularity and the estimated budgetary cost consequently increased substantially, reaching a total of 2,782 million euro in 2019 (0.59% of GDP), especially due to a strong increase in the cost of the corporate income taxation benefits.

This report presents the results of the fourth evaluation of public support to business R&D in Belgium, which aims at providing an indication of the extent to which direct support (regional subsidies) and indirect support (tax incentives) have contributed to the strong rise in R&D intensity, by supporting R&D activities of companies that would not have been performed without public support. The assessment of the effectiveness and efficiency of public support is complicated by data limitations and the difficulty of estimation procedures to provide an indication of the causal impact of support on the R&D expenditures of companies. In keeping with the previous evaluations, the estimation strategy adopted in this evaluation is to consider a baseline estimation and to compare the results with the results from alternative estimation procedures, to establish whether robust conclusions can be obtained.

The evaluation provides robust indications that direct support (regional subsidies), and the partial exemption from payment of the withholding tax on the wages of R&D personnel, encourage companies to invest in R&D activities, in addition to the public support that they receive. This result confirms the conclusions of the previous evaluations. This finding also holds for the partial exemption for R&D employees with a bachelor's degree, which was not included in previous evaluations as it was only introduced in 2018. Equally in line with previous evaluations, there are few indications of additionality for the tax credit for R&D investment and the patent income deduction. The tax deduction for R&D investment, which given partial information was not fully assessed in the previous evaluations, is found to result in additional R&D expenditures by companies. The most worrying finding of this fourth evaluation concerns the innovation income deduction. This corporate income taxation incentive was introduced in 2016 to replace the patent income deduction. The estimations presented in this report provide robust indications of crowding out for this tax scheme, that is, it appears that the innovation income deduction is financing R&D expenditures that companies would finance themselves in the absence of the tax support. The fact that the corporate income taxation incentives, except for the tax deduction for R&D investment, seem ineffective or even result in crowding out, points at an opportunity to increase the efficiency of R&D tax benefits, especially considering that they claim the lion's share of the budgetary cost of public support to business R&D in Belgium.

This report also provides estimates of the impact of the innovation bonus, which consists in a compensation that is exempted from social security contributions, for workers that generate innovative ideas within a company, and EU funding of research by Belgian companies. Estimates suggest additionality for the innovation bonus but crowding out for EU funding.

Considering distinct groups of firms and industries along several dimensions, reveals substantial heterogeneity in the impact of public support, even with opposite signs for different groups of firms and industries, that may cancel each other out in estimations that consider all R&D active firms as a homogenous population. For example, it appears that the crowding out of some corporate income taxation incentives mainly applies to large and older firms, firms that belong to a multinational group, and to highly concentrated industries. These results should draw attention to the potentially negative impact of public support on market dynamism, as it may reinforce market concentration and winners-take-most effects, and to low efficiency of public support in highly concentrated industries. The results in this report reveal substantial heterogeneity in the impact of public support across industries, but even more so across firms (within industries). This suggests that by targeting specific industries or groups of firms, the effectiveness and efficiency of public support may be increased. Such an approach however requires a well-defined and evidence-based framework, which does not appear in prospect today. Moreover, the conditionality of public support may be at odds with EU state aid rules, which generally prohibit public support to specific companies or industries, although this is right at the core of the current discussion on industrial policy and mission-oriented programs.

In line with the previous evaluations, there are clear indications that when companies combine several public support schemes, the effectiveness of individual instruments in stimulating R&D decreases substantially. However, the combination of different support instruments does not appear to be the problem as such, but rather the combination of large amounts of support without any cap on the total amount of public support that companies receive. The effectiveness of public support decreases with increasing total public support, both in terms of the rate of support and the total amount of support. The crowding out of corporate income taxation incentives is revealed at the highest levels of the total amount of public support. This suggests that the introduction of a cap on public support can contribute to an increase in the efficiency and can be instrumental in containing the considerable rise in the budgetary cost of public support, which is predominantly due to those tax incentives that appear least effective. An analysis of 20 OECD countries, including Belgium, indicates that R&D tax incentive schemes that cap the amount of supported R&D expenditure, or reduce the support rate once a certain threshold has been reached, are likely to show greater additionality.

Arguments for public support to business R&D rely mainly on the assumed existence of a positive impact from the R&D activities of companies on the rest of the economy. These spillovers create a gap between the private return to R&D and the social return to R&D. As companies are only interested in the private return of their R&D activities, they may not invest sufficiently from a societal perspective, hence the potential role of subsidies and tax incentives to support business R&D. This report examines, in more detail than the previous evaluations, the role of public support in the potential results of R&D activities. The choice of output indicator, and of variables through which spillovers may be detected, is however not trivial and hampered by the lack of a clear indication as to which output indicators law makers had in mind when introducing public support. Considering indicators like productivity, turnover, value added and profit, self-financed R&D seems to generate a positive private return. The private return to R&D financed with regional subsidies appears to be even higher than self-financed R&D. The private return to R&D financed through partial exemption from payment of the withholding tax is found to be negative in some cases, which could indicate that R&D activities financed through these schemes support marginal activities. Estimates also suggest that R&D financed through corporate income taxation incentives generates a positive return for the beneficiaries of the support, though generally lower than the return to self-financed R&D and R&D financed with regional subsidies. However, as these tax incentives can only be used by profitable firms and firms with successful past R&D activities, resulting in current patent or innovation income, estimates of a positive “impact” on output may simply reflect that good performance is a necessary condition to benefit from these tax incentives. There are indications of positive spillovers, for example from R&D of firms that combine support schemes, but also of negative spillovers which may hint at business-stealing effects and imitation by laggards. Young firms, domestic firms that do not belong to a multinational group, and firms with only occasional R&D activities, do not appear to benefit from R&D by other firms. This casts doubt on the extent to which knowledge spills over to Belgian companies that do not belong to a multinational group. Because the necessary data are currently not available, this evaluation does not consider foreign R&D, which is known to be an important source of spillovers for companies in small open economies like Belgium. The absence of foreign spillover variables may bias the estimates of the private return to R&D, and the estimates of domestic spillovers. The inclusion of foreign spillovers in future evaluations is certainly worth considering. Although the potential results of business R&D are the ultimate motivation for public support, the mentioned limitations in estimating the impact of R&D financed through public support on the output of the beneficiaries of support as well as on the rest of the economy, warrant substantial caution in the interpretation of the estimates on output presented in this report.

Recently, several authors and international organizations have started to warn for the risk that public support may result in the over-subsidization of applied research and the under-funding of (public) basic research despite the well-known importance of basic research and the complementarity between public and private R&D. Belgium has become one of the most generous OECD countries in terms of tax support to business R&D. As tax incentives tend to encourage applied research and experimental development, more than basic research, a reflection may be appropriate on whether the mix of public support in Belgium does not overly encourage applied research and experimental development, at the expense of investment in (public) basic research and complementarities between companies and other actors of the innovation system.

Synthèse

La Belgique figure parmi les sept pays de l'UE à avoir atteint son objectif d'investissements dans la recherche et le développement (R&D) en 2020. Avec des dépenses en R&D égales à 3,48 % du Produit intérieur brut (PIB), la Belgique a largement dépassé l'objectif d'intensité de R&D de 3 % et a pris la deuxième place, juste derrière la Suède. La forte intensité de R&D en 2020 s'explique en partie par un recul du PIB (dénominateur de l'intensité de R&D) dû au Covid-19, mais la Belgique est néanmoins l'un des pays de l'UE dont l'intensité de R&D a le plus progressé depuis 2010.

Pour concrétiser son engagement à atteindre l'objectif des 3 %, fixé lors du Conseil européen de Barcelone en 2002, le gouvernement fédéral a instauré, à partir de 2005, plusieurs incitants fiscaux dans l'objectif de soutenir la R&D des entreprises. Cette aide indirecte, sous la forme d'incitants fiscaux, est venue compléter l'aide directe substantielle (subventions) octroyée par les trois Régions. Les incitants fiscaux à la R&D ont été accordés par le biais de l'impôt des personnes physiques, comme la dispense partielle de versement du précompte professionnel sur les salaires du personnel de R&D, ou par le biais de l'impôt des sociétés, au titre de crédit d'impôt pour les investissements en R&D et de déduction des revenus des brevets. En 2018, une dispense partielle pour le personnel R&D titulaire d'un bachelier a complété les quatre mesures de dispense déjà existantes. La déduction pour revenus de brevets, introduite en 2008, a été remplacée en 2016 (et supprimée en 2021) par une déduction pour revenus d'innovation. Celle-ci a été élaborée conformément aux lignes directrices de l'OCDE sur l'érosion de la base d'imposition et le transfert de bénéfices (BEPS), qui visent à lutter contre l'évasion fiscale des entreprises multinationales. Les incitants fiscaux en faveur de la R&D des entreprises ont progressivement gagné en popularité et, partant, leur coût budgétaire estimé a considérablement augmenté pour atteindre 2 782 millions d'euros (0,59 % du PIB) en 2019, en raison notamment d'une forte augmentation du coût des incitants liés à l'impôt des sociétés.

Ce rapport présente les résultats de la quatrième évaluation de l'aide publique à la R&D des entreprises en Belgique. L'évaluation a visé à déterminer dans quelle mesure les aides directes (subventions régionales) et indirectes (incitants fiscaux) ont contribué à la forte augmentation de l'intensité de R&D, en soutenant des activités de R&D que les entreprises n'auraient pas réalisées en l'absence d'aide publique. L'évaluation de l'efficacité et de l'efficience de l'aide publique est compliquée par les limites des données et la difficulté à fournir des indications du lien de causalité entre l'aide et les dépenses de R&D des entreprises. Dans la continuité des évaluations précédentes, la stratégie d'estimation adoptée ici consiste à réaliser une estimation de référence et à comparer ses résultats avec les résultats d'autres méthodes d'estimation afin d'établir si des conclusions robustes peuvent être dégagées.

L'évaluation fournit des indications robustes qui montrent que l'aide directe (les subventions régionales) et la dispense partielle de versement du précompte professionnel sur les salaires du personnel de R&D encouragent les entreprises à investir dans les activités de R&D, au-delà de l'aide publique qu'elles reçoivent. Ce résultat confirme les conclusions des évaluations précédentes. Ce constat vaut aussi pour la dispense partielle en faveur du personnel de R&D titulaire d'un bachelier, qui n'était pas prise en compte dans les évaluations précédentes puisqu'elle a été introduite en 2018. Comme dans les évaluations précédentes, il y a peu d'indications d'additionnalité pour le crédit d'impôt pour les investissements en R&D et la déduction pour revenus de brevets. La déduction fiscale pour les investissements en R&D qui, faute d'informations complètes, n'avait pas été complètement évaluée dans les analyses précédentes, incite les entreprises à consacrer des moyens plus importants à la R&D. Le résultat le plus inquiétant de cette quatrième évaluation concerne la déduction pour revenus d'innovation. Cette incitation fiscale liée à l'impôt des sociétés a été introduite en 2016 pour remplacer la déduction pour revenus de brevets. Les estimations présentées dans ce rapport aboutissent à des indications robustes d'effets d'éviction pour ce régime fiscal. Autrement dit, il semble que la déduction pour revenus d'innovation finance des dépenses de R&D que les entreprises financeraient de toute manière elles-mêmes en l'absence d'incitants fiscaux. Le fait que les incitants fiscaux octroyés par le biais l'impôt des sociétés, à l'exception de la déduction fiscale pour les investissements en R&D, semblent inefficaces, voire s'accompagnent d'effets d'éviction, montre qu'il existe une marge pour accroître l'efficience des incitants fiscaux à la R&D, surtout qu'ils représentent la majeure partie du coût budgétaire de l'aide publique à la R&D des entreprises en Belgique.

Ce rapport fournit également des estimations de l'impact du bonus à l'innovation. Celui-ci consiste en un bonus exonéré de cotisations sociales octroyé aux travailleurs qui soumettent des idées innovantes au sein d'une entreprise. Le financement européen de la recherche par les entreprises belges est également évalué. Les estimations suggèrent une additionnalité pour le bonus à l'innovation mais un effet d'éviction pour le financement européen.

La prise en compte de différents groupes d'entreprises et de branches, suivant plusieurs dimensions, a révélé une hétérogénéité substantielle des effets de l'aide publique. Les résultats pour différents groupes d'entreprises et de branches peuvent avoir des signes opposés, qui sont susceptibles de s'annuler dans les estimations qui considèrent toutes les entreprises actives en R&D comme une population homogène. Ainsi, il apparaît que les effets d'éviction liés à certains incitants fiscaux accordés par le biais de l'impôt des sociétés sont surtout observés dans les grandes entreprises et les entreprises plus anciennes, les entreprises appartenant à des multinationales et les entreprises de branches très concentrées. Ces résultats devraient attirer l'attention sur l'impact potentiellement négatif de l'aide publique sur la dynamique de marché étant donné qu'elle peut renforcer la concentration du marché et les effets du "winners-take-most", et sur la faible efficacité de l'aide publique dans les branches fortement concentrées. Les résultats de ce rapport mettent en lumière une hétérogénéité substantielle des effets de l'aide publique entre les branches, et encore davantage entre les entreprises (au sein des branches). Il serait dès lors possible d'accroître l'efficacité et l'efficience de l'aide publique en ciblant des branches ou groupes d'entreprises spécifiques. Une telle approche nécessite toutefois un cadre bien défini, fondé sur des données probantes, ce qui fait défaut aujourd'hui. En outre, la conditionnalité des aides publiques peut être contraire aux règles de l'UE sur les aides d'État, qui interdisent généralement de cibler les aides publiques sur des entreprises ou branches spécifiques. La question du ciblage est toutefois au cœur du débat actuel sur la politique industrielle et les programmes axés sur les missions.

Comme dans les évaluations précédentes, il y a des indications claires que lorsque les entreprises combinent plusieurs aides publiques, les instruments individuels sont beaucoup moins efficaces pour stimuler la R&D. Ce n'est pas la combinaison des instruments elle-même qui semble poser un problème, mais plutôt la combinaison d'aides importantes, sans aucun plafonnement du montant total d'aide dont bénéficient les entreprises. L'efficience de l'aide publique diminue lorsque l'aide publique totale augmente, à la fois au niveau du taux d'aide et du montant total d'aide. Les effets d'éviction des incitants fiscaux se manifestent aux montants les plus élevés de l'aide publique totale. Ces résultats montrent que plafonner les aides publiques peut contribuer à accroître l'efficience de ces aides et peut contribuer à contenir l'augmentation considérable de leur coût budgétaire, principalement causée par les incitants fiscaux qui semblent les moins efficaces. Une analyse de vingt pays de l'OCDE, dont la Belgique, révèle que les régimes d'incitation fiscale à la R&D qui plafonnent les montants des aides ou réduisent le taux d'aide une fois un certain seuil atteint, sont susceptibles de présenter une plus grande additionnalité.

Les arguments en faveur de l'aide publique à la R&D des entreprises reposent principalement sur l'existence supposée d'un impact positif des activités de R&D des entreprises sur le reste de l'économie. Ces effets de spillover induisent un rendement privé de la R&D inférieur à son rendement social. Comme les entreprises ne sont intéressées que par le rendement privé de leurs activités de R&D, elles risquent de ne pas investir suffisamment d'un point de vue de la société dans son ensemble, d'où le rôle potentiel des subventions et des incitants fiscaux pour stimuler la R&D des entreprises. Le présent rapport examine, de manière plus détaillée que les évaluations précédentes, le rôle de l'aide publique dans les résultats potentiels des activités de R&D. Le choix de l'indicateur d'output, et des variables permettant de détecter les spillovers, n'est pas anodin et est compliqué par l'absence d'indications claires sur les indicateurs de production que les législateurs avaient à l'esprit lorsqu'ils ont introduit l'aide publique. Si l'on considère des indicateurs tels que la productivité, le chiffre d'affaires, la valeur ajoutée et les bénéfices, la R&D autofinancée semble générer un rendement privé positif. Le rendement privé de la R&D financée par des subventions régionales semble être encore plus élevé que la R&D autofinancée. Le rendement privé de la R&D financée par la dispense de versement du précompte professionnel s'avère négatif dans certains cas, ce qui pourrait indiquer que les activités de R&D financées par ces dispositifs soutiennent des activités moins utiles du point de vue économique. Les estimations suggèrent également que la R&D financée par des incitants liés à l'impôt des sociétés génère un rendement positif pour les bénéficiaires de l'aide, bien qu'il soit généralement inférieur au rendement de la R&D autofinancée et de la R&D financée par des subventions régionales. Toutefois, étant donné que seules les entreprises bénéficiaires et les entreprises dont les activités de R&D antérieures ont été concluantes, c'est-à-dire qu'elles génèrent des revenus de brevets ou d'innovations, ont accès à ces incitants fiscaux, les « effets » positifs peuvent simplement refléter le fait que de bonnes performances sont une condition nécessaire pour bénéficier de ces incitants. Les estimations montrent qu'il y'a des indications d'effets de spillover positifs de la R&D, par exemple lorsque les entreprises combinent les dispositifs d'aide, mais autres résultats suggèrent aussi des effets de spillover négatifs, qui pourraient révéler des effets de 'business stealing' ou d'imitation par des concurrents plus à la traîne. Les jeunes entreprises, les entreprises domestiques qui n'appartiennent pas à un groupe multinational et les entreprises ayant des activités de R&D occasionnelles, ne semblent pas bénéficier de la R&D des autres entreprises. Cela jette un doute sur le degré de diffusion de la connaissance parmi les entreprises belges qui n'appartiennent pas à un groupe multinational. Faute de données, cette évaluation ne prend pas en compte la R&D étrangère, qui est connue pour être une source importante de spillovers pour les entreprises actives dans une petite économie ouverte comme l'est la Belgique. L'absence de variables sur les spillovers étrangers pourrait biaiser les estimations du rendement privé de la R&D ainsi que les estimations des spillovers domestiques. Il serait dès lors indiqué d'inclure à l'avenir les spillovers étrangers dans les évaluations. Même si les résultats potentiels de la R&D des entreprises sont la motivation ultime de l'aide publique, les limites qui accompagnent les estimations justifient une grande prudence dans l'interprétation de l'impact de l'aide publique sur l'output présenté dans ce rapport.

Récemment, plusieurs auteurs et organisations internationales ont commencé à mettre en garde contre le risque que l'aide publique subventionne de manière excessive la recherche appliquée et sous-finance la recherche fondamentale (publique), malgré l'importance bien connue de la recherche fondamentale et la complémentarité des R&D publique et privée. La Belgique est l'un des pays de l'OCDE les plus généreux sur le plan des incitants fiscaux à la R&D des entreprises. Comme ces incitants tendent à encourager la recherche appliquée et le développement expérimental, plus que la recherche fondamentale, il convient de se demander si l'offre d'aides publiques en Belgique n'encourage pas trop la recherche appliquée et le développement expérimental, au détriment des investissements dans la recherche fondamentale (publique) et des complémentarités entre les entreprises et d'autres acteurs du système d'innovation.

Synthese

België is één van de slechts zeven EU-lidstaten die de vooropgestelde Europa 2020-doelstelling voor investeringen in onderzoek en ontwikkeling (O&O) heeft bereikt. Met O&O-uitgaven gelijk aan 3,48 % van het bruto binnenlands product (bbp), overtrof België ruimschoots zijn 3%-doelstelling voor O&O en nam het de tweede plaats in, nipt achter Zweden. De hoge O&O-intensiteit in 2020 wordt gedeeltelijk verklaard door een daling van het bbp als gevolg van covid-19 (de noemer van de O&O-intensiteit), maar België is wel een van de EU-landen met de hoogste toename van de O&O-intensiteit sinds 2010.

Om de 3%-doelstelling te behalen die de Europese Raad van Barcelona in 2002 heeft vooropgesteld, heeft de Belgische federale regering vanaf 2005 verschillende belastingvoordelen ingevoerd om O&O in de ondernemingssector te stimuleren. Deze indirecte steun via belastingvoordelen kwam boven op de bestaande aanzienlijke directe steun (subsidies) van de drie Belgische gewesten. De belastingvoordelen voor O&O werden verleend via de personenbelasting, zoals een gedeeltelijke vrijstelling van doorstorting van de bedrijfsvoorheffing op de lonen van O&O-personeel, of via de vennootschapsbelasting, zoals een belastingkrediet voor investeringen in O&O en een belastingaftrek voor octrooi-inkomsten. In 2018 kwam er naast de vier bestaande mogelijkheden nog een gedeeltelijke vrijstelling van doorstorting van bedrijfsvoorheffing voor onderzoekers met een bachelorsdiploma. De belastingaftrek voor octrooi-inkomsten, die in 2008 werd ingevoerd, werd in 2016 vervangen door een belastingaftrek voor innovatie-inkomsten, in overeenstemming met de BEPS -richtlijnen van de OESO, om belastingontwijking door multinationals te vermijden. De populariteit van de belastingvoordelen voor O&O bij bedrijven is geleidelijk toegenomen en als gevolg stegen ook de budgettaire kosten tot 2,782 miljoen euro in 2019 (0,59 % van het bbp). Dat kwam vooral door de sterke stijging van de kosten van de voordelen verleend via de vennootschapsbelasting.

Dit rapport presenteert de resultaten van de vierde evaluatie van de overheidssteun voor O&O aan bedrijven in België, die een aanwijzing wil geven van de mate waarin directe steun (gewestelijke subsidies) en indirecte steun (belastingvoordelen) hebben bijgedragen tot de sterke stijging van de O&O-intensiteit, door O&O-activiteiten van bedrijven te ondersteunen die zonder overheidssteun niet zouden zijn uitgevoerd. De evaluatie van de doeltreffendheid en efficiëntie van overheidssteun wordt bemoeilijkt door databeperkingen en de moeilijkheid om via schattingsprocedures een aanwijzing te krijgen van de causale impact van de steun op de O&O-uitgaven van bedrijven. In overeenstemming met de vorige evaluaties bestaat de strategie in deze evaluatie erin een referentiescenario te bestuderen en de resultaten te vergelijken met de resultaten van alternatieve schattingsprocedures, om na te gaan of robuuste conclusies kunnen worden getrokken.

De evaluatie bevat robuuste aanwijzingen dat directe steun (regionale subsidies) en de gedeeltelijke vrijstelling van de doorstorting van de bedrijfsvoorheffing op de lonen van O&O-personeel bedrijven aanzetten om meer in O&O-activiteiten te investeren, naast de overheidssteun die zij ontvangen. Dit resultaat bevestigt de conclusies van de vorige evaluaties. Deze bevinding geldt ook voor de gedeeltelijke vrijstelling voor O&O-werknemers met een bachelorsdiploma, die in eerdere evaluaties niet is opgenomen omdat deze pas in 2018 is ingevoerd. Net als bij de vroegere evaluaties zijn er weinig aanwijzingen van additionaliteit voor het belastingkrediet voor investeringen in O&O en de belastingaftrek voor octrooi-inkomsten. De belastingaftrek voor investeringen in O&O, die gezien de partiële informatie niet volledig kon worden beoordeeld in de vorige evaluaties, blijkt te leiden tot extra O&O-uitgaven door bedrijven. De meest verontrustende bevinding van deze vierde evaluatie betreft de belastingaftrek voor innovatie-inkomsten. Dit voordeel verleend via de vennootschapsbelasting werd in 2016 ingevoerd ter vervanging van de belastingaftrek voor octrooi-inkomsten. De schattingen in dit rapport leveren robuuste aanwijzingen van verdringingseffecten voor deze maatregel. Dat houdt in dat de belastingaftrek voor innovatie-inkomsten O&O-uitgaven lijkt te financieren die ondernemingen zonder de steun zelf zouden financieren. Het feit dat de belastingvoordelen verleend via de vennootschapsbelasting, met uitzondering van de belastingaftrek voor O&O-investeringen, ondoeltreffend lijken of zelfs tot verdringingseffecten leiden, wijst op een mogelijkheid om de efficiëntie van de belastingvoordelen voor O&O te verhogen, vooral omdat zij het leeuwendeel uitmaken van de budgettaire kosten van de overheidssteun voor O&O aan bedrijven in België.

Dit rapport bevat ook schattingen van de impact van de innovatiebonus, die bestaat uit een volledige vrijstelling van sociale bijdragen op het loon van werknemers die binnen een onderneming nieuwe ideeën aanbrengen, en de EU-financiering van onderzoek door Belgische ondernemingen. De schattingen wijzen op additionaliteit voor de innovatiebonus, maar op verdringingseffecten voor EU-financiering.

Wanneer verschillende groepen ondernemingen en bedrijfstakken langs verschillende dimensies in aanmerking worden genomen, blijkt er een aanzienlijke heterogeniteit in de impact van de overheidssteun, zelfs met tegengestelde signalen voor verschillende groepen ondernemingen en bedrijfstakken, die elkaar kunnen opheffen in schattingen die alle O&O-actieve ondernemingen als een homogene populatie beschouwen. Zo blijkt dat de verdringingseffecten van sommige belastingvoordelen verleend via de vennootschapsbelasting vooral gelden voor grote en oudere ondernemingen, ondernemingen die tot een multinationale groep behoren en voor sterk geconcentreerde bedrijfstakken. Deze resultaten moeten de aandacht vestigen op de potentieel negatieve impact van overheidssteun op de marktdynamiek, aangezien die steun de marktconcentratie en de ‘winners-take-most’-effecten kan versterken, en op de geringe efficiëntie van overheidssteun in sterk geconcentreerde bedrijfstakken. De resultaten in dit rapport onthullen een aanzienlijke heterogeniteit in de impact van overheidssteun tussen bedrijfstakken, maar nog meer tussen bedrijven (binnen bedrijfstakken). Dit suggereert dat de doeltreffendheid en efficiëntie van de overheidssteun kan worden verhoogd door zich te richten op specifieke bedrijfstakken of groepen van ondernemingen. Een dergelijke aanpak vereist echter een welomschreven en evidence-based kader, dat momenteel niet in zicht is. Bovendien kunnen de voorwaarden van overheidssteun strijdig zijn met de Europese staatsteunregels, die in principe steun aan specifieke bedrijven of bedrijfstakken verbieden, hoewel dit juist de kern vormt van de huidige discussie over industriebeleid en missiegerichte programma's.

In overeenstemming met de vorige evaluaties zijn er duidelijke aanwijzingen dat wanneer ondernemingen verschillende steunmaatregelen combineren, de doeltreffendheid van de afzonderlijke instrumenten bij het stimuleren van O&O aanzienlijk afneemt. De combinatie van verschillende steuninstrumenten lijkt echter niet het probleem als zodanig te zijn, maar veeleer de combinatie van grote steunbedragen zonder enige beperking van het totale bedrag aan overheidssteun dat bedrijven ontvangen. De doeltreffendheid van de overheidssteun neemt af naarmate de totale overheidssteun toeneemt, zowel wat betreft het steunpercentage als het totale steunbedrag. De verdringingseffecten van belastingvoordelen via de vennootschapsbelasting komt aan het licht op de hoogste niveaus van het totale bedrag aan overheidssteun. Dit wijst erop dat de invoering van een plafond voor overheidssteun kan bijdragen tot een hogere efficiëntie en nuttig kan zijn om de aanzienlijke stijging van de budgettaire kosten van overheidssteun, voornamelijk voor belastingvoordelen die het minst doeltreffend lijken, binnen de perken te houden. Uit een analyse van 20 OESO-landen, waaronder België, blijkt dat belastingvoordelen voor O&O die het steunbedrag voor O&O-uitgaven beperken of het steunpercentage verlagen zodra een bepaalde drempel is bereikt, waarschijnlijk een grotere additionaliteit vertonen.

De argumenten voor overheidssteun aan O&O bij bedrijven berusten voornamelijk op de veronderstelling dat de O&O-activiteiten van bedrijven een positieve impact hebben op de rest van de economie. Deze spillovers creëren een kloof tussen het particuliere rendement van O&O en het maatschappelijke rendement van O&O. Aangezien bedrijven alleen geïnteresseerd zijn in het particuliere rendement van hun O&O-activiteiten, investeren zij wellicht onvoldoende vanuit maatschappelijk oogpunt, vandaar de potentiële rol van subsidies en belastingvoordelen om O&O bij bedrijven te ondersteunen. In dit rapport wordt uitvoeriger dan in de vorige evaluaties ingegaan op de rol van overheidssteun in de potentiële resultaten van O&O-activiteiten. De keuze van de outputindicator en van de variabelen aan de hand waarvan spillovers kunnen worden opgespoord, is echter niet evident en wordt bemoeilijkt door het ontbreken van duidelijke aanwijzingen over welke outputindicatoren de wetgevers in gedachten hadden toen zij overheidssteun invoerden. Voor indicatoren zoals productiviteit, omzet, toegevoegde waarde en winst, lijkt zelfgefinancierd O&O een positief particulier rendement op te leveren. Het particuliere rendement van met regionale subsidies gefinancierd O&O blijkt zelfs hoger te zijn dan dat van zelfgefinancierd O&O. Het particuliere rendement van met gedeeltelijke vrijstelling van doorstorting van bedrijfsvoorheffing gefinancierde O&O blijkt in sommige gevallen negatief te zijn, hetgeen erop zou kunnen wijzen dat met deze maatregelen gefinancierde O&O-activiteiten marginale activiteiten ondersteunen. Uit de schatting blijkt ook dat O&O gefinancierd door belastingvoordelen via de vennootschapsbelasting een positief rendement oplevert voor de begunstigden van de steun, hoewel dit rendement doorgaans lager ligt dan het rendement van zelfgefinancierd O&O en O&O dat wordt gefinancierd met regionale subsidies. Aangezien deze belastingvoordelen echter alleen kunnen worden gebruikt door winstgevende bedrijven en bedrijven met succesvolle O&O-activiteiten in het verleden, die hebben geleid tot huidige octrooi- of innovatie-inkomsten, kunnen de schattingen van een positieve ‘impact’ op de productie gewoon weerspiegelen dat goede prestaties een noodzakelijke voorwaarde zijn om voor deze belastingvoordelen in aanmerking te komen. Er zijn aanwijzingen voor positieve spillovers, bijvoorbeeld van O&O van bedrijven die steunmaatregelen combineren, maar ook voor negatieve spillovers die kunnen wijzen op ‘business stealing’-effecten en imitatie door achterblijvers. Jonge bedrijven, binnenlandse bedrijven die niet tot een multinationale groep behoren en bedrijven met slechts incidentele O&O-activiteiten lijken niet te profiteren van O&O door andere bedrijven. Dit doet twijfel rijzen over de mate waarin kennis overslaat naar Belgische bedrijven die niet tot een multinationale groep behoren. Omdat de nodige gegevens momenteel niet beschikbaar zijn, wordt in deze evaluatie geen rekening gehouden met buitenlands O&O, waarvan bekend is dat het een belangrijke bron van spillovers is voor ondernemingen in kleine open economieën zoals België. Het ontbreken van buitenlandse spillover-variabelen kan de schattingen van het particulier rendement op

O&O en de schattingen van de binnenlandse spillovers vertekenen. Het opnemen van buitenlandse spillovers in toekomstige evaluaties is zeker het overwegen waard. Hoewel de potentiële resultaten van O&O voor bedrijven de uiteindelijke motivatie voor overheidssteun zijn, nopen de genoemde beperkingen bij de schatting van de impact van met overheidssteun gefinancierd O&O op de output van de begunstigden en op de rest van de economie tot grote voorzichtigheid bij de interpretatie van de in dit rapport gepresenteerde schattingen van de output.

Onlangs hebben verschillende auteurs en internationale organisaties gewaarschuwd voor het risico dat overheidssteun leidt tot oversubsidiëring van toegepast onderzoek en onderfinanciering van (openbaar) fundamenteel onderzoek, ondanks het algemeen bekende belang van fundamenteel onderzoek en de complementariteit tussen openbaar en particulier O&O. België is een van de meest genereuze OESO-landen wat betreft fiscale steun voor O&O aan bedrijven. Aangezien belastingvoordelen eerder toegepast onderzoek en experimentele ontwikkeling aanmoedigen dan fundamenteel onderzoek, kan het aangewezen zijn na te gaan of de mix van overheidssteun in België niet te veel toegepast onderzoek en experimentele ontwikkeling aanmoedigt, ten koste van investeringen in (openbaar) fundamenteel onderzoek en complementariteit tussen ondernemingen en andere actoren van het innovatiesysteem.

1. Introduction

This section provides an overview of direct support (subsidies) and indirect support (tax incentives), provided by public authorities in Belgium, for R&D activities of companies. It shows the evolution in the use and budgetary cost of public support and the trend in R&D intensity.

1.1. Public support to business R&D in Belgium

The three regions of Belgium (Brussels-Capital Region, Flemish Region, and the Walloon Region) have been granted most competencies in the field of R&D policy since 1993. They provide direct support for R&D and innovation to companies, mainly through subsidies.

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 several tax incentives in support of R&D activities by companies, as many fiscal instruments still fall under federal authority.

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 R&D personnel in companies that cooperate in research with a university, a higher education institution in the European Economic Area or a scientific institution registered by the Council of Ministers (as of 1 October 2005);
- Young Innovative Companies (YIC)[1] (as of 1 July 2006);
- for R&D personnel with a PhD degree in exact or applied sciences, doctor degree in (veterinary) medicine or a civil engineering degree (as of 1 January 2006);
- for R&D personnel with a master's degree, except for master’s degrees in social and human sciences (as of 1 January 2007).

For the first two measures the exemption originally amounted to 50% and for the last two to 25%. The exemption, for all four measures, was raised to 65% in July 2008, and to 75% in January 2009. Since 2013 the rate of partial exemption amounts to 80%

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 scheme was initially set at 40%, but it was raised to 80% in January 2020, equal to the current rate of exemption for the four other schemes. The total amount of the partial exemption for R&D employees with a

[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.

bachelor's degree is limited to 25% (50% for small companies) of the total amount of partial exemption for the other two categories of R&D employees.[2]

In 2006, the federal government introduced the possibility for companies to grant an "innovation bonus" to its creative workers, to reward innovative ideas implemented within the company. The bonus is a 100% net compensation as it is completely exempted from social security contributions, both for the employer and the employee(s). The bonus is not restricted to researchers or R&D personnel but can be granted to any employee that contributes real added value to a company's normal activities. The bonus is given to a maximum of 10% of workers (three people in companies of fewer than 30 people).[3]

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)[4]. 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 tax years, is refunded.[5] For tax year 2021 the rate of deduction was 13.5% of the investment or acquisition value for a one-off deduction and 20.5% of the annual depreciation for a spread deduction. A law that was adopted in March 2022, limits the possibility to combine the partial exemption from payment of the withholding tax on the wages of R&D personnel with the tax credit.

From 2008 onwards, the federal government granted 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[6] and furthermore applies a nexus ratio which links the tax benefit to the amount of R&D undertaken by the beneficiary or in the country that provides the benefit. On the other hand, in addition to income from patents, the deduction also applies to income from plant variety 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 was gradually phased out through a grandfather (transition) period that ended in June 2021. In aligning the tax deduction on innovation income with the BEPS guidelines, Belgium opted for a broad interpretation of qualifying income and assets (for example, in addition to patents, it also includes plant variety rights, orphan medical products, certain data and market exclusivity rights and copyright-protected computer programs) and provided in the possibility to carry forward any unused portion to subsequent tax years, when taxable income is not sufficient to fully absorb the total amount of the deduction (Heyvaert 2018).[7] Faulhaber (2017) argues that because the European Court of Justice ruled that tax credits may not discriminate based on the location of R&D activities, the nexus approach could not require a link between the location of R&D and the country providing tax benefits but had to consider a less

[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 schemes for companies.

[3] For more information, see: https://economie.fgov.be/en/themes/enterprises/develop-and-manage-business/support-and-incentives.

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

[5] Limits apply to the amount of unused tax credit that can be carried forward.

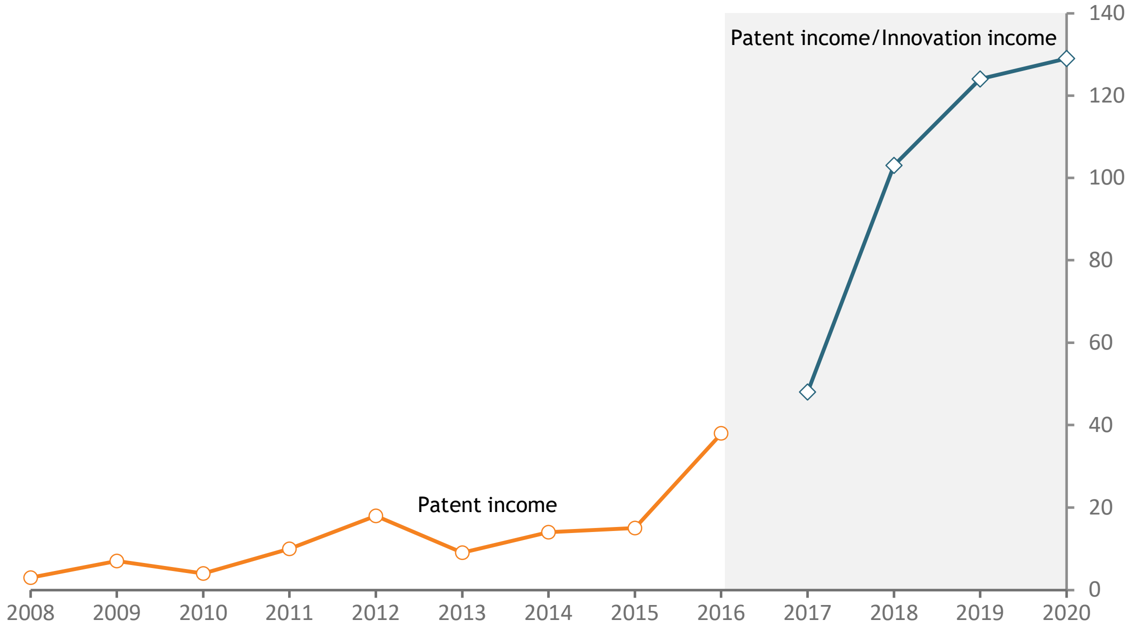
[6] Gross income includes R&D expenditures for which a tax deduction already applies.

[7] The reform of Belgian corporate income taxation, adopted in 2017, limits the possibility of certain tax deductions (including the part of the tax deduction for innovation income that is carried forward) in that 30% of profits that exceed 1 million euro, after applying these deductions, is considered as a minimum tax base, which is fully taxable at the going CIT rate.

intuitive link between the entity incurring R&D expenditures and the entity receiving the tax benefits. As a result, the nexus approach is likely to reduce income shifting but, because of the constraints imposed by European Union law, creates more distortions and more possibilities for income shifting than a version that would focus directly on the location of the income.

In a recent report, the Court of Audit (2021) points out that the regulatory framework of Belgian corporate income tax incentives for R&D is very complicated, that vague goals have been formulated (complicating evaluation) and that several concepts are defined ambiguously, giving rise to problems of interpretation, application and even legal certainty and equal treatment of taxpayers. The Court of Audit points out that the innovation income deduction also applies to patents, even when novelty has not been established by the European Patent Office. One of the main problems in the application of the innovation income deduction is the determination of gross innovation income, especially concerning royalties embedded in the sales price of products and services, or revenue embedded in the application of production processes. The number of applications for a preliminary decision by the Belgian Ruling Commission on the tax deduction for innovation income increased dramatically since its introduction, as can be seen in Graph 1.

Graph 1 **Number of applications for a ruling on the tax deduction for patent income/innovation income (2008-2020)**

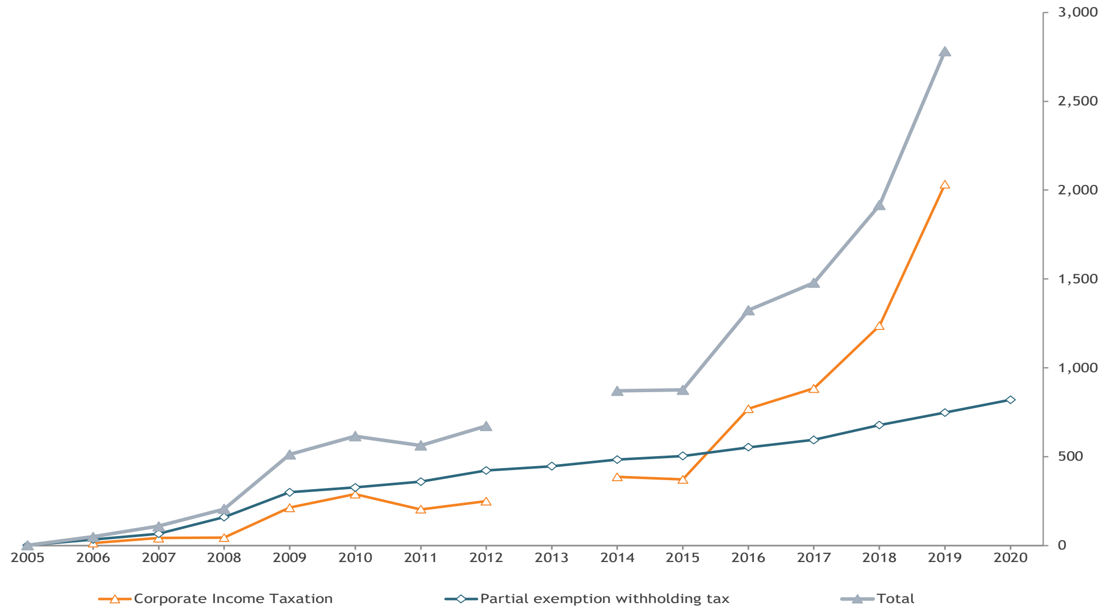


Source: Ruling Commission (FOD Financiën - Dienst Voorafgaande beslissingen in fiscale zaken - afdeling Ruling), annual reports. The patent income deduction was introduced in 2008. In 2016 it was replaced by an innovation income deduction. For the patent income deduction, the transition period of five years ended in 2021.

The Ruling Commission applies a rule of thumb for embedded licence fees, which can be considered as an application of the "at arm's length" principle, but which, as the Court of Audit points out, is not explicitly included in current legislation. Many applications for a preliminary decision by the Ruling Commission concern income from copyright-protected software. Additional problems arise in the transition of gross income to net income, on which the Ruling Commission does not provide an opinion, resulting in discussions between firms and tax administrations on applicable R&D expenditures, as these have not been defined in legislation (Court of Audit 2021).

Graph 2 shows the evolution of the budgetary cost of the tax incentives introduced by the federal government, using official data from the *Inventory of Tax Exemptions, Deductions and Credits having an impact on Federal Revenue*. The graph considers the two main groups of tax benefits: the total budgetary cost of all schemes of partial exemption from payment of the withholding tax on the wages of R&D personnel in companies (benefits through personal income taxation) and the total budgetary cost of all tax benefits provided through corporate income taxation. The budgetary cost of the partial exemption schemes increased gradually over the period 2005-2019, with the strongest increase at the beginning, when the schemes were introduced (2005-2007) and in 2008 and 2009 when the rate of partial exemption was raised to, respectively, 65% and 75%. The budgetary cost of the tax benefits provided through corporate income taxation increased substantially in 2009 and more recently in 2016.[8] As can be seen in Graph 2, the evolution in the budgetary cost of tax benefits in support of R&D is largely driven by the evolution in the budgetary cost of tax benefits through corporate income taxation, especially the strong increase since 2016. In 2019, the budgetary cost of all R&D tax benefits was 2,782 million euro.

Graph 2 Budgetary cost of tax incentives for business R&D (2005-2020)
Million euro



Source: Official statistics from the Inventory of Federal Fiscal Expenditures. Data on the tax deduction for patent income not available for 2013. Data on corporate income taxation not available for revenue year 2020 (tax year 2021).

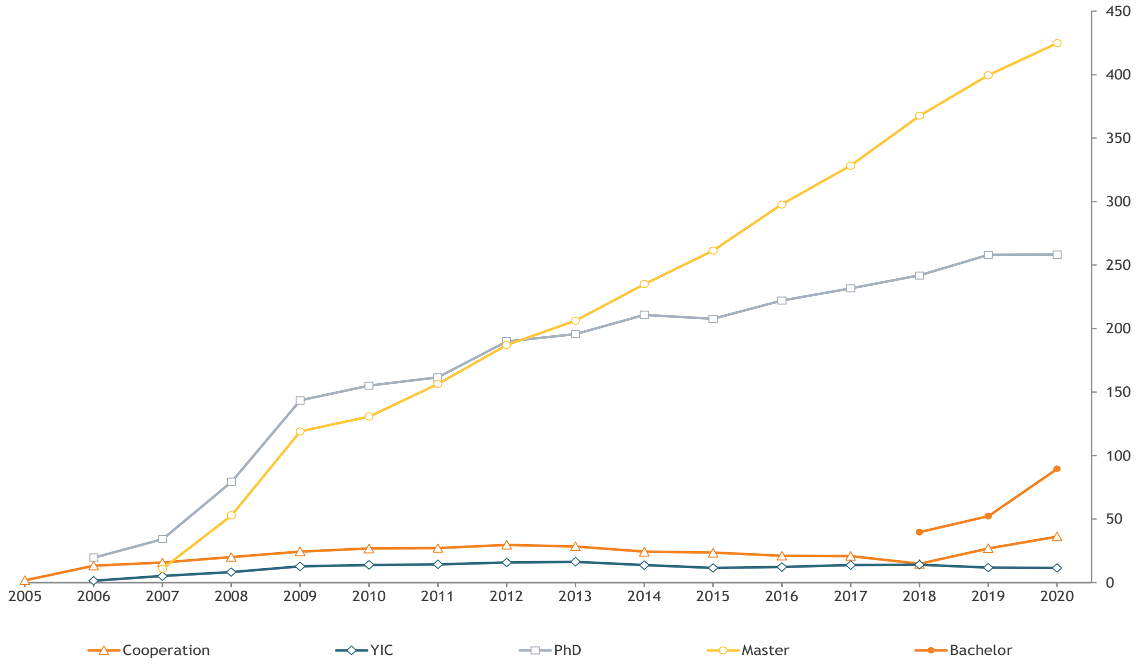
The evolution of the budgetary cost of the two main groups of tax benefits, broken down by individual schemes, is shown in Graph 3 for the partial exemption from payment of the withholding tax and in Graph 4 for tax benefits provided through corporate income taxation.

As can be seen in Graph 3, the two schemes of partial exemption from payment of the withholding tax that are based on the degree of R&D personnel, have a dominant share in the budgetary cost of the partial exemption schemes. The growth in the budgetary cost of the master's degree scheme started to

[8] The official estimate of the budgetary cost of the tax credit for R&D investment has been substantially revised since the third evaluation. This explains the difference between the current statistics and the statistics reported in Dumont (2019) and in previous OECD statistics on public support for business R&D.

rise more substantially than the PhD and civil engineer scheme from 2011, to the extent that it surpassed the latter scheme in 2013, with the gap increasing year by year.

Graph 3 Budgetary cost of partial exemption form payment of the withholding tax (2005-2020)
Million euro



Source: Official statistics from the Inventory of Federal Fiscal expenditures.

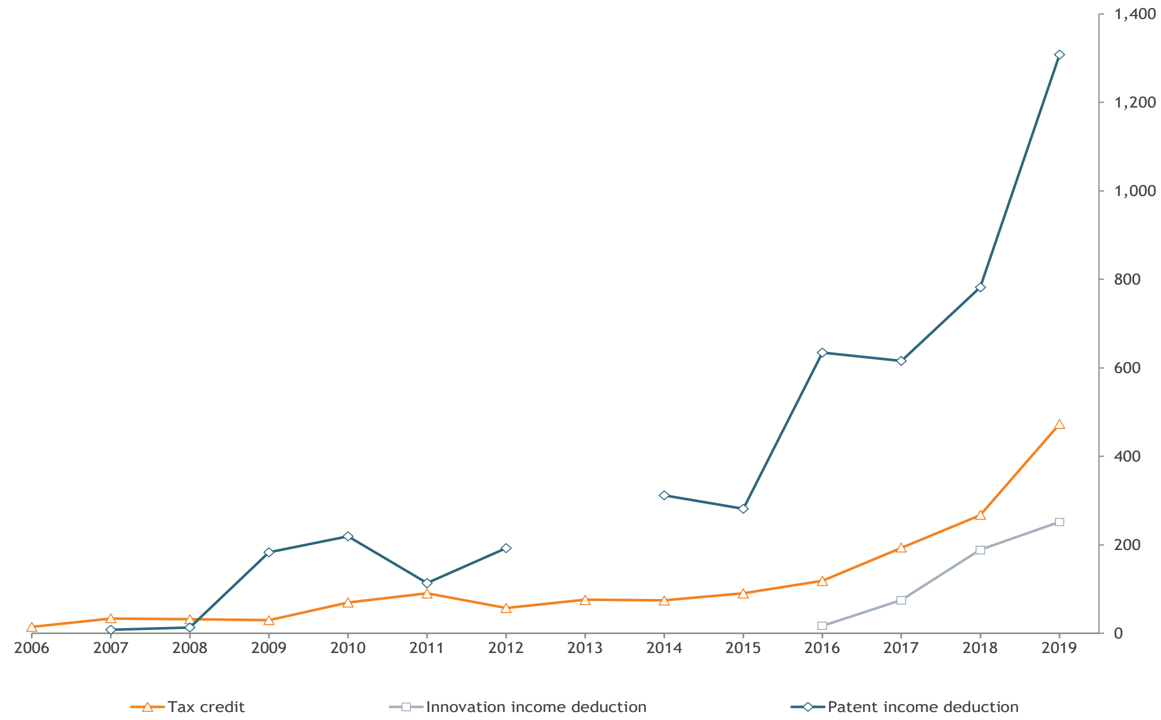
Graph 4 shows that the strong increase in the total budgetary cost of all R&D tax benefits is explained by the substantial increase in the budgetary cost of the patent income deduction, which was phased out in 2021. The innovation income deduction, introduced in 2016 to replace the patent income deduction, though still far less substantial in budgetary terms, witnessed a strong increase in the first two years after its introduction.

The introduction of tax incentives by the federal government, resulted in a clear shift in the policy mix in Belgium as can be seen in Graph 5 whish shows government tax relief (indirect support through tax benefits) and direct funding over the period 2000-2019 as a percentage of Business R&D Expenditures (BERD), using OECD statistics. The OECD Statistics aim at providing internationally comparable data, although there are pending issues that hamper a straightforward comparison (Valenduc 2019).

The patent income and innovation income deduction, with an important share in the budgetary cost of public support, are not considered in the OECD data on tax relief, as these only consider tax benefits based on R&D expenditures.

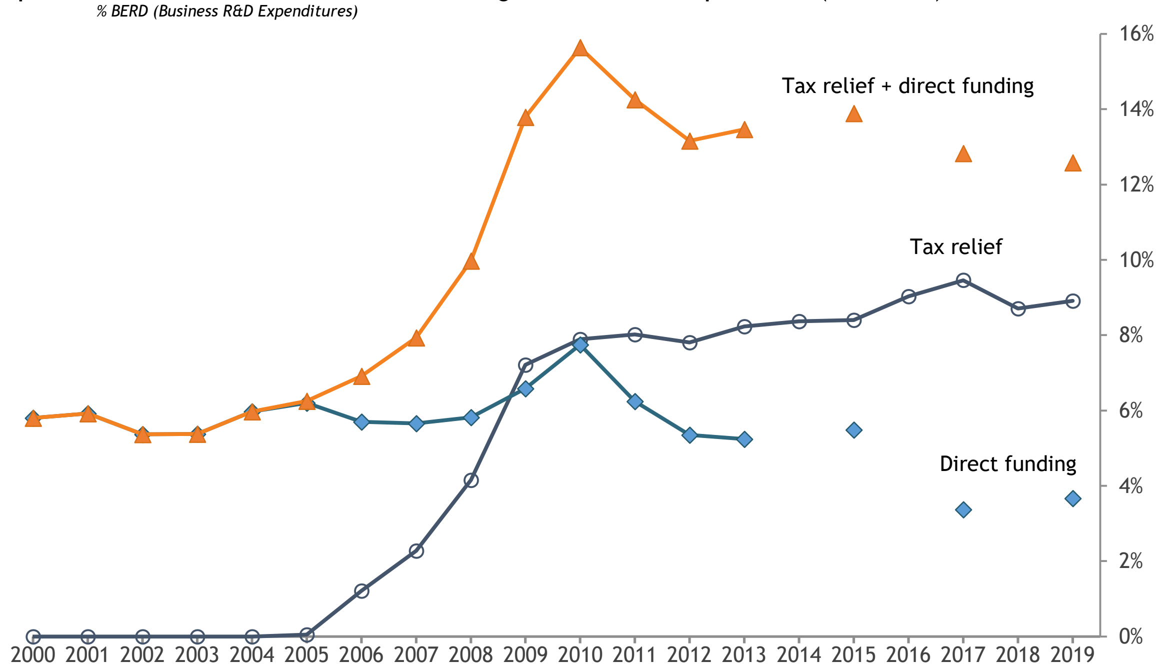
Between 2000 and 2005 public support to business R&D in Belgium was rather stable as a percentage of BERD and only consisted in direct funding (regional subsidies).

Graph 4 **Budgetary cost of tax benefits through corporate income taxation (2006-2019)**
Million euro



Source: Official statistics from the Inventory of Federal Fiscal expenditures. Data on the tax deduction for patent income not available for 2013.

Graph 5 **Government tax relief and direct funding of Business R&D expenditures (2000-2019)**
% BERD (Business R&D Expenditures)



Source: OECD R&D Tax Incentives Database, December 2021. The graph shows direct funding and tax relief in support of R&D as a percentage of Business R&D Expenditures (BERD), following OECD definitions. For Belgium, direct funding mainly denotes subsidies provided to firms by the three regions. Tax relief denotes Government Tax relief for R&D expenditures (GTARD), in effect, tax relief provisions that apply to taxpayers strictly as a result of their engagement in R&D performance and/or funding activities, relative to a normal or baseline tax structure. The tax deduction of patent income, which as can be seen in graph 4, represents a large share of the budgetary cost of Belgian tax benefits for R&D, is not considered in the OECD statistics, as it is not based on R&D expenditures. Data on direct funding are not available for 2014, 2016 and 2018.

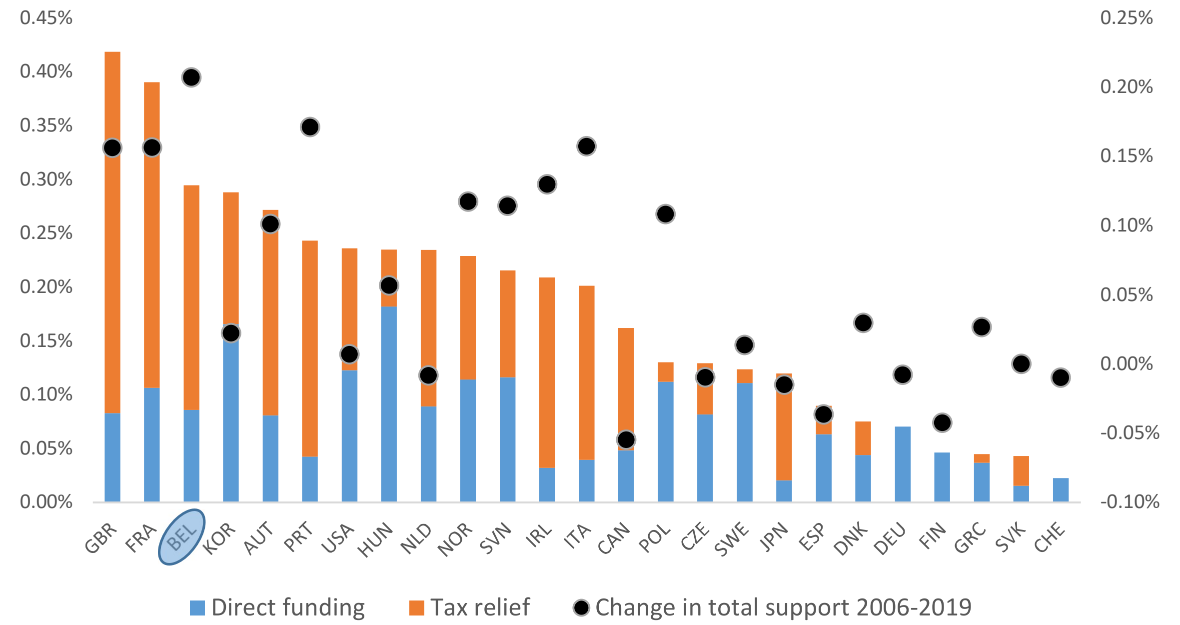
From 2005 onwards, the increase in public support as a percentage of BERD, is explained by the introduction and increasing popularity of tax benefits. The decrease in total public support as a percentage of BERD, from 2011 onwards, is explained by a substantial drop in direct funding.

In 2018, general tax relief as a percentage of BERD, was almost three times as high as direct funding in Belgium, bearing in mind that the most important tax benefit in budgetary terms, patent income deduction, is not considered in the data.

As a result of a major reform of Belgian corporate income taxation in 2017, the nominal tax rate on corporate income has been gradually reduced from 33.99% in 2017 to 25% in 2020 (income year). As of 2020, small companies benefit from a reduced rate of 20% on the first tranche of 100,000 euro in taxable income. A tax rate of 25% implies that, for example, the innovation income deduction can result in an effective tax rate on innovation income of only 3.75% although the advantage of specific tax deductions decreases when the general tax rate is reduced.

Comparing public support to business R&D relative to GDP in 25 OECD countries, Graph 6 shows that Belgium ranked third in 2019. In terms of change in total public support over the period 2006-2019, Belgium witnessed the highest growth.

Graph 6 **Direct government funding and tax support for business R&D in 25 OECD countries (2019)**
% GDP



Source: OECD R&D Tax Incentives Database, December 2021. The graph shows, on the left y-axis, direct funding and tax relief in support of R&D as a percentage of GDP, following OECD definitions, for a group of 25 OECD countries, ranked by decreasing total public support as a percentage of GDP. The bars show data for 2019 (except for Spain, Sweden and USA for which the data are for 2018). The right y-axis shows the change in total support as a percentage of GDP between 2006 and the most recent year for which data are available.

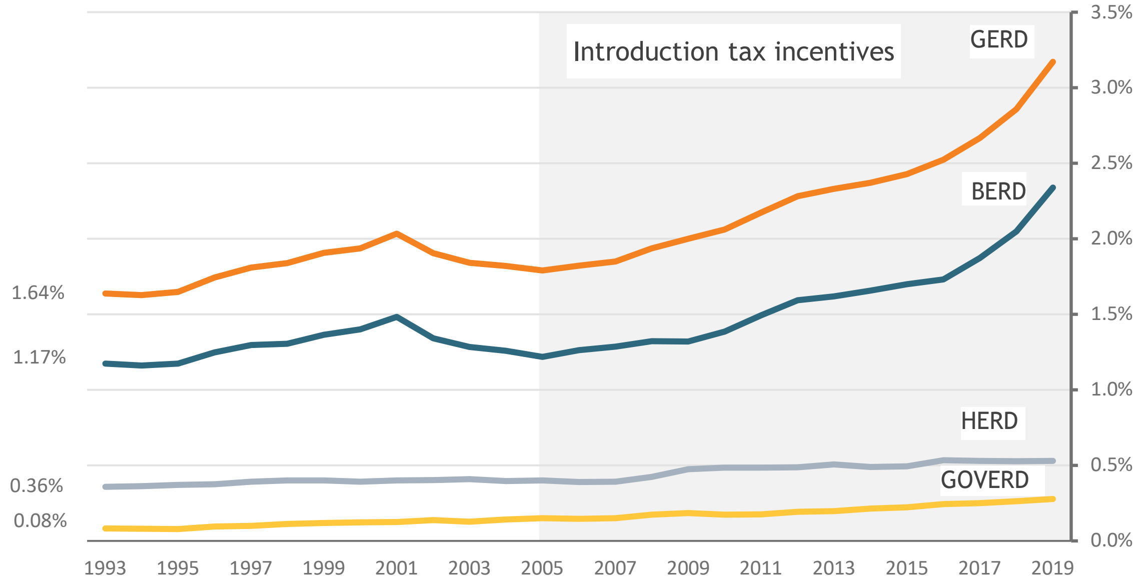
The use, and the generosity of tax incentives in support of business R&D, strongly increased in OECD countries since 2003 and there is a clear shift in the policy mix from direct funding to indirect funding, especially since 2009. In 2018, tax support represented 56% of total government support to business R&D compared to 36% in 2006. The shift in the policy mix appears to be even more substantial in EU countries (OECD 2021 a, pp.100-101).

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).

1.2. R&D intensity

Graph 7 shows gross domestic R&D spending (GERD) for Belgium, relative to GDP (in %) for the period 1993-2019.[9] The graph also provides the breakdown of GERD into Business Enterprise sector R&D expenditures (BERD), Higher Education R&D expenditures (HERD) and Government R&D Expenditures (GOVERD). With GERD relative to GDP equal to 3.48% in 2020, Belgium surpassed its Europe 2020 target, set at 3%.[10] In 2020 Belgium had the second highest R&D intensity in the EU, narrowly behind Sweden, and was only one of seven EU countries to reach its target (European Commission 2022).

Graph 7 R&D Expenditures by sector of performance Belgium (1993-2019)
% of GDP



Source: OECD Main Science and Technology Indicators. The table shows R&D expenditures by sector of performance:(business enterprise (BERD), higher education (HERD) and government (GOVERD). GERD denotes total Gross domestic expenditure on R&D

As Graph 7 shows, R&D intensity decreased between 2001 and 2005 and started to increase again from 2005 onwards, which coincides with the introduction of tax incentives by the federal government. The graph also clearly shows that the increase in GERD relative to GDP from 2005 onwards is entirely driven by the increase in BERD relative to GDP, as R&D expenditures by Higher education and Government institutes witnessed very moderate growth.

Over the period 2007-2019, Belgium was one of the OECD countries with the lowest levels of government support provided through general university funds, which provide universities discretion on the

[9] The year 1993 is considered as the first year, as of 1993 data for Belgium are based on full surveys and no longer on a combination of budget figures and survey findings.

[10] The high R&D intensity in 2020 is partially explained by a drop in GDP, the denominator of R&D intensity, due to Covid-19.

usage of funds. This was somewhat in contrast with a tendency among OECD countries to increase government support through general university funds (OECD 2021 b, p. 5).

According to IMF (2021) basic scientific research is under-funded in advanced economies and targeting support to basic scientific research would be the first-best policy to raise long-term growth and stimulating more public-private partnerships would be second-best.

In a similar vein, Akcigit, Hanley and Serrano-Velarde (2021) argue that uniform subsidies for research may result in over-subsidizing applied research and accentuating misallocation of research effort, whereas policies that support public basic research and its interaction with the private sector are significantly welfare-improving.

Irrespective of the question how instrumental the tax incentives that were introduced by the federal government have been in raising R&D expenditures of the Business Enterprise sector, Graph 7 reveals a clear rise in applied research and experimental development by companies that has not been matched by an increase in the more basic research performed by higher education and government institutes.

As Graph 2 and Graph 7 show, both public support to business R&D and R&D intensity of the business sector increased substantially since 2005. The evaluation of public support, presented in the following sections, aims at providing an indication of the extent to which the tax incentives that have been introduced from 2005 onwards in Belgium have contributed to the rise in R&D intensity, by supporting additional R&D activities of companies, that is R&D activities that would not have been performed without public support. The methodology that is adopted for this evaluation is discussed in the next section.

2. Evaluation methodology and estimation procedures

This section briefly discusses the arguments to provide public support to R&D activities of companies and how to evaluate this support. Subsection 2.2 discusses the different estimation procedures that are considered to evaluate public support.

This section to a large extent resumes section 2 and section 4 of the previous evaluation (Dumont 2019).

2.1. The rationale of public support to business R&D and its evaluation

The rationale to provide public support for R&D activities of private companies, hinges on the assumption that, due to market failures, private firms will invest less in R&D than socially optimal.[11] By providing subsidies or tax incentives, governments aim at encouraging firms to perform R&D activities that they would not consider without support. The efficiency of public support can be assessed by the extent to which the support stimulates additional private R&D activities. From a recent meta-regression analysis, Dimos et al. (2022) conclude that subsidies as well as tax benefits appear to induce additional business R&D, and that neither instrument (direct or indirect support) systematically outperforms the other although their effectiveness depends on the specific features and the policy mix.

European Commission (2014) discusses the requirements of evaluations of state aid.[12] 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?).

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

[11] If companies are not able to appropriate all benefits from their risky investment in R&D, the social return to business R&D will exceed the private return and public authorities may have an incentive to provide support to business R&D to raise business R&D to a more social optimal level.

[12] In July 2021, the European Commission adopted an extension of the scope of the General Block Exemption Regulation for state aid, which allow Member States to implement certain aid measures without prior Commission scrutiny. The revised rules concern aid granted by national authorities for projects funded via certain EU centrally managed programmes under the new Multiannual Financial Framework; certain State aid measures that support the green and digital transition and are, at the same time, relevant for the recovery from the economic effects of the coronavirus pandemic. (European Commission 2021)

beneficiaries, it can be assumed to be distortive as it provides beneficiaries with windfall gains (European Commission 2014).

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 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.

Recognizing the limitations of all procedures that try to tackle selection issues and endogeneity, the results of several alternative 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, 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. In contrast with previous evaluations, this fourth evaluation acknowledges the policy mix involved in direct support by considering distinct categories of subsidies, whether subsidies are provided for research or development, are bottom-up or provided within a specific theme or domain and whether collaboration with other companies, universities or research institutes is involved. The fourth evaluation also considers the innovation bonus and EU funding of research by Belgian companies.

The main research question of this evaluation concerns input additionality:

How much additional R&D expenditures of companies result from direct support (regional subsidies) and indirect support (federal tax incentives)?

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) and on potential spillovers.

The major difficulty in assessing the impact 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.

Borrás and Edquist (2013) consider three categories of innovation policy 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 report 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 warranted but beyond the scope of this paper.

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

2.2. Estimation procedures

The evaluation of the impact 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 a competitive procedure, 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, only a minority of R&D active firms take advantage of them. 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 biased. Different estimation procedures exist to address the selection bias 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 evaluations, 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, section 4 reports the results of a selection model, instrumental variables estimation, and dynamic panel estimation. Details of the advantage and limitations of these different estimation procedures can be found in Dumont (2015).

The different tax incentives that were introduced by the federal government, from 2005 onwards, 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).[13]

[13] Aggregate R&D intensity could also change due to reallocation. For example, even if the R&D intensity of all firms does not change, an increase in the share in value added (or turnover) of firms with high R&D intensity results in an increase in

The baseline specification used in this paper to estimate the impact of public support 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:

$$ln(RD_{it}) = \alpha_0 + \sum_{j=1}^{J} \beta_j^{Support,j} \, ln\left(A_{it}^{Support,j}\right) + \sum_{k=1}^{K} \beta_k^{Control} \; X_{it}^{Control,k} + \varepsilon_{it} \qquad (1)$$

Dependent variable:

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

Explanatory variables:

$A_{it}^{Support,j}$: total amount of support received by company *i* in year *t* through support scheme *j*

$A_{it}^{Control,k}$: variables not related to public support for R&D, included to control for potential determinants of the R&D expenditures of companies

ε_{it}: error term (assumed to be randomly distributed with an expected value of 0 and a constant variance)[14]

The parameters of interest in specification (1) are $\beta_j^{Support,j}$. As both R&D expenditures and the amount of support are included in logs, the estimates of these parameters represent constant elasticities. Given that R&D expenditures are considered after subtraction of the amount of public support for R&D, the null hypothesis $\beta_j^{Support,j} = 0$, implies no additionality and no crowding out of support scheme *j*, in line with the consensus view of neutrality of public support for R&D (Dimos and Pugh 2016). A statistically significant positive coefficient provides indications of additionality whereas a statistically significant negative coefficient would indicate crowding out.[15]

The schemes of public support that are considered are direct support (with distinct categories), the five schemes of partial exemption of payment of the withholding tax on the wages of R&D personnel (including the scheme for R&D employees with a bachelor's degree, introduced in 2018), the tax credit for R&D investment, the tax deduction for R&D investment (data only available until 2012), the tax deduction for patent income and the tax deduction for innovation income (introduced in 2016 to replace the

aggregate R&D intensity (share-weighted sum of the R&D intensity of all firms). This effect may be substantial but the partial nature of data, especially concerning real responses to the R&D survey, precludes a reliable assessment of this reallocation effect.

14 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 (for example, 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.

15 When total R&D expenditures are considered, without subtracting the amount of public support received, the null hypothesis implies full crowding out of public support, for which few studies find indications. Rejection of this null hypothesis is therefore not very informative. Greenland et al. (2016) point out that the p-value, on which assertions of statistical significance are based, indicates the degree to which the data conform to the pattern predicted by the null (test) hypothesis and all the other assumptions used in the test and that the p-value does not denote the probability that the null hypothesis is true as it is assumed that the null hypothesis is true. Considering a null hypothesis with low prior probability is therefore not very useful. Imbens (2021) argues that as a small p-value, is necessary - though not sufficient - to reject the null hypothesis in favour of the alternative hypothesis, reporting p-values seems a reasonable way to summarize evidence if there is substantial prior probability in favour of the null hypothesis.

tax deduction for patent income), the innovation bonus and EU funding received by Belgian firms through the 7th Framework Programme (2007-2013) and the 8th Framework (Horizon 2020) Programme (2014-2020).

For most instruments, the amount of public support received by firms can easily be computed from the data. This is more complicated for the corporate income taxation (CIT) incentives. For these incentives, the data, which are provided by taxation year, need to be linked to the income year, as this is the year to which the deductions apply (deduction computed on R&D expenditures or income of income year). Moreover, for some CIT incentives, several codes need to be considered and a tax rate needs to be applied to the amount of deduction/credit. As such the data on CIT incentives do not necessarily perfectly match with official statistics on the budgetary cost as shown in Graph 4.[16]

Given the highly skewed distribution of R&D expenditures and public support (as shown in Table 2 in section 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).[17] Only real responses of firms in the R&D survey, with regard to their R&D expenditures, are considered. Estimation of the impact of public support relies on the fact that not all R&D active firms receive public support, as well as on the variation in the amount of direct or tax support received by firms with R&D activities.

The estimations include control variables that denote characteristics that may affect the R&D investment decisions of firms such as turnover, the number of employees, firm age and capital intensity. In addition, region, industry and year dummies are included. When possible, time-varying industry-specific characteristics are captured by including industry-year dummies, following Aghion et al. (2012) and Einiö (2014).

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[16] Moreover, the R&D Policy Mix data do not provide information on public support received by self-employed entrepreneurs which is included in official statistics.

[17] In the R&D Survey, companies are asked to report their total (internal) R&D expenditures, irrespective of how these expenditures are financed. In principle, the total amount of public support received by companies is included in the reported R&D expenditures.

3. Data

This section describes the firm-level data that are used for the evaluation and provides some descriptive statistics on the use by companies of the distinct support measures.

3.1. R&D Policy Mix data

As for the three previous evaluations (Dumont 2012/2013, 2015, 2019), this fourth evaluation is based on data from the R&D Policy Mix database, created by the Federal Public Service Finance. The database links information from the Belgian biennial R&D survey, provided by the Federal Science Policy Office, to data on the direct support (subsidies) for R&D, provided by the three regional agencies in charge of granting subsidies (Innoviris for Brussels, VLAIO for Flanders and SPW Économie, Emploi, Recherche for Wallonia), and to data on the fiscal incentives granted by the federal government (different schemes of partial exemption from advance payment of the withholding tax for R&D personnel and incentives provided through corporate income taxation). The database also contains information, from the National Social Security Office, on innovation bonuses, granted by companies to employees who have created added value by innovation. The Federal Public Service Economy provides data on the number of patents granted by the Belgian Office for Intellectual Property. For this evaluation data on patents applied for by Belgian companies at the European Patent Office (EPO) have been added. The data on R&D activities and public support for R&D are matched with data from annual accounts of companies which provide information on potential determinants of R&D investment. The first evaluation covered the period 2001-2009, the second evaluation the period 2003-2011 and the third evaluation the period 2003-2015. This fourth evaluation, which covers the period 2003-2019, in contrast with previous evaluations, also considers the partial exemption for the remuneration of R&D employees with a bachelor's degree in qualifying study fields (starting from January 2018), and the innovation income deduction, which was introduced in 2016 to replace the patent income deduction, which was terminated in 2021. Publicly available data on funding by the European Commission of research by Belgian companies, through the 7th Framework Programme (2007-2013) and the 8th Framework (Horizon 2020) Programme (2014-2020)[18], was also matched with the other data.

The R&D Policy Mix database contains information on the total amount of support received by 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 and other firm characteristics that may affect companies' decisions on R&D activities.

[18] The multi-annual Framework Programmes for research and innovation were created by the European Union to support and foster research in the European Research Area. The 1st Framework Programme covered the years 1984-1987. The 8th Framework Programme, which ran from 2014 to 2020 was labelled Horizon 2020. The current 9th Framework Programme - labelled Horizon Europe - started in 2021 and will run until 2027. European Union (2017) provides an overview of the history of the Framework Programmes and the shift from an initial focus on pre-competitive research to a wider scope that also addresses societal challenges and the fragmentation of the European Research Area.

3.2. Descriptive statistics

This section provides descriptive statistics based on the R&D Policy Mix data that are used for the evaluation. As the evaluation in this report is based on partial data[19], the statistics reported in this section are indicative and should not be considered as official statistics.

Table 1 shows the average and median of R&D expenditures and of the amount of public support for R&D in 2019. The last column shows the number of firms that have reported internal R&D expenditures in the R&D survey or the number of firms that have benefitted from a specific support instrument in 2019. The distribution of R&D expenditures and public support is highly skewed as can be seen by the large difference between the average and the median. Average R&D expenditures are ten times larger than median R&D expenditures. For regional subsidies and the partial exemption for Young Innovative Companies (YIC), the average and the median are least far apart, indicating a more balanced distribution. By far the most skewed are two tax incentives provided through corporate income taxation (CIT), the tax credit for R&D investment (average more than 27 times as high as the median) and the patent income deduction (average more than 49 times as high as the median). The three schemes of partial exemption for R&D personnel with a specific degree are clearly the most popular instrument among firms. The tax incentives provided through corporate income taxation are used by few companies, especially relative to the 3,615companies that have reported R&D activities in 2019, but the average amount is far higher than for other support schemes. Though in 2019, relatively few Belgian companies received EU funding for research through Horizon 2020 (in effect, 210), the average and median amount of EU funding was substantial, which warrants the inclusion of this additional support scheme in the evaluation of public support for R&D to Belgian companies.

Table 1 Average and median amount of R&D and public support and number of firms
In euro (2019)

	Average	Median	Number of firms
R&D expenditures	2328425	220000	3615
Regional subsidies	184805	79000	1480
Research cooperation	46982	12987	183
Young Innovative Company (YIC)	30137	14401	391
PhDs and civil engineers	195516	28799	1260
Master	144398	30225	2600
Bachelor	29767	5568	1611
Tax credit R&D investment	566216	20715	433
Patent income deduction	3535196	72280	377
Innovation income deduction	1090112	100570	407
Innovation bonus	25878	5500	264
EU funding	817794	281241	210

Note: The second column shows the average amount of public support for companies that benefitted from the instrument in 2019. The third column shows the median amount of public support and the final column the number of firms that benefitted from the support or the number of firms that reported internal R&D expenditures in the R&D survey.

R&D expenditures and public support to business R&D are highly concentrated in the largest companies as can be seen in Table 2, which shows the share by quartile, with firms ranked in ascending order. The 25% of firms (fourth quartile) with the highest R&D expenditures account for almost 94% of all

[19] For example, no information on independent entrepreneurs is included in the data.

R&D expenditures. For most schemes of public support, the share of the top 25% firms is lower than 94%, suggesting that these schemes are less concentrated.

Table 2 Share of each quartile in R&D expenditures and public support for R&D
In % (2019)

	First quartile	Second quartile	Third quartile	Fourth quartile	Min / Max
R&D expenditures	0.3	1.4	4.3	93.9	1000 /1.0e+09
Regional subsidy	2.3	7.4	15.6	74.7	20 / 1.1e+07
Research cooperation	0.8	4.7	11.6	82.9	70 / 1100000
Young Innovative Company	1.6	8.2	19.1	71.1	200 / 320000
PhDs and civil engineers	0.6	2.3	6.6	90.4	9 / 3.7e+07
Master	1.0	3.4	9.5	86.1	8 / 2.0e+07
Bachelor	0.5	2.9	8.4	88.1	2 / 7400000
Tax credit R&D	0.1	0.5	2.0	97.5	6 / 7.2e+07
Patent income deduction	0.1	0.3	1.2	98.4	100 / 5.8e+08
Innovation income deduction	0.3	1.4	6.3	92.0	170 / 1.4e+08
Innovation bonus	1.3	3.5	8.3	86.9	400 / 2400000
EU funding	2.2	6.3	13.5	78.1	4600 / 3.4e+07

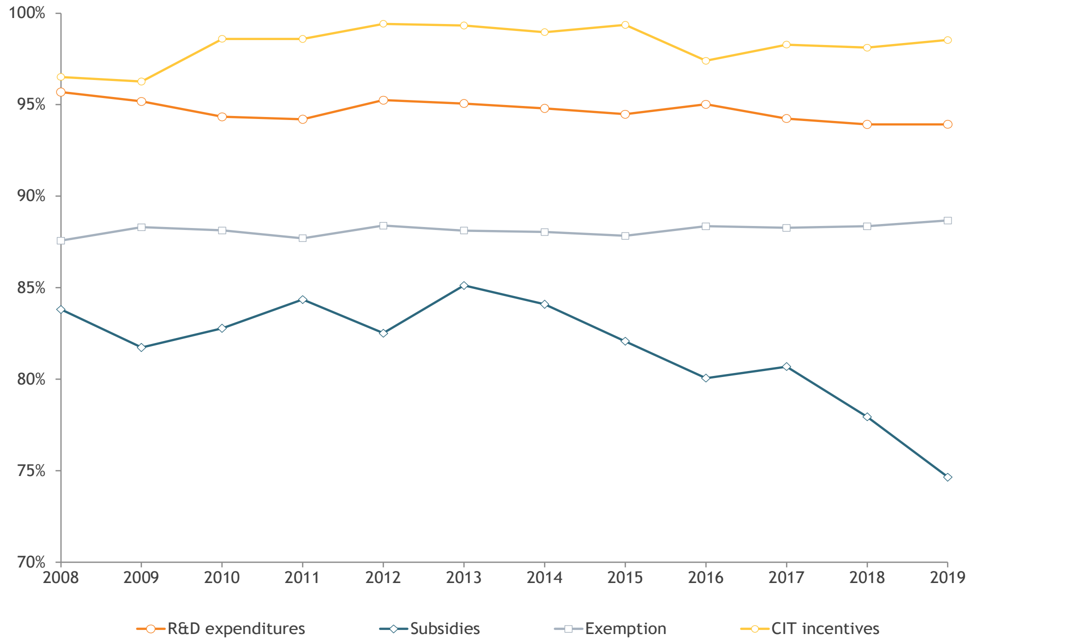
Note: The second up to the fifth column show the share of the first up to the fourth quartile in total R&D expenditures or the total amount of subsidies or tax benefits received by firms in 2019. The first (fourth) quartile groups the 25% of firms with the lowest (highest) R&D expenditures or amount of public support received. The last column shows the minimum and the maximum amount in euro (rounded).

This clearly holds for regional subsidies and the partial exemption for Young Innovative Companies. On the other hand, the tax credit for R&D investment and the patent income deduction are even more concentrated, with a share of the fourth quartile of respectively 97.5% and 98.4%. The innovation income deduction is less concentrated than the patent income deduction, which it replaced in 2016.

In its report on Belgian corporate income taxation (CIT) incentives for R&D, The Court of Audit (2021) pointed out that the tax deduction for innovation income is less concentrated in large companies and more evenly spread across different industries than the patent income deduction, for which three large pharmaceutical companies alone claimed 70% of the total amount of support received by firms in 2018. Statistics reported by The Court of Audit (2021) show that in 2018, the tax deduction for innovation income was popular among companies in *Financial service and insurance activities* and in *Software development*, whereas no pharmaceutical company made use of this support scheme as they probably continued to use the patent income deduction during the transitionary phase-out period 2016-2021.

Graph 8 shows the evolution of the share of the fourth quartile over the period 2008-2019, for R&D expenditures and the three main groups of public support to business R&D, regional subsidies, five schemes of partial exemption and three corporate income taxation (CIT) incentives (tax credit, patent income deduction and innovation income deduction). During the entire period, the share of the fourth quartile was highest for CIT incentives, above the share of the fourth quartile of R&D expenditures, which witnessed a slight decrease. The share of the fourth quartile for the partial exemption schemes was rather constant and substantially lower than the share in R&D expenditures. Regional subsidies are clearly less concentrated than tax incentives and show a strong decrease between 2008 and 2019, probably explained by increased attention of regional agencies to SMEs and start-ups.

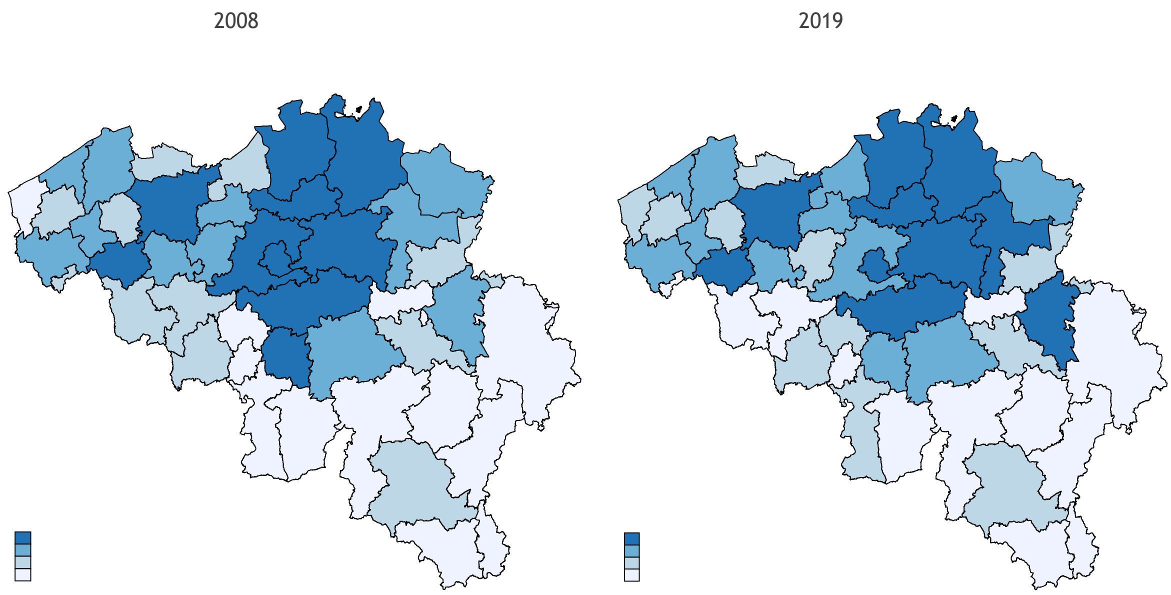
Graph 8 Evolution of the share of the fourth quartile in R&D expenditures and public support (2008-2019)
% of total R&D expenditure or amount of public support



Note: The graph shows the share of the fourth quartile (top 25%) in total R&D expenditures (internal) and public support, considering three main groups: subsidies, five schemes of partial exemption and three corporate income taxation (CIT) incentives (tax credit, patent income deduction and innovation income deduction).

Graph 9 shows the geographical concentration of R&D expenditures in 2008, by which year most of the tax incentives had been introduced, and 2019, the final year for which data are available. The 43 administrative districts of Belgium are coloured in four shades of blue, which, in ascending order, reflect the share of firms in that district, in R&D expenditures by all firms in Belgium.

Graph 9 Geographic concentration of R&D expenditures in Belgium in 2008 and 2019

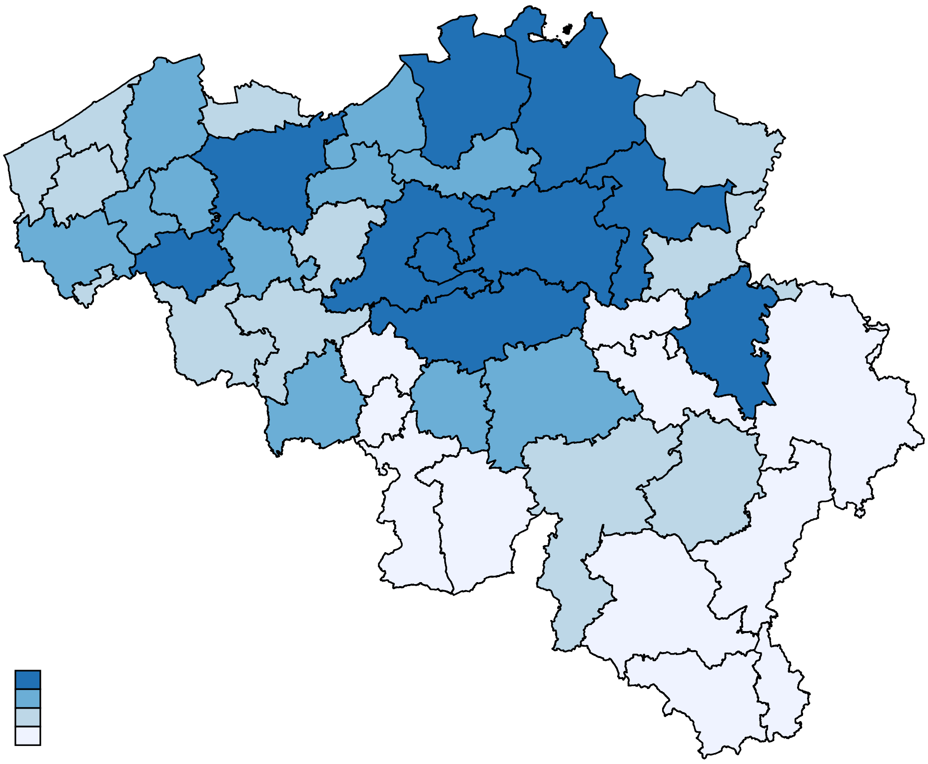


Note: The graph shows the concentration of R&D expenditures by administrative district in 2008 and 2019. The districts with the highest share in total R&D expenditures are coloured in dark blue and the districts with the lowest share are coloured in light blue.

The districts with the highest (lowest) share are coloured in dark (light) blue. R&D activities are clearly concentrated in the central-northern districts. The concentration appears to have been rather stable between 2008 and 2019 although the share of two central districts (Halle-Vilvoorde and Charleroi) decreased whereas two eastern districts (Hasselt and Liège) witnessed an increase in their share in total R&D expenditures.

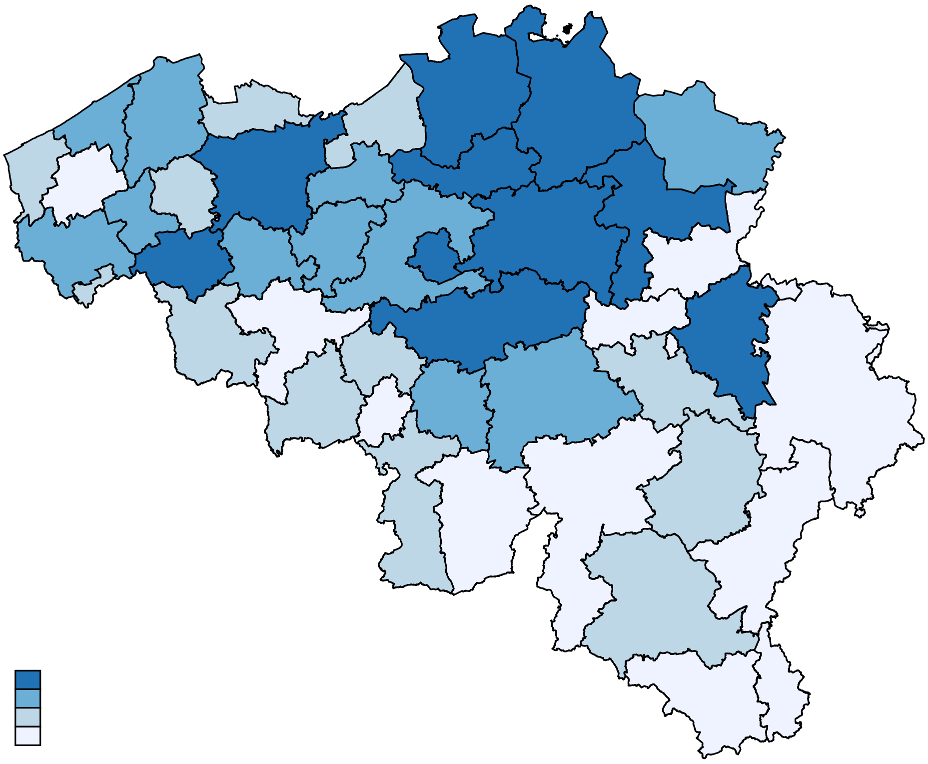
Graph 10 up to Graph 12 show the geographical concentration of the share in the total amount of public support to business R&D in 2019, for the three main groups of support: regional subsidies, the five schemes of partial exemption from payment of the withholding tax on the wages of R&D personnel and the three main tax incentives provided through corporate income taxation. To a large extent, the geographical concentration of public support coincides with the geographical concentration of R&D expenditures in districts in the central-northern part of Belgium. The district Mechelen, which belongs to the group of Belgian districts with the highest share in R&D expenditures in 2019 did not belong to the districts with the highest share in the amount of regional subsidies received by firms. Whereas the district Halle-Vilvoorde, which in 2008 was among the districts with the highest share in R&D expenditures but no longer in 2019, was among the districts with the highest share in the amount of regional subsidies in 2019. The ten districts with the highest share in the amount of partial exemption from payment of the withholding tax on the wages of R&D personnel, were the same ten districts with the highest share in R&D expenditures in 2019. Of the ten districts with the highest share in R&D expenditures in 2019, only the district Leuven was not among the ten districts with the highest share in support for R&D through corporate income taxation received by firms.

Graph 10 Geographic concentration of regional subsidies in Belgium in 2019



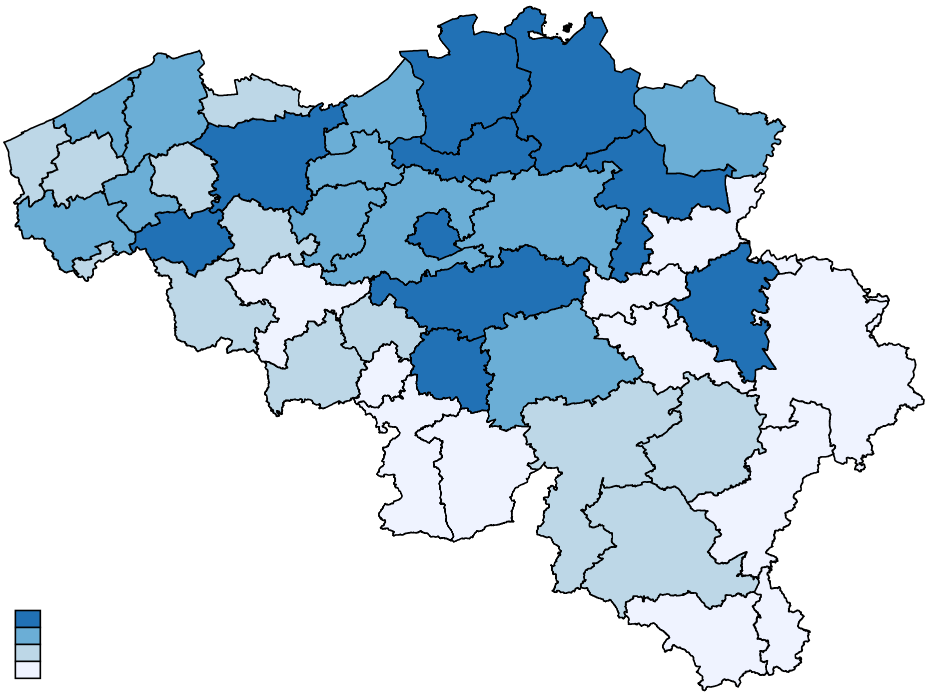
Note: The graph shows the concentration of regional subsidies, by administrative district in 2019. The districts with the highest share in the total amount of regional subsidies received by firms are coloured in dark blue and the districts with the lowest share are coloured in light blue.

Graph 11 Geographic concentration of partial exemption in Belgium in 2019



Note: The graph shows the concentration of the five schemes of partial exemption from payment of the withholding tax on the wages of R&D personnel, by administrative district in 2019. The districts with the highest share in the total amount of partial exemption received by firms are coloured in dark blue and the districts with the lowest share are coloured in light blue.

Graph 12 Geographic concentration of corporate income taxation (CIT) incentives in Belgium in 2019



Note: The graph shows the concentration of the three main tax incentives provided through corporate income taxation (tax credit for R&D investment, patent income deduction and innovation income deduction), by administrative district in 2019. The districts with the highest share in the total amount of CIT incentives received by firms are coloured in dark blue and the districts with the lowest share are coloured in light blue.

The district Charleroi, which was among the districts with the highest share in R&D expenditures in 2008 but no longer in 2019, was one of the ten districts with the highest share in support for R&D through corporate income taxation received by firms. In 2019, eight districts belonged to the top districts with highest share in total R&D expenditures as well as in the total amount of public support received by firms in the three main groups of support: Antwerpen, Brussel/Bruxelles, Gent, Hasselt, Kortrijk, Liège, Nivelles and Turnhout.

Table 3 shows the ten industries (two-digit NACE) with the highest share in total R&D expenditures and the ten industries with the highest share in the total amount of public support for R&D received, for all individual support schemes.

Table 3 The ten industries with the highest share in total R&D expenditures and public support for R&D in 2019
In % (two-digit NACE code in brackets)

	1	2	3	4	5	6	7	8	9	10
R&D expenditures	19.4 (21)	12.4 (72)	11.6 (62)	8.8 (77)	5.4 (70)	5.0 (71)	4.6 (46)	3.6 (26)	3.4 (28)	3.1 (20)
Regional subsidy	16.9 (72)	13.2 (62)	7.6 (71)	6.5 (26)	6.2 (46)	5.6 (24)	5.4 (70)	5.3 (21)	4.7 (28)	2.9 (22)
Partial Exemption:										
Research cooperation	19.0 (70)	17.1 (72)	15.0 (20)	9.3 (62)	6.8 (71)	4.9 (46)	4.4 (77)	4.4 (58)	3.0 (25)	2.8 (23)
Young Innovative Company	39.3 (62)	14.2 (71)	10.2 (72)	6.0 (70)	5.3 (63)	5.2 (46)	3.4 (47)	2.0 (32)	1.7 (73)	1.4 (27)
PhDs and civil engineers	28.7 (21)	11.2 (70)	10.5 (72)	8.9 (62)	5.3 (20)	4.8 (71)	4.5 (77)	4.1 (26)	3.8 (46)	2.8 (28)
Master	12.6 (62)	9.1 (71)	8.9 (21)	8.9 (72)	6.7 (26)	5.9 (70)	5.6 (46)	5.4 (28)	5.1 (45)	3.2 (20)
Bachelor	28.8 (21)	16.8 (62)	7.3 (72)	6.4 (70)	4.8 (71)	4.6 (26)	4.3 (20)	4.2 (28)	3.5 (46)	2.4 (61)
Corporate income taxation (CIT) incentives:										
Tax credit R&D	30.4 (21)	16.7 (72)	15.6 (77)	7.9 (62)	5.5 (50)	3.8 (46)	3.4 (24)	3.2 (20)	3.1 (26)	2.0 (71)
Patent income deduction	57.1 (21)	14.2 (72)	7.0 (28)	4.0 (30)	2.9 (25)	2.2 (61)	1.8 (45)	1.7 (24)	1.6 (26)	1.5 (32)
Innovation income deduction	17.9 (62)	12.3 (24)	12.2 (21)	9.4 (25)	9.3 (61)	8.1 (26)	3.0 (58)	2.8 (46)	2.7 (53)	2.6 (20)
Other funding:										
Innovation bonus	12.5 (62)	11.7 (41)	8.1 (10)	6.5 (20)	6.0 (71)	5.9 (46)	4.3 (27)	4.2 (25)	4.2 (26)	4.0 (22)
EU funding	29.5 (72)	17.7 (71)	14.5 (70)	9.1 (62)	4.5 (20)	3.5 (46)	2.7 (82)	2.4 (58)	1.7 (26)	1.4 (94)

Note: The table shows the share, in 2019, 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 five industries with the highest share in R&D expenditures, on their own, account for 57.6% of all R&D expenditures: Manufacture of basic pharmaceutical products and pharmaceutical preparations (21), Scientific research and development (72), Computer programming, consultancy and related activities (62), Rental and leasing activities (77) and Activities of head offices; management consultancy activities (70). There are considerable differences between the top five industries, in the extent to which they benefit from specific support schemes. Relative to their share in R&D expenditures, companies in Manufacture of basic pharmaceutical products and pharmaceutical preparations (21) have a high share in support received through the partial exemption for R&D personnel with a PhD or civil engineering degree and the partial exemption for R&D personnel with a bachelor's degree. Their share in tax incentives for R&D provided through corporate income taxation is even more substantial, especially for the tax credit for R&D investment (30.4%) and even more so for the patent income deduction, for which companies in this industry account for 57.1% of the total amount of support received in 2019.

Companies in Scientific research and development (72), not too surprisingly, have a relatively high share in the amount of regional subsidies and EU funding received by firms in 2019 but also in the amount of support received through the partial exemption for firms that cooperate in R&D. To a lesser extent companies in this industry also benefit much, relative to their share in R&D expenditures, from the tax credit for R&D investment and the patent income deduction.

Companies in Computer programming, consultancy and related activities (62), have a relatively high share in the total amount of support received through the partial exemption for R&D personnel with a bachelor's degree and the innovation income deduction but especially for the partial exemption for R&D personnel of Young Innovative companies, with a share of 39.3%. As mentioned before, the Court of Audit (2021) found that in 2018 the innovation income deduction was popular among companies in Financial service activities and in Software development. In 2019 companies in Manufacture of basic pharmaceutical products and pharmaceutical preparations (21) and Scientific research and development (72) made substantially more use of the patent income deduction than of the innovation income deduction. This is probably explained by the transitory phase-out period from 2016 to 2021 for the patent income deduction. It is likely that these two industries have become the main beneficiaries of the innovation income deduction after 2021 when the patent income deduction was terminated but there are no data available for these support schemes in income year 2021.

Table 4 shows the degree of match between administrative data on public support to business R&D and data on R&D expenditures from the biennial R&D survey. For each support scheme, the table shows the percentage of firms that benefitted from that scheme in 2019, that responded in the 2020 R&D survey to have performed R&D in 2019 (second column), the percentage that responded not to have had any R&D expenditures in 2019 (third column), the percentage of firms with support that did not respond to the survey (fourth column) and finally the percentage of firms that received public support but were not in the list of companies to which the R&D survey was sent in 2020. As in previous evaluations, the most surprising result is that for each support scheme, some companies that received support for R&D in 2019, responded explicitly not to have had any R&D expenditures in 2019, although the percentage is generally low. In comparison with the previous evaluations, the percentage of firms that receive support for R&D that are not on the R&D survey list decreased, indicating that the list provides an increasingly good match of firms that receive public support.

Table 4 Responses of firms that received public support, as to R&D expenditures in 2019 (2020 R&D Survey)
Number (share in % in brackets)

	Performed R&D	Did not perform R&D	No response	Not in list R&D firms
Regional subsidy	755 (51%)	76 (5%)	470 (32%)	179 (12%)
Research cooperation	97 (53%)	11 (6%)	65 (36%)	10 (5%)
Young Innovative Company	204 (52%)	14 (4%)	151 (39%)	22 (6%)
PhDs and civil engineers	681 (54%)	59 (5%)	459 (36%)	61 (5%)
Master	1347 (52%)	114 (4%)	930 (36%)	209 (8%)
Bachelor	814 (51%)	57 (4%)	510 (32%)	230 (14%)
Tax credit R&D	229 (53%)	22 (5%)	136 (31%)	46 (11%)
Patent income deduction	145 (36%)	10 (3%)	100 (25%)	145 (36%)
Innovation income deduction	163 (46%)	5 (1%)	90 (25%)	97 (27%)
Innovation bonus	89 (34%)	19 (7%)	58 (27%)	98 (22%)
EU funding	91 (43%)	16 (8%)	56 (27%)	47 (22%)

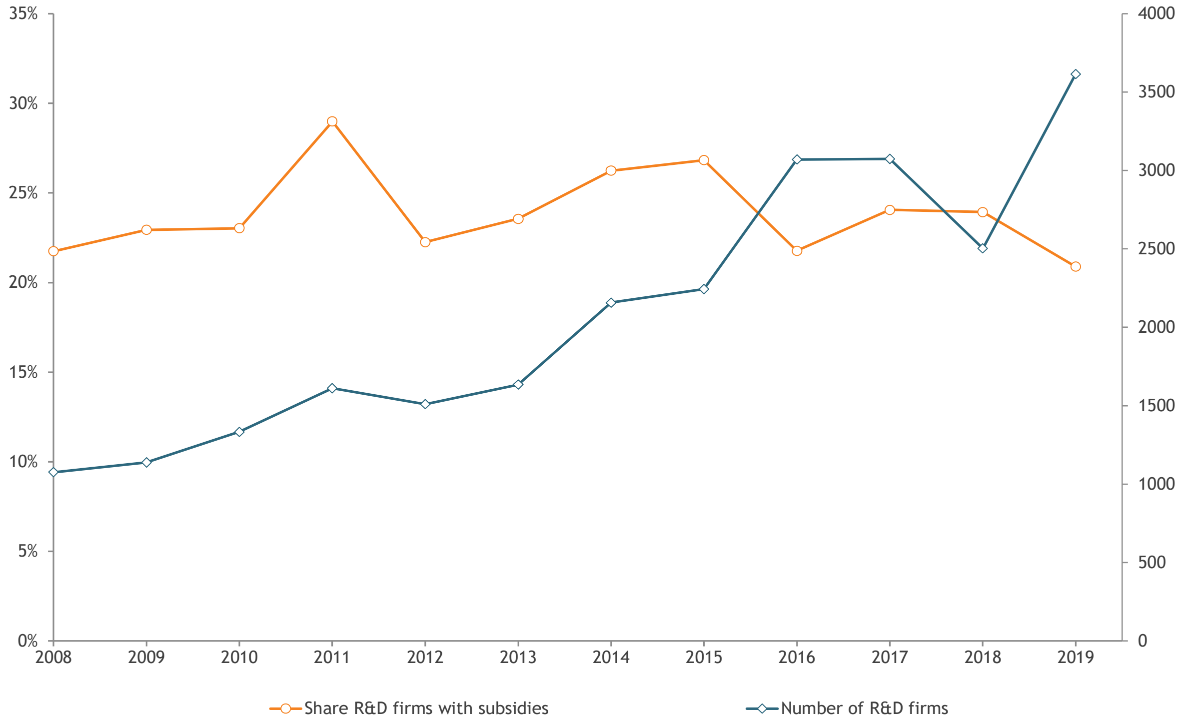
Note: The table shows the response in the 2020 R&D Survey, of firms that received public support for R&D in 2019, on the question whether they performed R&D in 2019 (second column) or not (third column). The fourth column shows the number of firms that received support but did not respond to the survey 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 brackets denote the share of each of the four groups in the total number of firms that received support through that specific scheme.

As a result of firms explicitly responding not to have had any R&D expenditures, firms not responding to the R&D survey or not being listed, for most support schemes only for about half of firms that received support, information is available on R&D expenditures, which is necessary to evaluate the effects of public support on R&D.

Graph 13 shows the evolution over the period 2008-2019 of the share of firms that reported non-zero R&D expenditures in the biennial R&D survey that received regional subsidies. The share has been rather stable with an average of 24%. The trend is slightly decreasing, especially towards the end of the period, with a period-low of 21% in the last year (2019). This can probably be explained by the strong rise in the number of firms that report non-zero R&D expenditures in the R&D survey, as also shown in Graph 13.

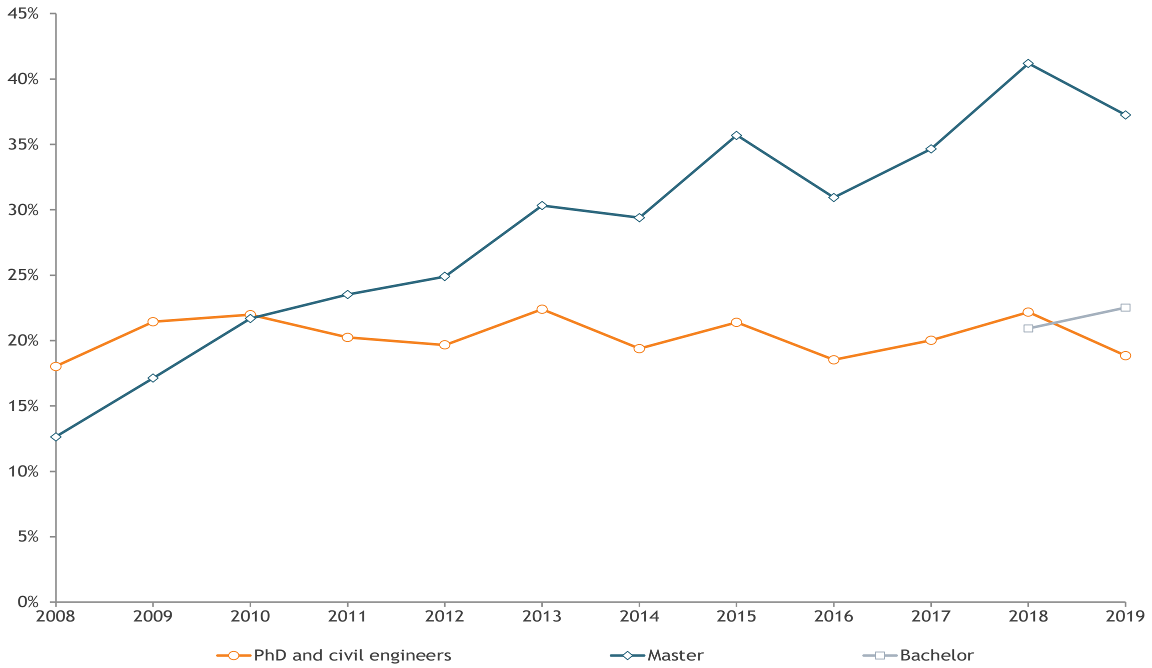
Graph 14 shows the evolution of the percentage of R&D firms (reported non-zero R&D expenditures) that have used one of the schemes of partial exemption of payment of the withholding tax on the wages of R&D personnel based on the educational degree of R&D employees. The share of R&D firms to use the partial exemption for PhDs and civil engineers has fluctuated around 19%. Since its introduction in 2007, the partial exemption for R&D personnel with a master's degree has gradually become more popular mong R&D firms, with the share of firms using this scheme surpassing the share of firms that used the partial exemption for PhDs and civil engineers in 2010 and steadily increasing afterwards. Remarkably, the partial exemption for R&D personnel with a bachelor's degree was already slightly more popular among R&D firms one year after its introduction in 2018 than the partial exemption for PhDs and civil engineers.

Graph 13 Evolution of the percentage of R&D firms that received direct support (2008-2019)



Note: The graph shows the percentage of firms that reported strictly positive R&D expenditures in the biennial R&D survey that have benefitted from regional subsidies in the same year. The number of R&D firms denotes the number of firms that have reported non-zero R&D expenditures in the biennial R&D survey.

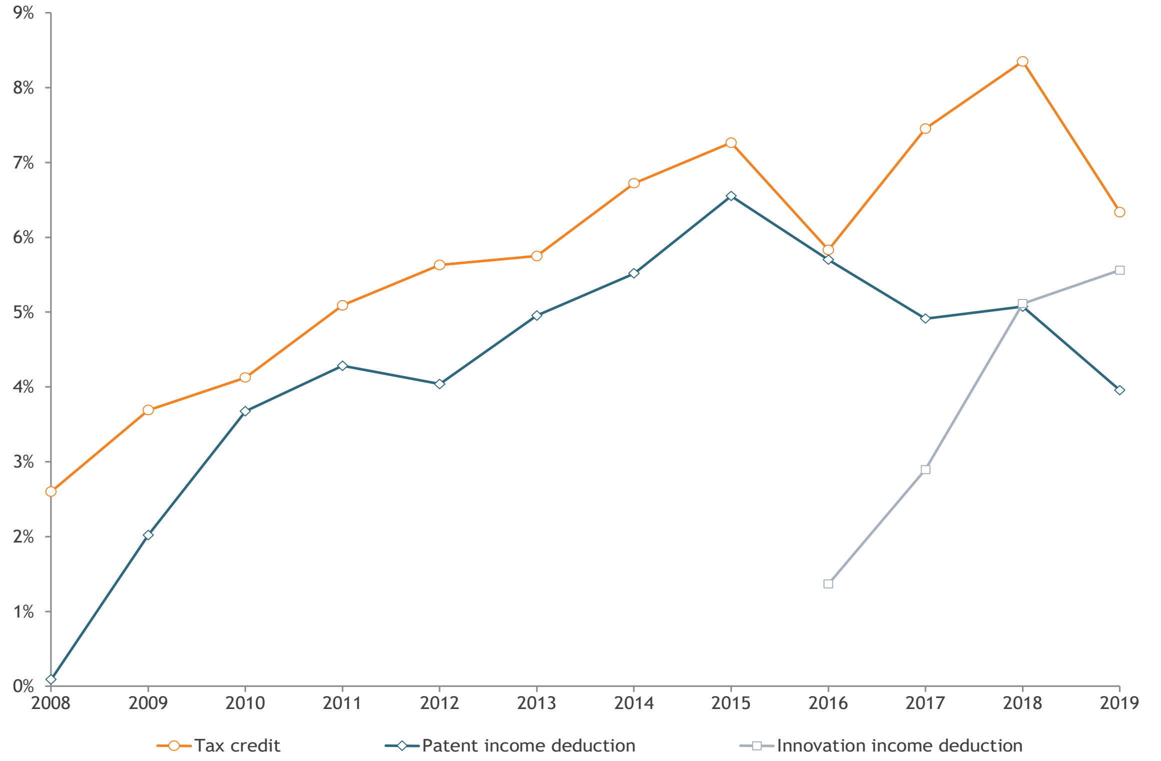
Graph 14 Evolution of the percentage of R&D firms that received public support through the partial exemption for R&D personnel based on the educational degree (2008-2019)



Note: The graph shows the percentage of firms that reported strictly positive R&D expenditures in the biennial R&D survey that have benefitted from one of the three schemes of partial exemption from payment of the withholding tax on the wages of R&D personnel, based on the educational degree of R&D employees in the same year.

Graph 15 shows the share of R&D firms that used one of the three main tax incentives through corporate income taxation (CIT) in the period 2008-2019. The share increased substantially, albeit starting from a very low level. The impact of the replacement of the patent income deduction in 2016 by the innovation income deduction can be clearly observed.

Graph 15 Evolution of the percentage of R&D firms that benefitted from the three main tax incentives provided through corporate income taxation (2008-2019)



Note: The graph shows the percentage of firms that reported strictly positive R&D expenditures in the biennial R&D survey that have benefitted from one of the three main corporate income taxation (CIT) incentives for R&D in the same year.

After increasing steadily between 2008 and 2015, the share of firms using the patent income deduction dropped from 2016 onwards (transitory five-year phase-out ended in 2021). The innovation income deduction on the other hand has become relatively more popular since its introduction in 2016. Even despite the strong increase in the share of R&D firms using the CIT incentives, at the end of the period less than 10% benefit from these incentives. These incentives, which account for the bulk of the total budgetary cost of public support to business R&D, clearly favour a small group of mainly large firms.

Despite the growing popularity of public support among R&D firms, less than half of the firms that reported non-zero R&D expenditures in 2019, used the most popular scheme (partial exemption for R&D personnel with a master's degree).

Table 5 provides indications on the extent to which firms combine different schemes of public support to business R&D. The first line shows, for each support scheme, the share of firms that benefited from that scheme but not from any other support scheme (single use). For the partial exemption for R&D personnel with a PhD or civil engineering degree and the partial exemption for R&D personnel with a bachelor's degree, the share of single use firms is very low (respectively 9% and 8%).

Table 5 Policy mix: combinations of public support for R&D in 2019
In %

	Subsidies	Cooperation	YIC	List 1	List 2	List 3	Tax credit R&D investment	Patent income deduction	Innovation income deduction	Innovation bonus	EU funding
Single use:	40	31	33	9	21	8	20	44	32	55	38
Combined with one other support scheme:											
Subsidies		10	14	3	4	0	4	4	4	2	7
Cooperation	1		1	0	0	0	0	1	0	1	0
Young Innovative Companies (YIC)	4	1		0	1	0	3	1	3	1	1
List 1 (PhD and civil engineers)	2	2	1		6	1	1	1	2	2	1
List 2 (Master’s degree)	6	4	7	12		27	3	6	5	3	1
List 3 (Bachelor’s degree)	0	0	0	1	17		0	0	0	0	0
Tax credit R&D investment	1	1	4	0	1	0		1	1	0	1
Patent income deduction	1	2	1	0	1	0	1		1	0	0
Innovation income deduction	1	1	3	1	1	0	1	1		0	0
Innovation bonus	0	2	1	0	0	0	0	0	0		0
EU funding	1	0	1	0	0	0	1	0	0	0	
Combined with 2 or more other support schemes:	41	46	36	73	49	64	66	41	51	36	50

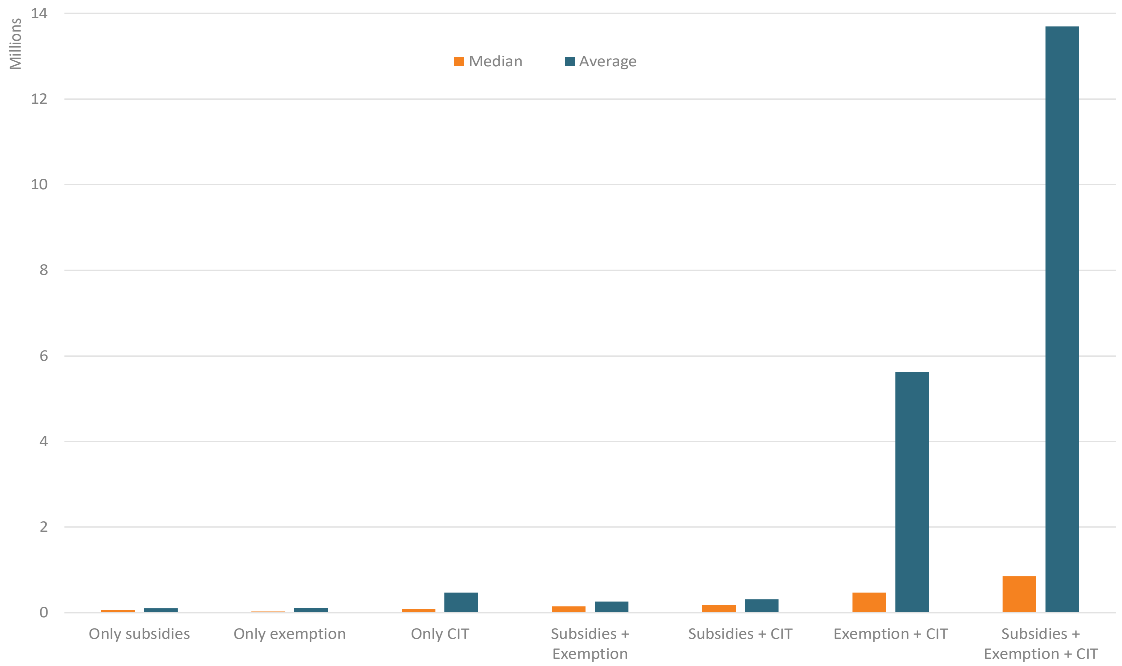
Note: The table shows the share of firms that received, in 2019, only one of the given forms of public support (single use), combined it with one of the other benefits or combined it with at least two other benefits (last line).

Except for the innovation bonus, for all schemes less than half of the firms that benefit from a specific support scheme do not combine this with support through some other scheme. Of firms that combine only two support schemes, combinations of the schemes of partial exemption for R&D personnel based on the educational degree are popular. Of firms that use the partial exemption for R&D personnel with a master's degree, 27% combine this only with the partial exemption for R&D personnel with a bachelor's degree.

A large share of firms that benefit from public support combine at least three different support schemes, especially firms that use the partial exemption for R&D personnel with a PhD or civil engineering degree (73% of which combine this support with at least two other support schemes) and the tax credit for R&D investment (66% of which combine this support with at least two other support schemes). The large extent to which firms combine different schemes of public support to business R&D emphasises the need to account for all schemes in evaluating the impact of each individual scheme. As the support received through different schemes is clearly not independent, ignoring some support schemes is likely to result in biased estimates of the impact of individual schemes.

Graph 16 reveals the stark difference in the total amount of public support received by firms that only use one of the three main groups of support (regional subsidies, partial exemption schemes or corporate income taxation (CIT) incentives) and firms that combine support from the three groups. The total amount of public support to business R&D is clearly dominated by firms that combine partial exemption schemes with corporate income taxation incentives and even more so by firms that combine support from all three main groups of public support.

Graph 16 Average and median amount of support: single use versus combination of support schemes (2019)

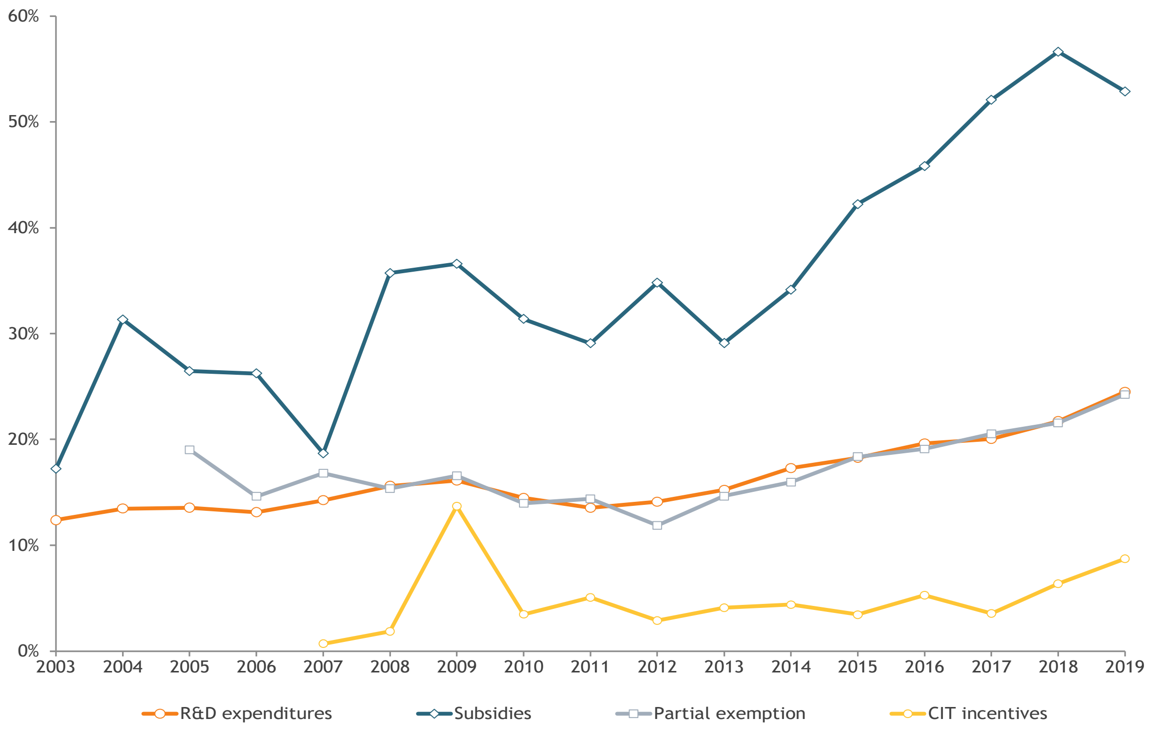


Note: The graph shows the average and median of total public support received by firms that only used one of the three main groups of public support (regional subsidies, partial exemption, and corporate income taxation (CIT) incentives) and for firms that combined support from different groups in 2019. The partial exemption group comprises the five schemes of partial exemption from payment of the withholding tax on the wages of R&D personnel and the CIT group comprises the tax credit for R&D investment, the patent income deduction, and the innovation income deduction.

A spending review of the partial exemption from payment of the withholding tax in Belgium finds that especially large firms combine several schemes and that the introduction of the exemption for bachelors seems of greater use to firms that already used the exemption for masters and PhDs (Janssens and Luyten 2021). This reflects the fact that especially the largest R&D firms combine support from all three groups, with the bulk of the budgetary cost of support accounted for by the tax incentives provided through corporate income taxation (as can be seen in Graph 2).

Data on firm ownership of Belgian companies, provided by Hambÿe et al. (2022), permit to consider three groups of firms: domestic companies, companies that belong to a Belgian multinational group and companies that belong to a foreign-owned multinational group. Graph 17 shows the evolution of the share of Belgian domestic firms in total R&D expenditures (based on responses in the biennial R&D survey) and their share in public support for the three main groups: regional subsidies, partial exemption schemes and corporate income taxation (CIT) incentives. Of the three groups of firms, Belgian domestic firms have the smallest share in total R&D expenditures but this share more than doubled over the period 2003-2019. The rise in the share of domestic firms in regional subsidies is even more impressive, from 17% in 2003 to 53% in 2019. The increase in the share in R&D expenditures has clearly been accompanied by direct support provided by the regions. The share of domestic firms in support provided through partial exemption form payment of the withholding tax is remarkably similar to the share in R&D expenditures over the period considered.

Graph 17 Share in total R&D expenditures and public support of domestic firms (2003-2019)

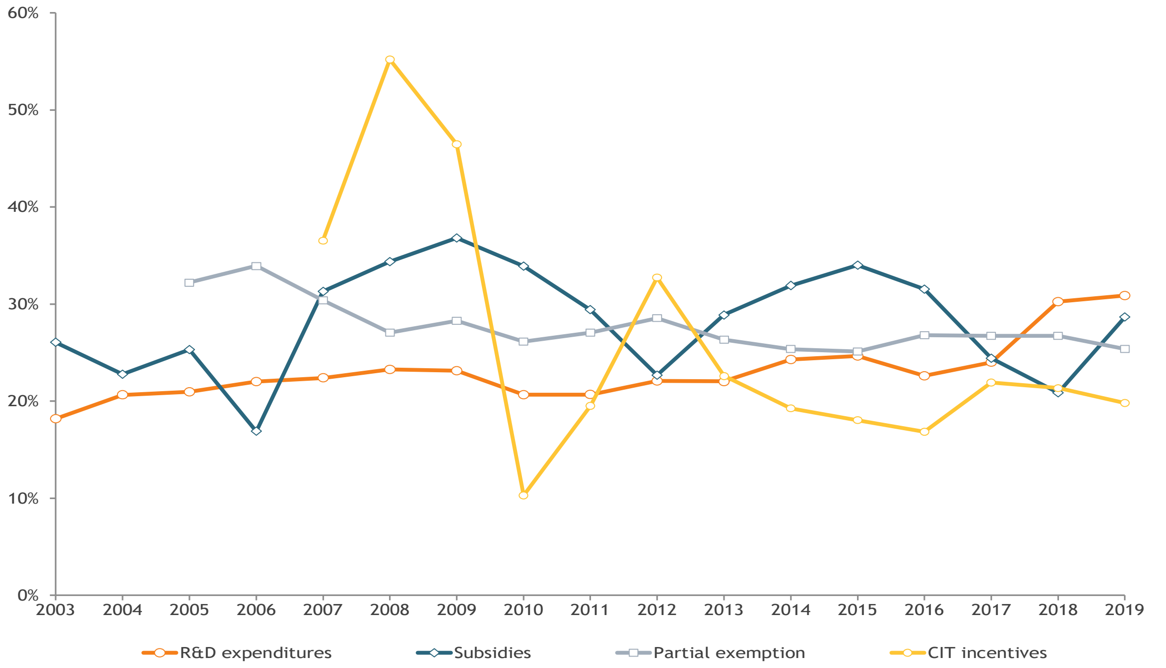


Note: The graph shows the share in total (internal) R&D expenditures and the share in public support of Belgian domestic companies (based on information on firm ownership provided by Hambÿe et al. 2022). Partial exemption comprises the five schemes of partial exemption of payment of the withholding tax on the wages of R&D personnel and CIT incentives comprises the three main tax incentives provided though corporate income taxation (CIT), the tax credit for R&D investment, the patent income deduction, and the innovation income deduction.

The share of domestic firms, in support provided through corporate income taxation (CIT), increased over time but remains well below the share of this group of firms in R&D expenditures. Public support for this group of firms clearly comes from regional subsidies and partial exemption and less from CIT incentives.

Graph 18 shows the share in R&D expenditures and the share in public support to business R&D for the group of firms that belong to a Belgian multinational group. Their share in R&D expenditures also increased but at a slower pace than for domestic firms. The share of these firms in direct support (regional subsidies) fluctuated around their share in R&D expenditures. In 2019, they accounted for 31% of R&D expenditures whereas their share in direct support was 29%. The share of these firms in support through the partial exemption schemes exceeded the share in R&D expenditures in the first years of introduction of the partial exemption but this share gradually decreased over time, dropping below the share in R&D expenditures in 2018. The evolution of the share of firms that belong to a Belgian multinational group in support provided through corporate income taxation (CIT) is more erratic[20], with the share exceeding the share in R&D expenditures in the years after the introduction of the patent income deduction but decreasing over time and dropping below the share in R&D expenditures after 2013.

Graph 18 Share in total R&D expenditures and public support of firms that belong to a Belgian multinational group (2003-2019)



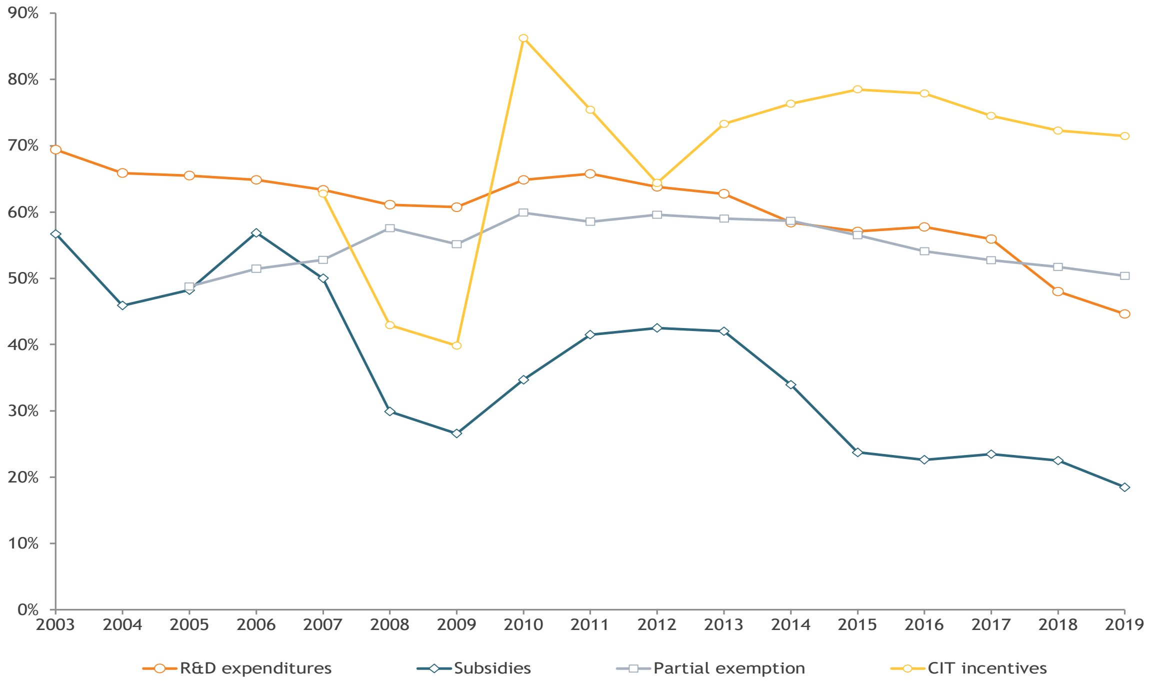
Note: The graph shows the share in total (internal) R&D expenditures and the share in public support of companies that belong to a Belgian multinational group (based on information on firm ownership provided by Hambÿe et al. 2022). Partial exemption comprises the five schemes of partial exemption of payment of the withholding tax on the wages of R&D personnel and CIT incentives comprises the three main tax incentives provided though corporate income taxation (CIT), the tax credit for R&D investment, the patent income deduction, and the innovation income deduction.

Graph 19 shows the share in R&D expenditures and the share in public support to business R&D for the group of firms that belong to a foreign-controlled multinational group. This group has the largest share in R&D expenditures over the entire period, but the trend is strikingly negative. The share of these firms in direct support is well below their share in R&D expenditures and decreased more dramatically over time. The share in support from the partial exemption started below the share in R&D expenditures

[20] The number of firms that use the patent income deduction is rather small. Fluctuations in patent income of individual companies can have a considerable impact on the aggregate amount of support received.

but gradually converged with very similar shares since 2014. The share of foreign-controlled Belgian firms in support provided through corporate income taxation (CIT), has a similar erratic – but opposite – pattern as the group of firms that belong to a Belgian multinational group, in the first years after the introduction of the patent income deduction but from 2010 onwards their share in CIT incentives clearly exceeds their share in R&D expenditures. From 2013 there is a growing divergence between the share of foreign-controlled Belgian firms in support received through corporate income taxation (CIT) and their decreasing share in R&D expenditures.

Graph 19 Share in total R&D expenditures and public support of firms that belong to a foreign-controlled multinational group (2003-2019)



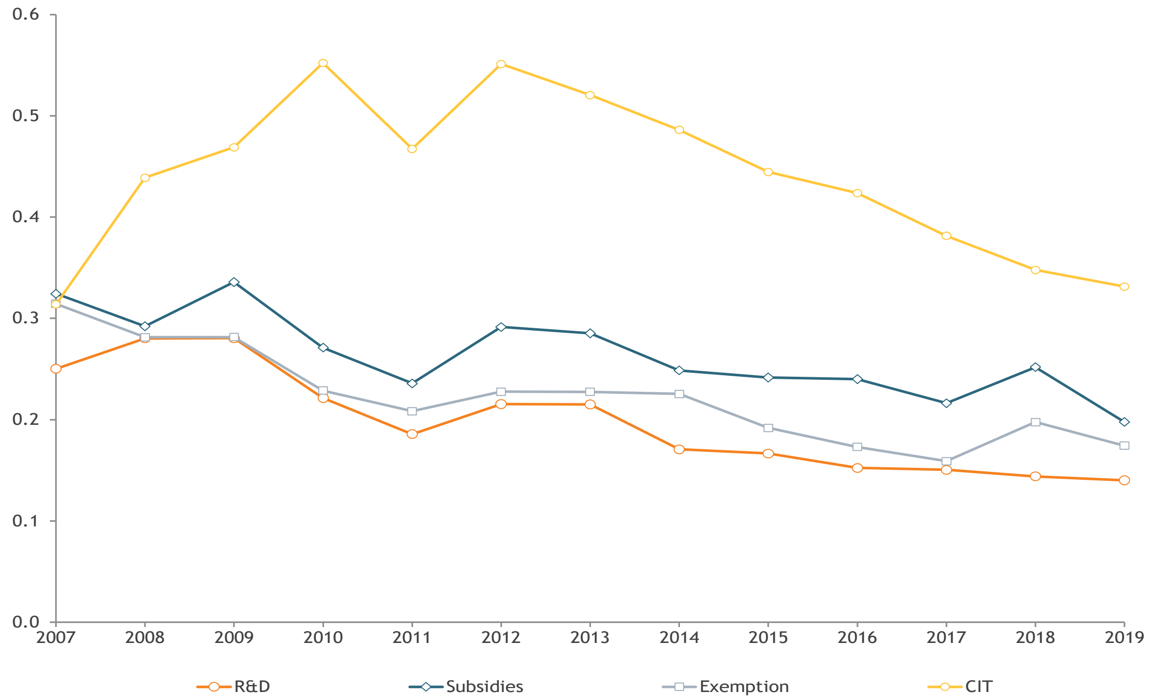
Note: The graph shows the share in total (internal) R&D expenditures and the share in public support of companies that belong to a foreign-controlled multinational group (based on information on firm ownership provided by Hambÿe et al. 2022). Partial exemption comprises the five schemes of partial exemption of payment of the withholding tax on the wages of R&D personnel and CIT incentives comprises the three main tax incentives provided though corporate income taxation (CIT), the tax credit for R&D investment, the patent income deduction, and the innovation income deduction.

Graph 20 shows the evolution of concentration of R&D expenditures and the three main groups of public support over the period 2007-2019. The evolution of concentration of subsidies and the partial exemption closely matches the level and the decline in concentration of R&D expenditures. The concentration of support for R&D provided through corporate income taxation increased until 2010-2013, after which it also started to decrease substantially, although the level of concentration is still higher than the concentration of the two other groups of public support and R&D expenditures.

The decrease in concentration in business R&D in Belgium is confirmed for the period 1995-2015 by OECD (2021 c). In other OECD countries (Chile, the Czech Republic, France and Norway) R&D concentration also decreased whereas it remained flat in other countries, except for Japan which witnessed an increase in R&D concentration. Countries with the strongest increase in tax support for R&D tend to have witnessed the strongest decline in R&D concentration. This could indicate that tax support stimulates (small) firms to start doing R&D (extensive margin) but if the introduction of tax incentives helps

R&D surveys to identify smaller R&D-performing firms, measured R&D concentration could also decrease even if actual R&D concentration remains unchanged (OECD 2021 c, p. 19).

Graph 20 Evolution of concentration of R&D expenditures and public support - Herfindahl-Hirschman Index



Note: The graph shows the concentration of internal) R&D expenditures and the amount of public support for the three main categories (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation incentives). As data on the tax deduction for R&D investment are only available until 2012, this CIT incentive is not considered. Concentration is measured by the Herfindahl-Hirschman Index which sums the squared shares of individual companies in R&D expenditures, or the amount of public support received. Only firms that reported R&D expenditures in the R&D Survey are considered.

4. Results

This chapter reports the results of the baseline estimation of the impact of public support to business R&D over the period 2003-2019. These results are compared to estimates from other procedures that address a possible selection bias and endogeneity, which complicate the estimation of the causal impact of public support to business R&D. Section 4.1 considers the input additionality of public support, in effect, the extent to which public support raises R&D expenditures of companies. In section 4.2 results are reported on behavioural additionality such as the impact of public support on the orientation of R&D activities (share of basic and applied research and experimental development). Section 4.3 considers the potential impact of support on output (turnover, profitability, productivity and patents).

4.1. Input additionality

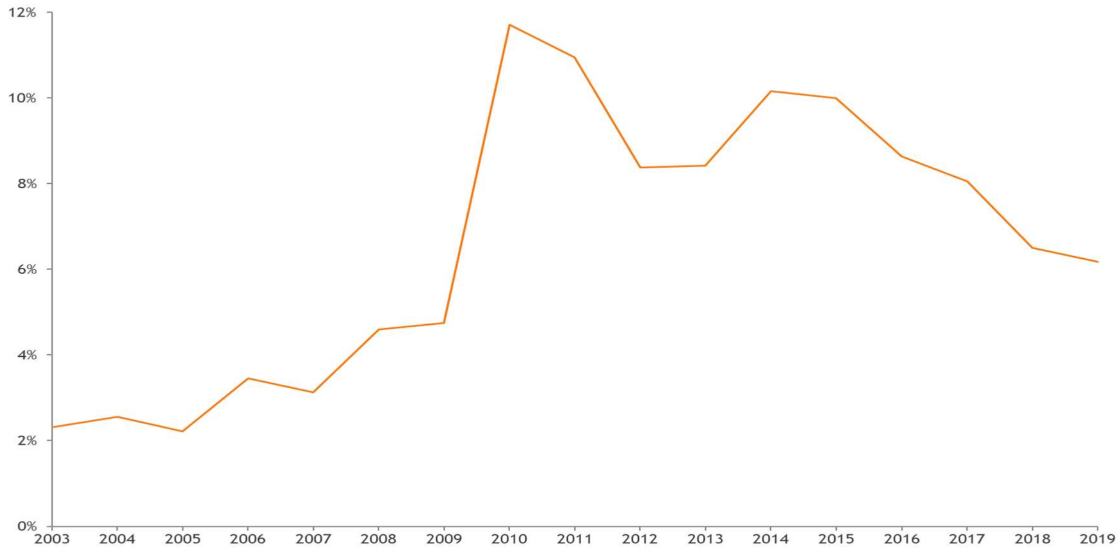
In this section the results of alternative estimations are reported of the extent to which public support results in additional R&D expenditures of companies (as R&D expenditures are considered as inputs of the innovation process this is called input additionality).

4.1.1. Baseline estimation

The baseline specification for estimation (see equation (1) on page 24) considers internal R&D expenditures net of the total amount of public support received by companies for their R&D activities. In the biennial R&D survey, companies are asked to report total R&D expenditures, irrespective of how these R&D expenditures are financed. In principle the amount of public support for R&D received by a company should be included in the reported R&D expenditures. From an econometric perspective it is advisable to regress R&D expenditures, net of public support, on the amount of support received (see footnote 15 on page 24). However, subtracting the amount of public support from R&D expenditures results in negative values for some companies. This may be explained by problems in the matching of different data sources but also by misunderstanding of companies of what should be included in the R&D expenditures reported in the R&D survey. Especially for the partial exemption from payment of the withholding tax on the wages of R&D personnel, companies may fail to understand that the total wage sum of R&D employees needs to be included in R&D expenditures, abstracting from the partial exemption, that is, needs to be reported as if the partial exemption does not apply. This can be seen in Graph 21, which shows the share of R&D firms (which reported R&D expenditures) for which the amount of public support for R&D[21], based on administrative data, exceeds total R&D expenditures as reported in the R&D survey. There is a relatively strong increase in the share of firms with negative net R&D expenditures (R&D expenditures minus the amount of public support received) corresponding with the rising uptake by firms of the partial exemption for R&D personnel with a PhD or civil engineering degree and the partial exemption for R&D personnel with a master's degree (see Graph 3). In 2010, for 11.7% of firms net R&D expenditures were negative.

[21] For corporate income taxation (CIT) incentives, the amount of support received relates to the income year and not the taxation year.

Graph 21 Share of firms with negative net R&D expenditures (2003-2019)



Note: The graph shows the share of firms that have reported R&D expenditures in the biennial R&D survey for which subtracting the total amount of public support for R&D from reported R&D expenditures results in a negative value.

The share of firms with a negative value have decreased after 2010, probably reflecting increased awareness among respondents of the R&D survey of correct reporting of R&D expenditures. Negative net R&D expenditures point to unreliable data and are therefore not considered in the evaluation.[22] One estimation with total gross R&D expenditures (not subtracting the amount of public support) is reported for information (Table 14).

Table 6 shows the results of the baseline estimation, a panel estimation with firm fixed and time fixed effects.[23] The table shows the results of three alternative specifications. Results of an estimation that includes industry and year dummies are reported in the second column. The third column shows the results of an estimation that includes industry*year dummies, following Aghion et al. (2012) and Einiö (2014) to control for time-variant industry effects. The results of a fixed effects estimation, with industry and year dummies, in which an Inverse Hyperbolic Sine (IHS) transformation of net R&D expenditures is considered as dependent variable, instead of the logarithm, are reported in the final column. In the baseline specification, the logarithm of net R&D + 1 is considered, rather than just the logarithm of net R&D, so that the logarithm is also defined for firms that have reported zero R&D expenditures (see, for example, Lehto 2007). Santos Silva and Tenreyro (2006) point out that this transformation could result in biased estimates. An alternative that permits to keep zero-valued observations is the Inverse Hyperbolic Sine (IHS) transformation which consists in $log\left(R\&D + \sqrt{R\&D^2 + 1}\right)$.[24]

[22] As net R&D expenditures are included in log, it is not possible to include negative values anyway without any transformation.

[23] Wooldridge (2021) points out that with an unbalanced panel, two-way fixed effects estimation (including unit and time fixed effects, as is the case in the baseline specification) is preferred, as it allows correlation between sample selection and unobserved unit (firm) heterogeneity. The panel that can be constructed from matching the several Policy Mix data sources is strongly unbalanced.

[24] In the baseline specification, the logarithm of net R&D + 1 is considered instead of the logarithm of net R&D so that the logarithm is also defined for firms that have reported zero R&D expenditures. 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.

Table 6 Results of the baseline estimation (fixed effects panel)

	Log (1)	Log (2)	IHS
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.08 (10.88) ***	0.08 (10.54) ***	0.08 (11.11) ***
Partial exemption schemes:			
Research cooperation	0.14 (6.21) ***	0.15 (6.35) ***	0.14 (6.20) ***
Young Innovative Company	0.14 (7.18) ***	0.13 (6.37) ***	0.14 (7.24) ***
PhDs and civil engineers	0.05 (3.66) ***	0.04 (3.16) ***	0.05 (3.77) ***
Master	0.14 (11.05) ***	0.14 (11.00) ***	0.14 (11.08) ***
Bachelor	0.06 (4.03) ***	0.05 (3.18) ***	0.06 (3.97) ***
Corporate income taxation incentives:			
Tax credit R&D	-0.03 (-1.32)	-0.02 (-1.03)	-0.03 (-1.33)
Tax deduction R&D°	0.13 (8.26) ***	0.12 (6.56) ***	0.13 (8.28) ***
Patent income deduction	-0.05 (-3.92) ***	-0.04 (-2.72) ***	-0.05 (-3.81) ***
Innovation income deduction	-0.04 (-2.15) **	-0.05 (-2.44) **	-0.04 (-2.12) **
Other funding:			
Innovation bonus	0.11 (5.12) ***	0.10 (4.56) ***	0.11 (5.14)) ***
EU funding	-0.04 (-2.98) ***	-0.04 (-3.07) ***	-0.04 (-3.00) ***
Control variables:			
Turnover	0.06 (0.78)	0.07 (0.84)	0.06 (0.73)
Number of employees	1.13 (8.60) ***	1.12 (8.33) ***	1.17 (8.44) ***
Age	-1.54 (-3.95) ***	-1.20 (-5.12) ***	-1.22 (-5.22) ***
Capital intensity	0.15 (2.63) ***	0.17 (2.83) ***	0.16 (2.61) ***
Industry (two-digit NACE)	Yes	No	Yes
Year dummies	Yes	No	Yes
Industry * year dummies	No	Yes	No
R-squared (within)	0.08	0.13	0.08
Number of observations	29,221	29,221	29,215

Note: The table shows the results of fixed effects estimation of specification (1) on page 24. 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. °Data on the tax deduction for R&D investment is only available until 2012.

In principle, this transformation could also permit to include negative net R&D expenditures but as these probably point at unreliable data, they are not considered for estimation.

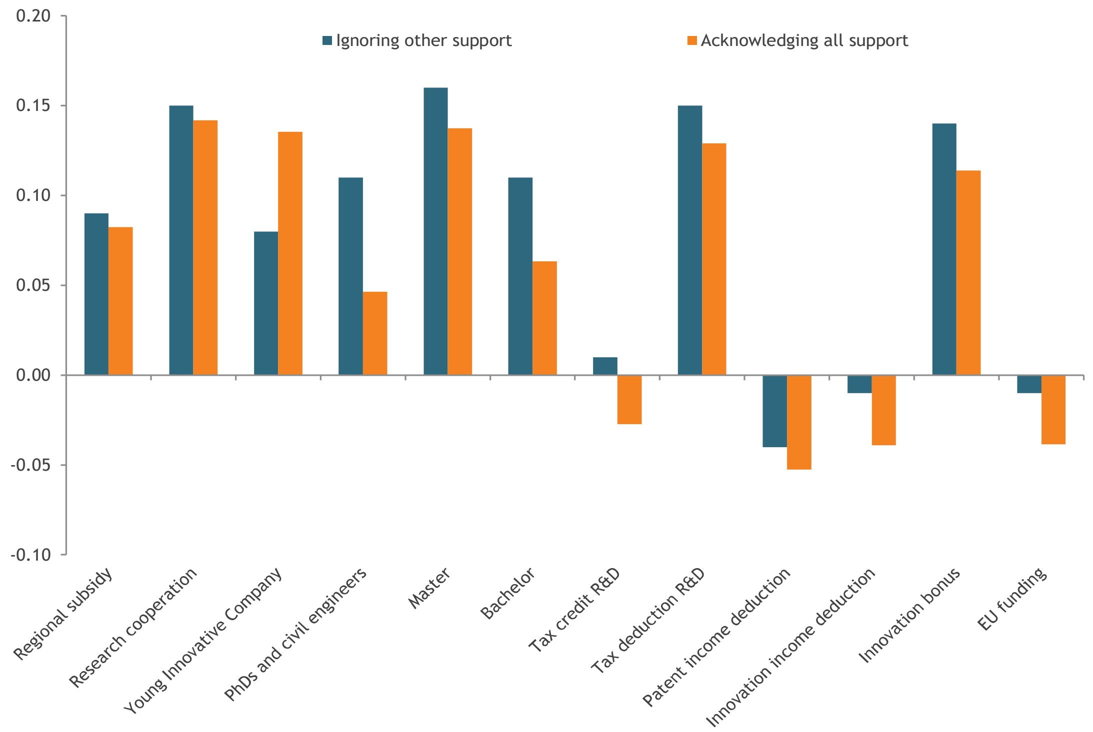
The coefficient estimates are very similar across the three alternative specifications. The control variables indicate that, conditional on the other variables, R&D expenditures increase with the number of employees and capital intensity but decrease with firm age.[25] Except for the tax credit for R&D investment, all coefficients of public support are statistically significant. As the dependent variable denotes R&D expenditures net of public support, the statistical significance of coefficient estimates provides a direct indication of additionality, if the coefficient is positive, and an indication of crowding out if the coefficient is negative. For regional subsidies and the five schemes of partial exemption from payment of the withholding tax on the wages of R&D personnel, all estimations suggest additionality. For the

[25] Table A3.1 in Annex 3 shows the results of an estimation with additional financial indicators included as control variables.

incentives provided through corporate income taxation, additionality is only found for the tax deduction for R&D investment, for which data is only provided until 2012. For the patent income deduction and the innovation income deduction, estimates suggest crowding out, in effect, part of the R&D activities that financed through these benefits would have been carried out in absence of the benefits. For the innovation bonus, estimates suggest additionality whereas indications of crowding out are found for EU funding.

The baseline specification includes all schemes of public support that are available for companies in Belgium. Controlling for all other available instruments, is necessary for an unbiased estimate of the effectiveness of each individual instrument. The bias of ignoring other support schemes in estimating the impact of individual schemes is shown in Graph 22.

Graph 22 Bias due to ignoring other public support to business R&D



Note: The orange bars denote the coefficient estimate of each individual support scheme resulting from the estimation of the baseline specification in which all support schemes are considered jointly (results as reported in the second column of Table 6). The blue bars denote the coefficient estimate of each individual support scheme resulting from regressions in which each support scheme is considered separately, ignoring all other schemes of public support received by firms.

The blue bars show the coefficient estimates of each support instrument that results from a separate regression in which only the specific instrument is included, without controlling for all other schemes[26], whereas the orange bars show the coefficient estimates from the baseline estimation, in which all support schemes are considered jointly (second column table 6). Except for the partial exemption from payment of the withholding tax for Young Innovative Companies, ignoring other support schemes results in the overestimation of the effectiveness of individual support schemes. For some partial exemption schemes (PhDs/civil engineers and Bachelors) the bias due to ignoring other public support is considerable.

[26] These estimates are not reported but available upon request.

In Table 6, the total amount of direct support is considered as a single category without acknowledging distinct categories of regional subsidies. Based on available information, subsidies can be categorized along three dimensions: distance to the market, thematic/bottom-up and cooperation. Table 7 shows the results of three separate estimations of the baseline specification along the three dimensions. Not surprisingly, the coefficient estimates for indirect support, the innovation bonus and EU funding are very similar to the results in Table 6. A statistically significant positive coefficient is found for R&D projects, in which the distinction between research and development cannot be provided, and for feasibility studies and specific SME support. For specific research subsidies and specific development subsidies, the coefficient is positive but not statistically significant.

Table 7 Results of fixed effects panel estimation with different categories of direct support

	Distance to market	Thematic/Bottom-up	Cooperation
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Direct support:			
Research	0.02 (1.51)		
Development	0.02 (1.51)		
Research and Development	0.08 (9.16) ***		
Feasibility study/SME support	0.07 (5.66) ***		
Bottom-up		0.08 (10.42) ***	
Thematic		0.02 (1.45)	
No R&D cooperation			0.05 (5.89) ***
R&D cooperation			0.08 (8.09) ***
Partial exemption schemes:			
Research cooperation	0.15 (6.31) ***	0.15 (6.34) ***	0.15 (6.26) ***
Young Innovative Company	0.13 (6.47) ***	0.13 (6.40) ***	0.13 (6.28) ***
PhDs and civil engineers	0.04 (3.15) ***	0.04 (3.20) ***	0.04 (3.09) ***
Master	0.14 (10.95) ***	0.14 (11.00) ***	0.14 (11.07) ***
Bachelor	0.05 (3.30) ***	0.05 (3.17) ***	0.05 (3.11) ***
Corporate income taxation incentives:			
Tax credit R&D	-0.03 (-1.20)	-0.02 (-1.06)	-0.02 (-1.14)
Tax deduction R&D°	0.12 (6.56) ***	0.12 (6.50) ***	0.12 (6.55) ***
Patent income deduction	-0.04 (-2.83) ***	-0.04 (-2.76) ***	-0.04 (-2.86) ***
Innovation income deduction	-0.05 (-2.41) **	-0.05 (-2.46) **	-0.05 (-2.46) **
Other funding:			
Innovation bonus	0.10 (4.45) ***	0.10 (4.58) ***	0.10 (4.54)) ***
EU funding	-0.04 (-3.18) ***	-0.04 (-3.07) ***	-0.04 (-3.10) ***
R-squared (within)	0.13	0.13	0.13
Number of observations	29,221	29,221	29,221

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with a breakdown of direct support into different categories. Estimations include industry-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. °Data on the tax deduction for R&D investment is only available until 2012.

The coefficient of subsidies for bottom-up projects is positive and statistically significant whereas the coefficient for subsidies for thematic projects is positive but not statistically significant. The coefficient of subsidies is statistically significant positive whether the project involves cooperation, or not, but the coefficient is larger for projects in which companies do cooperate with other companies or research organizations.

Table 8 shows the results of an estimation in which subsidies are further broken down by the type of research cooperation. The coefficient of subsidies for projects without cooperation is higher than most cooperation categories except for subsidies for projects in which companies cooperate with a research organization in their own region.

Table 8 Results of fixed effects panel estimation with detailed cooperation categories of direct support

Dependent variable (R&D expenditures net of public support)	
Explanatory variables (public support):	
Direct support:	
No cooperation	0.07 (7.88) ***
Cooperation with company in own region	0.04 (2.53) ***
Cooperation with research organization in own region	0.07 (5.98) ***
Cooperation with company in own region, in another region Belgium and abroad	0.05 (1.26)
Cooperation with research organization in own region, in another region Belgium and abroad	0.06 (2.23) **
Cooperation with company and research organization in own region	0.03 (2.46) **
Cooperation with company and research organization in own region, cooperation with another region Belgium and abroad	0.02 (0.42)
Partial exemption schemes:	
Research cooperation	0.15 (6.28) ***
Young Innovative Company	0.13 (6.43) ***
PhDs and civil engineers	0.04 (3.26) ***
Master	0.14 (11.02) ***
Bachelor	0.05 (3.18) ***
Corporate income taxation incentives:	
Tax credit R&D	-0.02 (-1.12)
Tax deduction R&D°	0.12 (6.66) ***
Patent income deduction	-0.04 (-2.90) ***
Innovation income deduction	-0.05 (-2.49) ***
Other funding:	
Innovation bonus	0.10 (4.58) ***
EU funding	-0.05 (-3.39) ***
R-squared (within) : 0.13	
Number of observations : 29,221	

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with a breakdown of direct support into different detailed categories of R&D cooperation. Estimations include industry-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. °Data on the tax deduction for R&D investment is only available until 2012.

The coefficients of subsidies for projects that involve cooperation with a company in the same region as well as cooperation with partners in another region and partners abroad are not statistically significant. This result may indicate that as cooperation permits partners to share costs, the impact of subsidies on R&D expenditures financed by companies is more limited than if companies need to pay the full cost.

Table 9 presents the results of an estimation of the baseline specification with direct support broken down by categories that combine the three dimensions.

Table 9 Results of fixed effects panel estimation with most detailed categories of direct support

Dependent variable (R&D expenditures net of public support)	
Explanatory variables (public support):	
Direct support:	
Research - bottom-up - no cooperation	0.03 (1.46)
Research - bottom-up - cooperation	0.01 (0.39)
Development - bottom-up - no cooperation	0.03 (1.62) *
Development - bottom-up - cooperation	-0.01 (-0.43)
Research and Development - bottom-up - no cooperation	0.05 (4.75) ***
Research and Development - bottom-up - cooperation	0.08 (6.84) ***
Feasibility study/SME support - bottom-up - no cooperation	0.03 (2.35) **
Feasibility study/SME support - bottom-up - cooperation	0.16 (6.33) ***
Research - thematic - no cooperation	-0.12 (-2.60) ***
Research - thematic - cooperation	0.01 (0.09)
Development - thematic - cooperation	0.04 (1.27)
Research and Development - thematic - cooperation	0.02 (1.24)
Partial exemption schemes:	
Research cooperation	0.15 (6.19) ***
Young Innovative Company	0.13 (6.35) ***
PhDs and civil engineers	0.04 (3.17) ***
Master	0.14 (11.07) ***
Bachelor	0.05 (3.13) ***
Corporate income taxation incentives:	
Tax credit R&D	-0.02 (-1.14)
Tax deduction R&D°	0.12 (6.58) ***
Patent income deduction	-0.04 (-2.83) ***
Innovation income deduction	-0.05 (-2.47) ***
Other funding:	
Innovation bonus	0.10 (4.56) ***
EU funding	-0.04 (-3.17) ***
R-squared (within) : 0.13	
Number of observations : 29,221	

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with a breakdown of direct support into different detailed categories. Estimations include industry-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. °Data on the tax deduction for R&D investment is only available until 2012.

The coefficient estimates of four categories are statistically significant with the highest impact for subsidies for feasibility studies and SME support that are bottom-up and involve cooperation. The coefficient estimate of thematic research projects without any cooperation is statistically significant negative.

The baseline estimation considers all individual public support schemes jointly, to provide an indication of the additionality of each support scheme, controlling for possible support provided through other schemes. This estimation does not permit to assess the extent to which the combination of different instruments of public support for R&D, results in higher or lower additionality than the single use of instruments. Table 10 shows the results of an estimation in which the baseline specification is adapted by distinguishing firms that only use one of the three main public support categories (regional subsidies, the partial exemption from payment of the withholding tax and tax incentives provided through corporate income taxation (CIT)) and firms that combine some of the three public support categories.

The second column shows the results of an estimation of the baseline specification (fixed effects) for the three main public support categories (without the further breakdown as in Table 6). In the third column, firms are split between those that only use one of the three main categories and those that combine at least two of the three categories. The last column shows the results of an estimation in which also firms that combine support categories are included for the estimation of "single use" of the main categories. Comparing the results from the third and the final column reveals the extent to which combination increases or decreases the additionality of each of the three main categories.

The results of the estimation with the three main categories of public support for business R&D, reported in the second column of Table 10, confirm the results of the estimation by individual support schemes that are reported in Table 6. The coefficient for regional subsidies and the partial exemption is statistically significant positive, providing indications of additionality, whereas the statistically significant negative coefficient for the tax incentives provided through corporate income taxation (CIT) suggest crowding out. When splitting firms between those that only use one of the three main categories and those that combine at least two categories, as reported in the third column, clearly indicates that the combination of public support reduces additionality. In this estimation all coefficients are positive and statistically significant but the coefficients of the variables that denote the combination of support are lower than the coefficients that denote single use, with the lowest coefficient for firms that combine all three support categories. Remarkably, the coefficient of the single use of tax incentives provided through corporate income taxation is substantially positive. The negative coefficient for these incentives, found in the second column is apparently not explained by the necessary crowding out of this type of support but rather by firm that combine these incentives with other public support. This can also be seen in the last column, in which the coefficient of the "single use" of tax incentives provided through corporate income taxation is again negative, as this group also includes firms that combine support categories. A statistically significant negative coefficient indicates the reduction in additionality of public support for firms that combine subsidies with the partial exemption and firms that combine alle three main support categories. The combination of regional subsidies and tax incentives provided through corporate income taxation appears to increase additionality.

Table 10 Results of fixed effects panel estimation – the impact of combining public support

	Three main categories of public support	Single use vs. combination	Individual categories vs. combination
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Single use (individual categories):			
Regional subsidy	0.08 (10.30) ***	0.17 (14.65) ***	0.09 (11.11) ***
Partial exemption schemes	0.21 (15.81) ***	0.21 (18.55) ***	0.22 (16.18) ***
Corporate income taxation (CIT) incentives	-0.03 (-2.69) ***	0.17 (4.68) ***	-0.04 (-3.28) ***
Combination:			
Regional subsidy + Partial exemption		0.11 (10.96) ***	-0.07 (-7.07) ***
Regional subsidy + CIT incentives		0.10 (2.18) **	0.11 (2.34) **
Partial exemption + CIT incentives		0.07 (5.60) ***	0.02 (1.49)
Regional subsidy + Partial exemption + CIT incentives		0.06 (4.36) ***	-0.04 (-2.89) ***
Other funding:			
Tax deduction°	0.10 (5.60) ***	0.21 (12.03) ***	0.10 (5.16) ***
Innovation bonus	0.09 (4.03) ***	0.24 (10.45) ***	0.09 (3.76) ***
EU funding	-0.03 (-2.22) **	0.05 (4.16) ***	-0.04 (-2.66) ***
Control variables:			
Turnover	0.07 (0.89)	0.08 (0.98)	0.08 (0.97)
Number of employees	1.08 (7.99) ***	1.23 (9.08) ***	1.08 (7.99) ***
Age	-1.20 (-5.19) ***	-1.16 (-5.02) ***	-1.02 (-5.18) ***
Capital intensity	0.16 (2.70) ***	0.18 (3.05) ***	0.16 (2.68) ***
R-squared (within)	0.13	0.14	0.14
Number of observations	29,221	29,221	29,221

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with firms split by whether they only use one of the three main public support groups (regional subsidies, partial exemption, and corporate income taxation (CIT) incentives) or whether they combine support from the three groups. The third column shows results of an estimation in which single use considers firms that only benefit from one of the three main support groups. The last column considers all firms that benefit from one of the three main public support groups, whether combined with other support or not. *, ** 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. °Data on the tax deduction for R&D investment is only available until 2012.

This confirms that CIT incentives are not problematic as such but that the combination of all three main support categories reduces additionality and even results in crowding out. Mohnen (2022) points at evidence provided by Huergo and Moreno (2017), that complementarity of public support for R&D holds for SMEs but not for large firms in Spain, to argue that overlap of different support measures or a lack of coordination in support programs provided by different decision makers, may result in excess support. To assess whether the complementarity between individual support categories also differs by company size in Belgium, Table 11 shows the results of three separate estimations with a breakdown by firm size (cf. second column Table 10).

Table 11 Results of fixed effects panel estimation - the impact of combining public support by company size

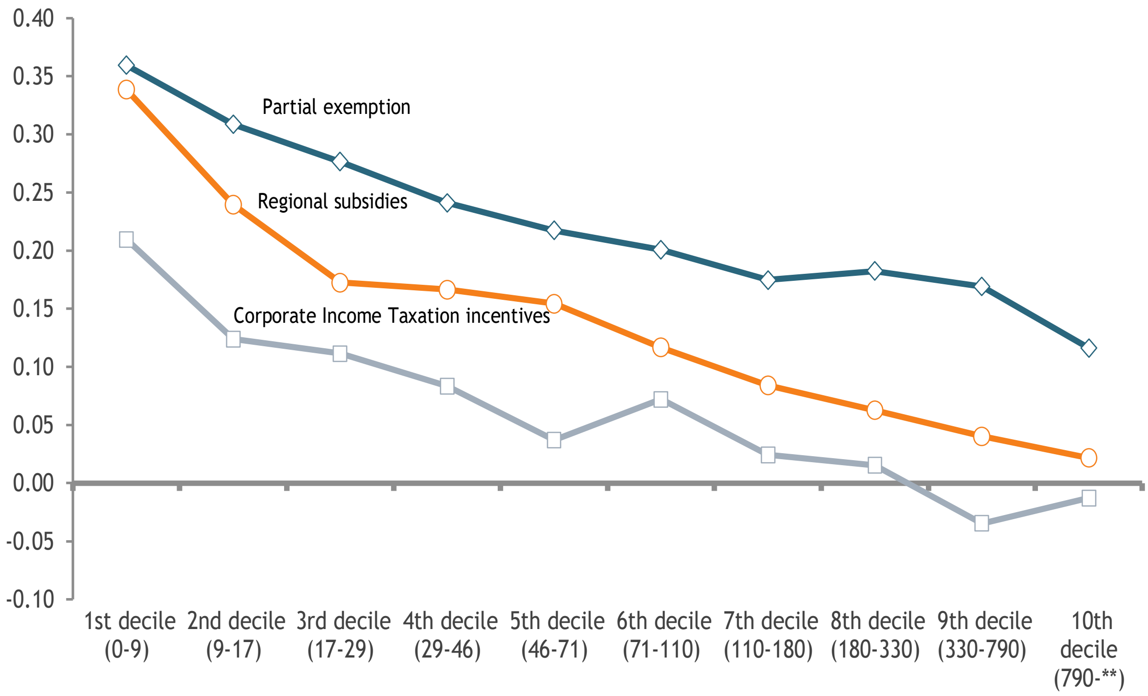
	< 50 employees	>=50 and < 100 employees	>= 100 employees
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Single use:			
Regional subsidy	0.15 (9.87) ***	0.20 (4.79) ***	0.16 (6.51) ***
Partial exemption schemes	0.19 (13.01) ***	0.12 (4.63) ***	0.20 (9.48) ***
Corporate income taxation (CIT) incentives	0.17 (4.07) ***	0.18 (1.71) *	0.15 (1.18)
Combination:			
Regional subsidy + Partial exemption	0.09 (7.44) ***	0.07 (2.52) **	0.11 (5.80) ***
Regional subsidy + CIT incentives	0.13 (2.51) **	-0.06 (-0.60)	-0.18 (-1.21)
Partial exemption + CIT incentives	0.06 (3.13) ***	0.03 (0.97)	0.04 (2.10) **
Regional subsidy + Partial exemption + CIT incentives	0.07 (2.52) **	0.04 (0.61)	0.03 (2.09) **
Other funding:			
Tax deduction°	0.21 (6.20) ***	0.11 (2.34) **	0.19 (7.54) ***
Innovation bonus	0.30 (7.45) ***	0.22 (2.63) ***	0.16 (5.30) ***
EU funding	0.08 (3.48 ***	0.06 (1.47)	0.02 (0.88)
Control variables:			
Turnover	0.11 (1.28)	-0.64 (-1.79) *	0.30 (1.07)
Number of employees	1.41 (8.60) ***	1.57 (1.84) *	0.94 (1.90) *
Age	-1.23 (-4.19) ***	-1.76 (-2.53) **	0.32 (0.59)
Capital intensity	0.17 (2.59) ***	0.01 (0.04)	0.19 (1.07)
R-squared (within)	0.14	0.33	0.31
Number of observations	18,062	4,204	6,955

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with firms split by whether they only use one of the three main public support groups (regional subsidies, partial exemption, and corporate income taxation (CIT) incentives) or whether they combine support from the three groups. The table reports results of an estimation by company size group in which single use considers firms that only benefit from one of the three main support groups (cf. column 3 in Table 10). *, ** 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. °Data on the tax deduction for R&D investment is only available until 2012.

Considering single use of the three main support categories, the clear indications of additionality for subsidies and the partial exemption, found in Table 10, are confirmed for all three firm size groups. On the other hand, the indication of additionality of the single use of CIT incentives is not found for companies with 100 or more employees, for which the coefficient is positive but not statistically significant. As to the combination of at least two of the three main support categories, there are indications that combining different support categories reduces additionality for all size groups, but the reduction is more substantial for large companies than for small companies, except for the combination of subsidies and the partial exemption.

For a further assessment of possible differences by firm size, in the additionality of public support, Graph 23 shows the coefficient estimates of a specification with the three main support categories, distinguishing firms by decile of the total amount of public support received for R&D activities. The coefficient estimates of all three support categories decrease with the total amount of public support.

Graph 23 Estimates by decile of the total amount of public support to business R&D (2003-2019)



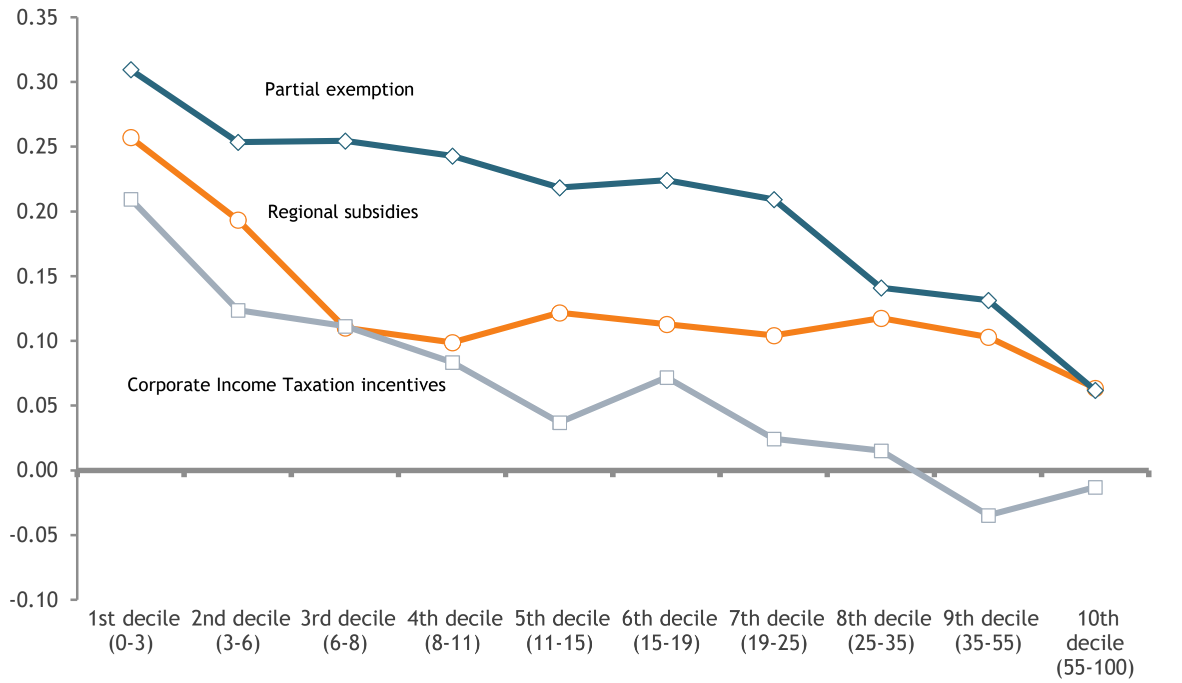
Note: The graph shows the coefficient estimate for each of the three main groups of public support in the baseline specification, in which firms are classified into ten groups according to the total amount of public support received (over all support schemes). The first group contains the 1st decile (bottom 10%) of firms with the lowest total non-zero amount of public support as well as all firms that did not receive any public support. The second group contains firms in the second decile (10%) of the total amount of public support until the tenth group which covers the top 10% of firms in terms of the total amount of public support for R&D received by firms. The minimum and maximum amount (rounded in 1000 euro) of each decile are shown in brackets. ** For reasons of confidentiality, the maximum of the total amount of public support in the highest decile is not reported.

For all deciles, the coefficient is highest for the partial exemption and lowest for the tax incentives provided through corporate income taxation. The coefficient estimates remain positive for all deciles for regional subsidies and the partial exemption, although the coefficient of regional subsidies drops substantially for higher deciles.

At lower deciles, the coefficient of the tax incentives provided through corporate income taxation is positive and relatively large, but it tends to zero from the 7th decile onwards and is negative for the 20% of companies with the highest amount of public support. This shows that the crowding-out effect of tax incentives provided through corporate income taxation apply to companies that receive the highest total amount of public support, which also happen to be the companies that, more than other companies, combine all support categories.

Graph 24 shows the difference by decile, in the coefficient estimates of the three main public support categories, but rather than using the total amount of public support, as in Graph 23, the rate of support, defined as the total amount of support over R&D expenditures, is used to define the deciles. The distinction between the total amount of support and the support rate is not trivial. The correlation between both is actually very close to zero, as some small R&D active companies have a high support rate. Despite the zero correlation between the amount of support and the rate of support, Graph 24 provides a similar pattern of a decrease in the coefficient with an increase in the support rate although the decrease for regional subsidies is less monotonic than when considering the amount of support.

Graph 24 Estimates by decile of the rate of total public support to business R&D (2003-2019)

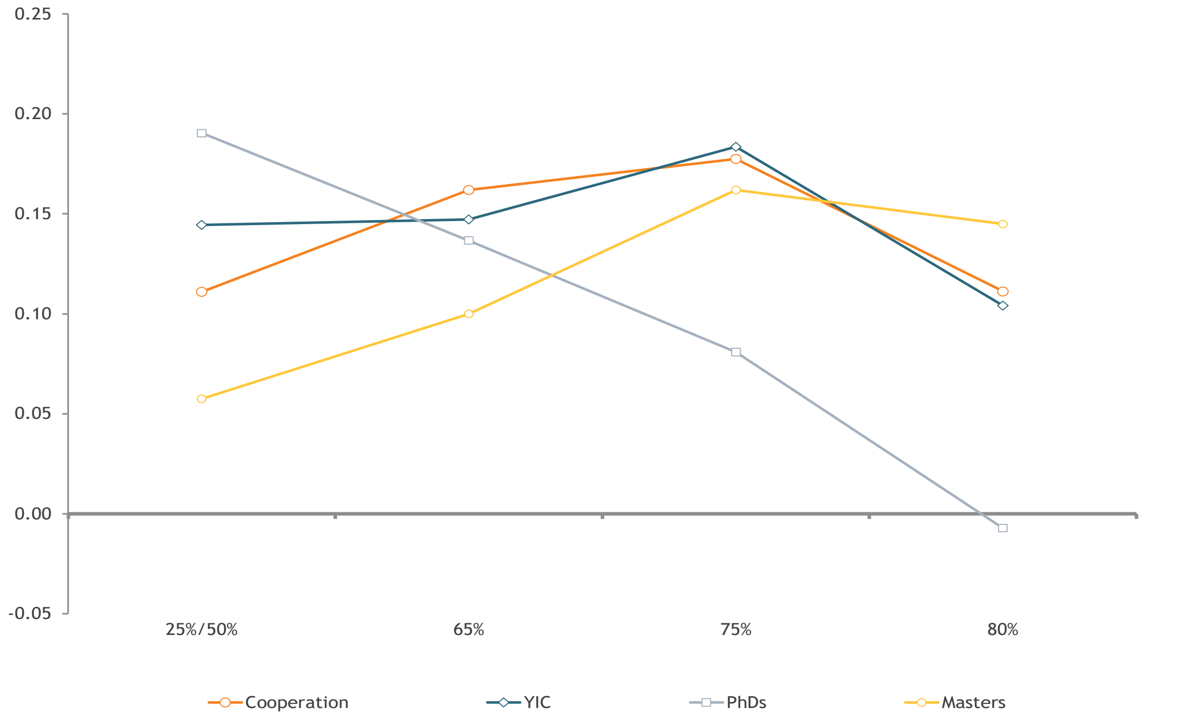


Note: The graph shows the coefficient estimate for each of the three main groups of public support in the baseline specification, in which firms are classified into ten groups according to the rate of total public support received (total public support/R&D expenditures). The first group contains the 1st decile (bottom 10%) of firms with the lowest total non-zero public support rate as well as all firms that did not receive any public support. The second group contains firms in the second decile (10%) of the total public support rate until the tenth group which covers the top 10% of firms in terms of the total public support rate. The minimum and maximum rate of support (in %) of each decile are shown in brackets.

The coefficient of the tax incentives provided through corporate income taxation is again negative for the two highest deciles. The crowing-out effects of these incentives are therefore not only explained by a high total amount of public support but also by a high rate of public support, which suggests that it is linked to the combination of different support schemes. The average support rate for the 9th decile is 44%, for the 10th decile it is 73%.

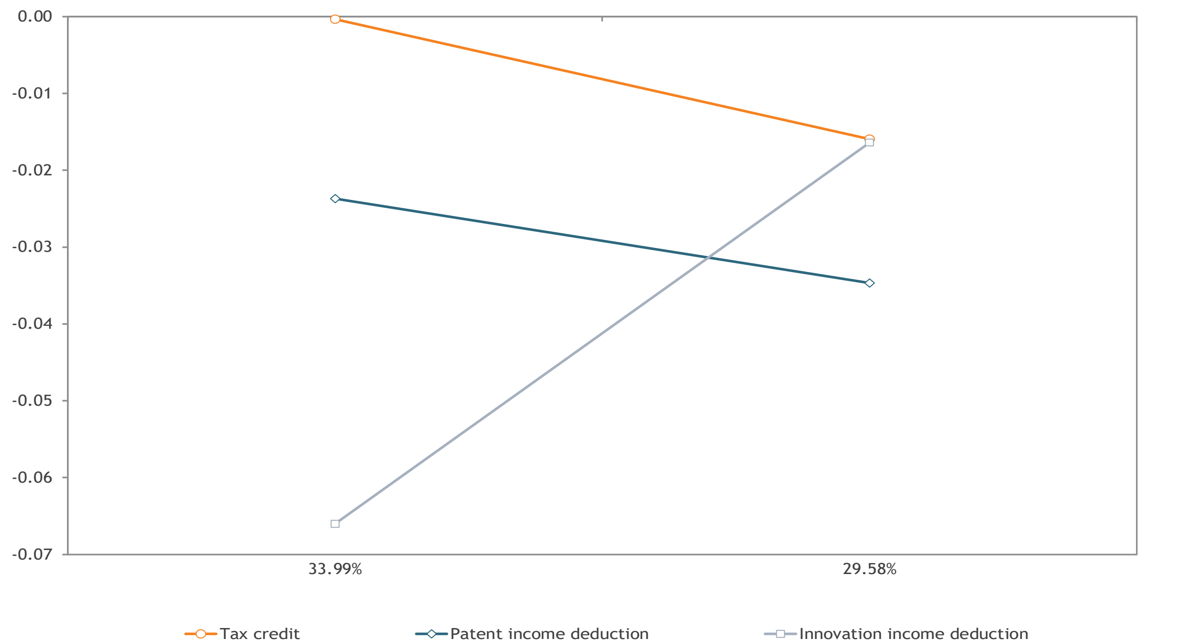
The rate of exemption, for the schemes of partial exemption from payment of the withholding tax, has been raised gradually, starting from 25% for the schemes based on the educational degree of researchers and 50% for the schemes for research cooperation and Young Innovative Companies, to 65% in 2008 for all schemes, to 75% in 2009 for all schemes and finally to 80% for all schemes in 2013. To assess the possible impact of the difference (change) in the rate of exemption, Graph 25 shows the coefficient estimates for four partial exemption schemes (excluding the partial exemption for bachelors which was introduced in 2018), with a breakdown by years in which a specific rate of exemption applied. For the partial exemption for researchers with a PhD or civil engineering degree, the coefficient decreases with the increase in the rate of exemption and is even negative (not statistically significant) for the final rate of exemption of 80%. It is not possible to distinguish between the impact of changes in the rate of exemption and potential selection issues due to improved knowledge over time among R&D active companies, of the partial exemption.

Graph 25 Coefficient estimates of four partial exemption schemes, by rate of exemption



Note: The graph shows the coefficient estimate for each of four partial exemption schemes (the scheme for bachelors that was introduced in 2018 is not included), by the rate of exemption that was applicable. The rate was gradually increased from a rate at introduction of 25% for PhDs and masters and 50% for the two other schemes, to 65% for all schemes in 2008, to 75% for all schemes in 2009 and finally to 80% for all schemes in 2013.

Graph 26 Coefficient estimates of corporate income taxation incentives by nominal rate of taxation



Note: The graph shows the coefficient estimate for each of the three corporate income taxation (CIT) incentives by the rate of taxation that was applicable. The nominal CIT rate, which was 33.99% during most of the period considered, was, because of the 2017 Belgian Corporate Tax reform, reduced to 29.58% for income years 2018 and 2019. As of income year 2020 (outside period considered in this evaluation) the nominal CIT rate is 25% (20% for SMEs taxable income below 100,000 euro.

For the three other schemes, the coefficient estimates increase with the increase of the initial rate to 65% in 2008 and to 75% in 2009 but decrease with the increase to 80% in 2013.

With the caveat of a possible selection bias due to the increasing knowledge of public support measures, the results in Graph 25 suggest that the increase in the rate of exemption to 80% may have been suboptimal.

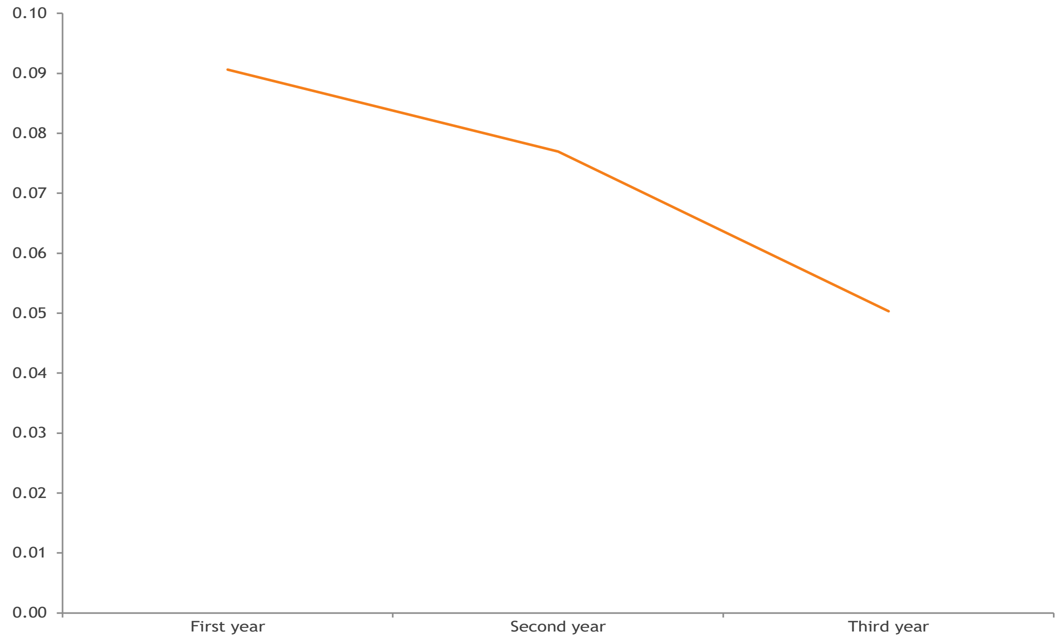
Graph 26 shows the difference in coefficient estimates for corporate income taxation incentives in the years when the nominal rate of corporate income taxation was 33.99% (2003-2017) and the years 2018 and 2019, when the rate was 29.58%, because of the 2017 Belgian Corporate Tax reform. As of income year 2020 (not included in this evaluation), the nominal CIT rate is 25%.

As data for the tax deduction for R&D investment are only available until 2012, this support scheme is not considered. In line with the results reported in Table 6, all coefficients are negative. For the tax credit and the patent income deduction, the coefficient estimate is lower for the lower nominal rate of 2018 and 2019 than for the higher nominal rate of the earlier years. For the innovation income deduction, which was introduced more recently than the two other incentives, the coefficient is higher for the lower nominal rate of 2018 and 2019, although still negative (not statistically significant).

The impact of public support for R&D could also change over time because of the persistence of support. To assess this possibility Graph 27, Graph 28 and Graph 29 show the coefficient estimates of public support distinguishing firms by the first, second, and third year of use of the instrument, for respectively regional subsidies (Graph 27), partial exemption (Graph 28) and corporate income taxation incentives (Graph 29).

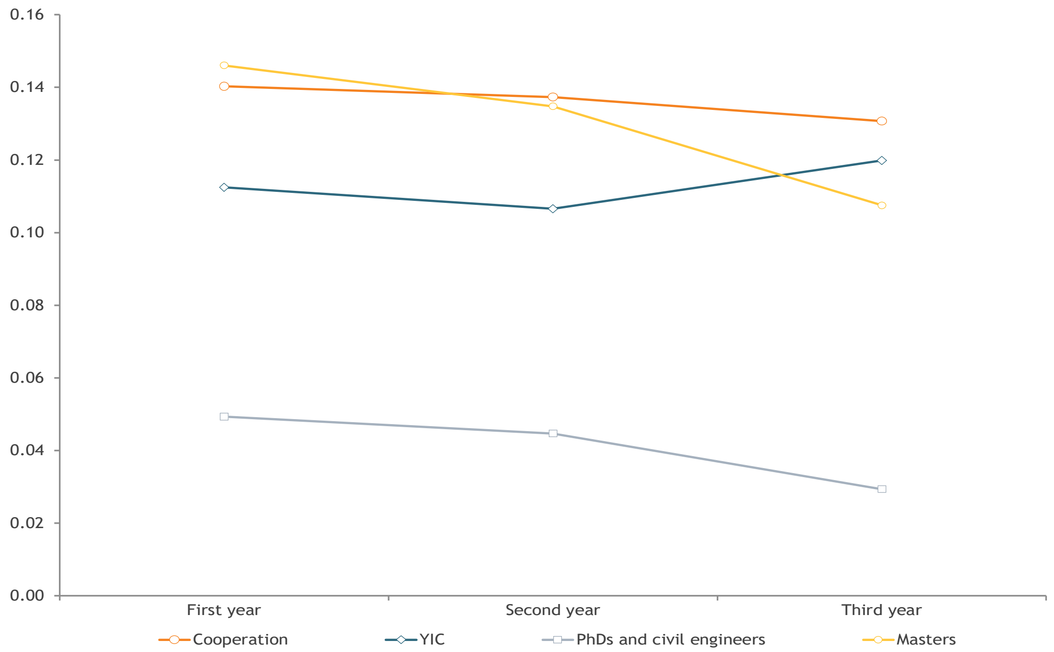
For most individual support schemes, additionality decreases with the number of years of use of a specific support scheme, as the highest coefficient is found in the first year of use, except for the partial exemption for Young Innovative Companies (Graph 28) and the innovation income deduction (Graph 29) for which the highest coefficient is found in the third year of use. For the innovation income deduction, there are only four years of observation, which moreover coincide with the reduction in the nominal tax rate in 2018, which resulted in a less negative coefficient than in 2016 and 2017, as suggested by Graph 26. The short period of observation makes it difficult to tell the difference between the impact of the reduction in the nominal tax rate, which reduces the benefit of specific tax incentives, and the impact of the persistence of use of public support. For the corporate income taxation incentives, except for the tax deduction for R&D investment, the coefficient estimates are close to zero or negative for the first, second and third year of use.

Graph 27 Coefficient estimates of regional subsidies, by persistence of use



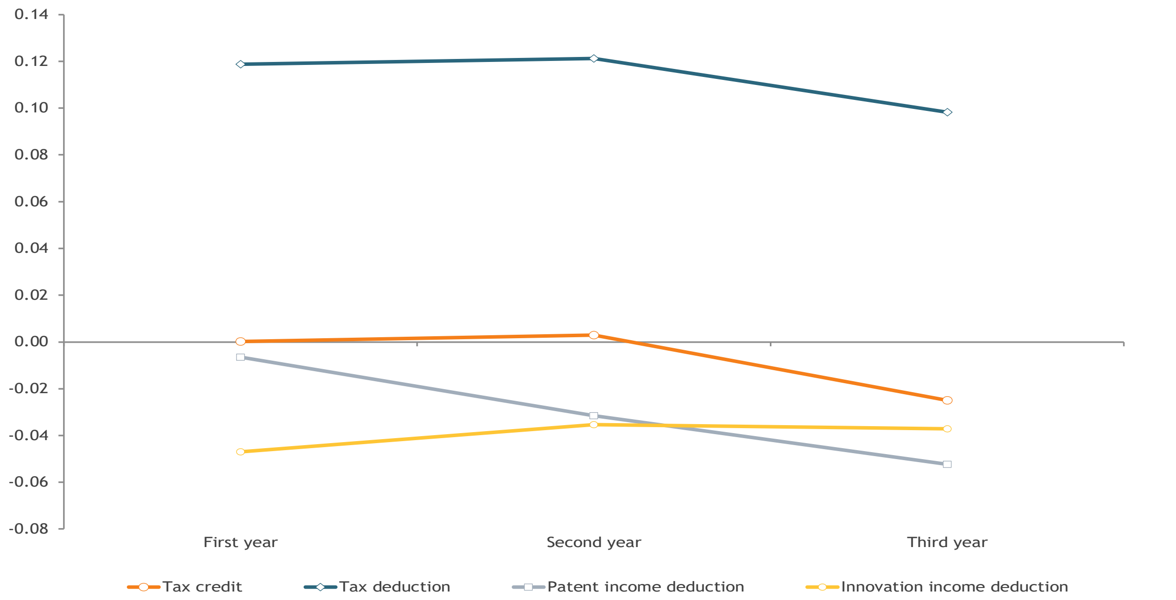
Note: The graph shows the coefficient estimates of regional subsidies in the baseline specification, in which three groups of firms are distinguished: firms that received regional subsidies in a year but not in the two previous years (first year), firms that received regional subsidies in two consecutive years (second year) and firms that received regional subsidies in three consecutive years (third year).

Graph 28 Coefficient estimates of partial exemption schemes, by persistence of use



Note: The graph shows the coefficient estimates of the partial exemption schemes in the baseline specification, in which three groups of firms are distinguished: firms that received partial exemption in a year but not in the two previous years (first year), firms that received partial exemption in two consecutive years (second year) and firms that received partial exemption in three consecutive years (third year).

Graph 29 Coefficient estimates of corporate income taxation (CIT) incentive, by persistence of use



Note: The graph shows the coefficient estimates of the corporate income taxation (CIT) incentives in the baseline specification, in which three groups of firms are distinguished: firms that benefitted from the CIT incentive in a year but not in the two previous years (first year), firms that benefitted from the CIT incentive in two consecutive years (second year) and firms that benefitted from the CIT incentive in three consecutive years (third year).

Table 12 shows the results of an estimation in which public support variables are lagged, respectively with one and two years, to account for a potential delay in the impact on R&D expenditures, which are often determined by firms as part of a medium-term strategy. The last column in Table 12 also includes a one-year lag of the dependent variable to account for persistence in R&D expenditures. Inclusion of a lagged dependent variable is problematic in a fixed effects estimation, so the results of this estimation need to be interpreted with caution. The dynamic panel estimation in section 4.1.2.d provides a more sophisticated approach to consider persistence in R&D activities. For most support schemes, the coefficient estimates in Table 12 are in line with the results in Table 6 but tend to decrease with lag length.

Table 13 provides coefficient estimates of public support schemes, distinguishing between firms with persistent R&D activities, defined as firms with eight up to 17 years of reported non-zero R&D expenditures and firms without persistent R&D activities, defined as firms with less than 8 years of reported non-zero R&D expenditures. Given that not all R&D active firms respond to the R&D survey and that only real responses are considered (not the estimates of R&D expenditures for non-respondents), the definition provides a proxy distinction between persistent and non-persistent R&D performers. The results suggest that additionality of public support is higher for non-persistent R&D firms than for persistent R&D firms which may suggest support for the argument by Mohnen (2022) that incremental tax incentives are more efficient than volume-based incentives although it should be pointed out that firms with persistent R&D are, on average, substantially larger than firms without persistent R&D activities and that the results to a large extent are in line with the results by firm size as reported in Table 15. During the period under consideration (2003-2019), only tax incentives based on the volume of R&D expenditures existed in Belgium, which does not permit to evaluate the possible difference in additionality between incremental and volume-based incentives. The coefficients that were statistically significant negative in Table 6 only appear to be so for persistent R&D firms in Table 13.

Table 12 Results of a fixed effects panel estimation with lagged variables

	Public support one -year lag	Public support two -year lag	Public support one -year lag + one-year lag of dependent variable included
Dependent variable (R&D expenditures net of public support)			
Dependent variable one-year lagged			0.53 (51.75) ***
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.05 (6.22) ***	0.02 (3.31) ***	0.03 (4.66) ***
Partial exemption schemes:			
Research cooperation	0.10 (4.53) ***	0.05 (2.65) ***	0.04 (3.72) ***
Young Innovative Company	0.07 (3.31) ***	0.06 (2.98) ***	0.01 (0.94)
PhDs and civil engineers	0.03 (2.11) **	0.03 (2.03) **	0.00 (0.42)
Master	0.08 (6.23) ***	0.01 (1.31)	0.03 (3.43) ***
Bachelor	0.03 (1.37)	-	0.02 (1.26)
Corporate income taxation incentives:			
Tax credit R&D	-0.02 (-1.25)	-0.01 (-0.64)	-0.01 (-0.73)
Tax deduction R&D°	0.06 (3.76) ***	0.02 (1.03)	0.04 (3.56) ***
Patent income deduction	-0.04 (-2.86) ***	-0.02 (-1.67) *	-0.01 (-1.78) *
Innovation income deduction	-0.04 (-2.03) **	-0.01 (-0.26)	-0.02 (-1.79) *
Other funding:			
Innovation bonus	0.05 (2.53) ***	0.00 (0.19)	0.03 (2.16) **
EU funding	-0.03 (-2.68) ***	-0.00 (-0.31)	-0.02 (-1.87) *
Control variables:			
Turnover	0.06 (0.68)	0.13 (1.43)	0.03 (0.51)
Number of employees	1.16 (7.27) ***	0.79 (4.40) ***	0.65 (5.95) ***
Age	-1.09 (-3.62) ***	-0.13 (-0.32)	-0.62 (-2.94) ***
Capital intensity	0.17 (2.60) ***	0.11 (1.48)	0.10 (2.26) **
R-squared (within)	0.13	0.14	0.39
Number of observations	19,963	13,872	19,047

Note: The table shows the results of a fixed effects estimation of specification (1) on p.24 with public support variables alternatively lagged one year and two years. The final column shows the results for an estimation with one-year lags of public support variables and a one-year lag of the dependent variable (Net R&D expenditures) included. 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. °Data on the tax deduction for R&D investment is only available until 2012. All estimations include industry*year dummies.

For non-persistent R&D firms, the coefficient of the tax credit for R&D investment, the patent income deduction, the innovation income deduction, and EU funding is even positive, though not statistically significant. As pointed out before, internal (intramural) R&D expenditures minus the amount of public support is used as the dependent variable in the baseline estimation, as an indicator of R&D expenditures self-financed by firms.[27]

[27] Table A3.2 shows the results of an estimation with respectively R&D intensity, the number of researchers and the ratio of R&D personnel to the number of employees is considered as dependent variable. Fewer coefficients of the public support variables are statistically significant with these alternative dependent variables than when using R&D expenditures. Table A3.3 shows the result of three alternative estimations with the average wage of researchers as dependent variable. Few coefficients are statistically significant. Only for the partial exemption, one of the three alternative estimates is statistically significant positive, and only at the 10% level, which could indicate that public support increases the wage of researchers. On the other hand, the three alternative coefficient estimates of the tax deduction for R&D investment are statistically significant negative.

Table 13 Results of a fixed effects panel estimation distinguishing between persistent R&D firms and non-persistent R&D firms

Dependent variable: (R&D expenditures net of public support)	Non-persistent R&D	Persistent R&D
Explanatory variables:		
Direct support:		
Regional subsidy	0.17 (12.17) ***	0.03 (3.87) ***
Partial exemption schemes:		
Research cooperation	0.33 (7.51) ***	0.04 (1.96) **
Young Innovative Company	0.19 (5.49) ***	0.03 (1.47)
PhDs and civil engineers	0.09 (3.43) ***	0.03 (2.42) **
Master	0.28 (13.47) ***	0.05 (3.92) ***
Bachelor	0.11 (4.30) ***	0.02 (1.71)
Corporate income taxation incentives:		
Tax credit R&D	0.07 (1.27)	-0.02 (-1.17)
Tax deduction R&D°	0.26 (5.07) ***	0.04 (3.28) ***
Patent income deduction	0.01 (0.34)	-0.03 (-3.67) ***
Innovation income deduction	0.01 (0.24)	-0.02 (-1.87) *
Other funding:		
Innovation bonus	0.24 (5.19) ***	0.10 (10.86) ***
EU funding	0.00 (0.04)	-0.04 (-2.14) **
Control variables:		
Turnover	0.16 (1.31)	-0.03 (-0.31)
Number of employees	1.13 (6.60) ***	0.77 (4.29) ***
Age	-1.97 (-6.11) ***	0.01 (0.05)
Capital intensity	0.18 (2.22) **	0.18 (2.65) ***
R-squared	0.12	0.10
Number of observations	20,212	9,009

Note: The table shows the results of a fixed effects panel estimation that considers firms with less than 8 years for which non-zero R&D expenditures are reported (non-persistent R&D) and firms with 8 up to 17 years of reported non-zero R&D expenditures (persistent R&D). Only real responses to the R&D survey are considered. Industry and year dummies are included but not reported. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. °Data on the tax deduction for R&D investment is only available until 2012.

Alternatively, gross internal R&D expenditures, as reported by firms in the R&D survey, can be considered. The results of this estimation are reported in the second column of Table 14. The third column of Table 14 shows the results of an estimation with external (extramural) R&D expenditures as dependent variable and the last column shows the results with internal plus external minus total public support as dependent variable. The results of the estimation with gross internal R&D expenditures are close to the results of the estimation with net internal R&D expenditures (gross R&D expenditures minus the total amount of public support) reported in Table 6, except for the coefficient of the innovation bonus which is not statistically significant when gross R&D expenditures are considered. Fewer support instruments have an impact on external R&D expenditures[28] than on internal R&D expenditures and not surprisingly, the impact is statistically significant for those support schemes that often imply cooperation, such as regional subsidies, or - by definition- require cooperation such as the partial exemption for research cooperation.

[28] Of firms that report non-zero internal (intramural) R&D expenditures, about 35% also report non-zero external (extramural) R&D expenditures.

Table 14 Results of a fixed effects panel estimation - Gross internal R&D expenditures, external R&D expenditures and total net R&D expenditures

Dependent variable:	Gross internal R&D expenditures	External R&D expenditures	Total R&D expenditures (Net of support)
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.08 (10.62) ***	0.08 (7.86) ***	0.08 (11.19) ***
Partial exemption schemes:			
Research cooperation	0.15 (6.41) ***	0.13 (4.66) ***	0.14 (6.36) ***
Young Innovative Company	0.11 (4.70) ***	0.03 (0.91)	0.12 (6.81) ***
PhDs and civil engineers	0.05 (3.27) ***	-0.01 (-0.26)	0.04 (3.47) ***
Master	0.11 (8.23) ***	0.01 (0.84)	0.12 (10.35) ***
Bachelor	0.07 (3.92) ***	-0.01 (-0.22)	0.05 (3.55) ***
Corporate income taxation incentives:			
Tax credit R&D	0.01 (0.39)	0.02 (0.65)	-0.05 (-2.62) ***
Tax deduction R&D°	0.14 (7.45) ***	0.08 (2.29) **	0.13 (8.34) ***
Patent income deduction	-0.03 (-2.00) **	-0.02 (-0.61)	-0.04 (-3.58) ***
Innovation income deduction	-0.01 (-0.31) **	0.01 (0.41)	-0.03 (-1.87) *
Other funding:			
Innovation bonus	0.04 (1.62)	0.10 (4.56) ***	0.10 (4.93)) ***
EU funding	-0.02 (-1.67) *	-0.04 (-3.07) ***	-0.04 (-3.32) ***
Control variables:			
Turnover	0.00 (0.05)	0.00 (0.01)	0.09 (1.09)
Number of employees	1.23 (9.30) ***	0.45 (3.35) ***	1.03 (7.95) ***
Age	-1.17 (-5.31) ***	-0.39 (-1.69) *	-1.12 (-5.05) ***
Capital intensity	0.15 (2.48) **	0.12 (2.11) **	0.15 (2.64) ***
R-squared (within)	0.08	0.04	0.08
Number of observations	31,486	31,326	29,345

Note: The table shows the results of a fixed effects estimation of specification (1) on p.24 using alternatively gross internal R&D expenditures (R&D expenditures as reported without subtracting the amount of public support received), external R&D expenditures and total net R&D expenditures (internal and external R&D expenditures minus the amount of public support received). 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. °Data on the tax deduction for R&D investment is only available until 2012. All estimations include industry*year dummies.

The results do not provide any indication of a shift from internal to external R&D expenditures as found by Acconcia and Cantabene (2018) for high-tech firms in Italy, in response to tax credits for R&D that were introduced in 2009 as part of a stimulus programme. The results of the last column are remarkably like the results reported in Table 6, which also does not come as a surprise given the dominance of internal over external R&D expenditures.

The impact of public support on R&D expenditures may differ according to specific firm characteristics. To assess potential firm heterogeneity, rather than estimating the baseline specification for the total panel of firms for which data are available, the baseline specification was estimated with firms split into groups according to different firm characteristics. Although splitting firms into separate groups reduces the number of observations, the separate regressions often explain more of the variance in R&D expenditures than the regression with the entire group of firms. This indicates the heterogeneity of the impact of public support along several dimensions. Considering regressions for distinct groups of firms provides information on which firm characteristics explain differences in additionality of public support.

Table 15 shows the results of a panel estimation with firms grouped by company size (number of FTE employees). A cross-country analysis, part of the OECD microBeRD project, found that the input additionality of R&D tax support is higher for small firms (10-49 employee) than for medium-sized firms (50-249 employees) and especially than for large companies (250 or more employees) although it is pointed out that this finding could be explained by the fact that small companies perform less R&D than large companies and that companies performing less R&D are more responsive to R&D tax incentives (Appelt et al. 2020).

Table 15 Results of a fixed effects panel estimation by firm size

	Less than 50 employees	Between 50 and 100 employees	Between 100 and 250 employees	More than 250 employees
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.07 (7.27) ***	0.09 (3.69) ***	0.06 (2.42) **	0.05 (2.52) **
Partial exemption:				
Research cooperation	0.20 (4.85) ***	0.11 (2.07) **	0.12 (2.51) **	0.04 (1.06)
Young Innovative Company	0.10 (4.07) ***	-0.01 (-0.08)	0.73 (2.96) ***	0.13 (1.84) *
PhDs and civil engineers	0.03 (1.77) *	0.04 (1.24)	0.03 (0.73)	0.06 (1.52)
Master	0.14 (7.75) ***	0.03 (0.93)	0.14 (3.82) ***	0.13 (3.72) ***
Bachelor	0.04 (1.49)	0.10 (2.02) **	0.09 (1.40)	0.01 (0.29)
CIT incentives:				
Tax credit R&D	0.06 (1.92) *	-0.04 (-0.33)	-0.02 (-0.24)	-0.08 (-2.24) **
Tax deduction R&D°	0.12 (3.27) ***	-0.01 (-0.14)	0.08 (1.54)	0.05 (1.95) *
Patent income deduction	0.03 (1.08)	0.01 (0.16)	-0.06 (-1.56)	-0.03 (-1.22)
Innovation income deduction	-0.02 (-0.98)	-0.00 (-0.08)	0.06 (0.75)	-0.06 (-2.10) **
Other funding:				
Innovation bonus	0.18 (4.15) ***	0.16 (1.94) *	0.05 (1.11)	0.01 (0.19)
EU funding	-0.00 (-0.17)	-0.01 (-0.31)	-0.15 (-3.11) ***	-0.04 (-1.86) *
Control variables:				
Turnover	0.10 (1.13)	-0.63 (-1.69) *	-0.85 (-2.59) ***	0.88 (2.14) **
Number of employees	1.25 (7.53) ***	1.45 (1.70) *	1.40 (1.49)	1.32 (1.84) *
Age	-1.36 (-4.58) ***	-1.73 (-2.27) **	0.96 (0.97)	0.08 (0.13)
Capital intensity	0.16 (2.46) **	0.06 (0.30)	0.02 (0.08)	0.28 (1.01)
R-squared (within)	0.13	0.31	0.37	0.43
Number of observations	18,136	4,151	3,665	3,269

Note: The table shows the results of a fixed effects panel estimation, by firm size category (based on the number of employees in FTE). 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.

The meta-regression analysis of Castellacci and Lie (2015) also suggests a stronger impact of R&D tax credits for SMEs.

The results in Table 15 provide mixed evidence of a clear-cut link between the impact of public support and company size. For regional subsidies and some partial exemption schemes (Young Innovative Companies and for researchers with a master's degree), the coefficient estimate for large companies is close to or even higher than the coefficient estimates for small companies. For the tax incentives provided through corporate income taxation (CIT) the impact clearly decreases with company size. Whereas the estimation with all companies estimated jointly (Table 6) provides a negative but not statistically significant coefficient for the tax credit for R&D investment, the coefficient estimate is positive and statistically significant (at 10%) for companies with less than 50 employees, but negative and statistically significant for companies with 250 or more employees. The statistically significant negative coefficient for the innovation income deduction for the entire group of companies (Table 6) seems to be explained mainly by large companies (250 or more employees), in line with the finding in Graph 23 of a negative coefficient for CIT incentives for the 9th and 10th decile of the total amount of public support received by firms.

Estimations in which the four firm size groups are further split into two groups according to the support rate confirm the finding of Graph 23 that the impact of public support decreases with the rate of support.[29] For small companies in the lower half of the distribution of the support rate, all coefficients of the public support variables are positive and seven statistically significant. For this group of firms, the coefficient of the innovation income deduction is even statistically significant positive, in contrast with the statistically significant negative coefficient for the entire panel of companies (Table 6). For small companies with a high rate of support (upper half of the distribution), five coefficients of the public support variables are negative and except for the positive coefficient of the partial exemption for research cooperation, none of the coefficients is statistically significant. For large companies (250 or more employees), the coefficient of the patent income deduction and the innovation income deduction is positive, though not statistically significant, for companies in the lower half of the distribution of the support rate whereas the coefficient estimate is statistically significant negative for large companies with a high rate of public support. The coefficient of the partial exemption for researchers with a bachelor's degree is statistically significant positive for large companies with a low rate of support and statistically significant negative for large companies with a high rate of support. These results clearly indicate that the impact of public support on R&D expenditures not only decreases with the total amount of support, which is clearly positively correlated with company size, but also with the rate of total public support, which is not correlated with company size.

Public support for R&D may have a negative impact on business dynamism if it is biased in favour of incumbents, to the disadvantage of entrants and young firms. Appelt et al. (2016) point at evidence that generous R&D tax incentives disproportionally benefit slow-growth incumbents and, as a result, reduce firm growth in R&D intensive sectors. The R&D Policy Mix data show that in Belgium, only tax incentives provided through corporate income taxation are biased in favour of old incumbents. The share of incumbents that have been active for more than 20 years, in public support through corporate income taxation exceeds their share in total R&D expenditures whereas their share in support through partial exemption is close to their share in R&D. The share of older incumbents in direct support (regional subsidies) is substantially lower than their share in R&D expenditures, indicating the relative focus of regional agencies on SMEs and young firms. Many R&D intensive start-ups have little income, which

[29] The results of these estimations are not reported but available upon request.

limits the use of CIT incentives like the patent income deduction and the innovation income deduction whereas they can benefit from the partial exemption for researchers from the first month of R&D activity.

Table 16 shows the results of a panel estimation of the baseline specification, with companies split into four age groups. A surprising result is that whereas regional subsidies relatively favour young firms, the coefficient of direct support is negative, though not statistically significant for companies of less than 10 years old. The statistically significant positive impact of direct support for the total panel of companies (Table 6) appears to apply only to companies that have been active for more than 10 years, with the largest coefficient estimate for companies older than 20 years.

Another surprising - and even problematic- finding is that the coefficient of the partial exemption for Young Innovative Companies is only statistically significant positive for firms older than 10 years, whereas 10 years is the age ceiling to qualify for this support scheme. The share of companies that benefit from the partial exemption for Young Innovative Companies that, according to firm-level information were older than 10 years at the time of use of the support scheme, increased substantially from its introduction in 2006 until 2011-2014, sometimes exceeding 18%. After 2014, the share decreased slightly although in the last year under consideration (2019) still some 16% of the firms that benefitted from this scheme, exceeded the 10 years age ceiling. The share of young R&D firms that benefitted from partial exemption for Young Innovative Companies increased gradually, reaching some 25%, in 2013. However, after 2013 the share started to fall, to about 15% in 2019. The data show that young firms started to rely more on the partial exemption for researchers with a master’s degree. In 2019, some 30% of young R&D active firms, benefitted from this support scheme, in effect, twice the share that benefitted from the specific Young Innovative Companies scheme. The impact of the partial exemption schemes is more generally higher and more statistically significant for incumbents older than 20 years except for the partial exemption for researchers with a bachelor’s degree, for which the coefficient is only statistically significant (at 10%) positive for firms less than 5 years old.

The coefficient estimates of the tax deduction for R&D investment and the innovation bonus are only statistically significant positive for firms that are at least 10 years old. The statistically significant negative coefficient for the patent income deduction and the innovation income deduction, found for the total panel of companies, applies especially to older incumbents. The fact that the group of firms older than 20 years is larger than the three other age groups combined, explains why the results for this group are closest to the results for all companies reported in Table 6. However, the fact that only the coefficient for the partial exemption for researchers with a master’s or bachelor’s degree is statistically significant for start-ups is a cause for concern, as is the finding that for companies between 5 and 10 years old none of the coefficients of the support variables is statistically significant positive.

Lahr and Mina (2021) argue that specific support measures may be useful to alleviate the financial constraints of young firms, but that public support should not only target formal R&D activities but also informal R&D activities that do not result in reported R&D expenditures but may support firm growth through the exploitation of new products and services.

Table 16 Results of a fixed effects panel estimation, by firm age

	Less than 5 years old	Between 5 and 10 years old	Between 10 and 20 years old	More than 20 years old
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	-0.02 (-1.48)	-0.02 (-1.36)	0.04 (2.89) ***	0.09 (7.41) ***
Partial exemption:				
Research cooperation	0.02 (0.24)	0.09 (1.24)	0.03 (1.04)	0.13 (3.99) ***
Young Innovative Company	0.02 (0.45)	0.06 (1.13)	0.13 (2.90) ***	0.20 (2.69) ***
PhDs and civil engineers	0.06 (1.36)	0.02 (0.51)	-0.02 (-1.11)	0.04 (2.07) **
Master	0.06 (2.19) **	0.07 (1.48)	0.14 (5.83) ***	0.13 (7.36) ***
Bachelor	0.09 (1.90) *	0.05 (1.12)	0.05 (1.46)	0.03 (1.33)
CIT incentives:				
Tax credit R&D	-0.04 (-1.02)	0.05 (1.03)	0.02 (0.40)	-0.01 (-0.36)
Tax deduction R&D°	0.04 (0.58)	0.02 (0.38)	0.05 (1.79) *	0.12 (5.12) ***
Patent income deduction	-0.06 (-1.34)	0.02 (0.47)	-0.01 (-0.34)	-0.05 (-2.52) ***
Innovation income deduction	0.04 (0.72)	-0.12 (-1.49)	-0.04 (-1.75) *	-0.04 (-1.76) *
Other funding:				
Innovation bonus	-0.14 (-1.60)	0.04 (0.59)	0.11 (2.11) **	0.11 (3.64) ***
EU funding	-0.03 (-0.81)	0.08 (2.35) **	0.00 (0.11)	-0.05 (-2.73) ***
Control variables:				
Turnover	0.25 (2.05) **	0.06 (0.26)	0.11 (0.51)	0.15 (0.96)
Number of employees	0.93 (3.38) ***	1.26 (3.30) ***	0.72 (2.41)	1.57 (7.23) ***
Age	-0.84 (-1.75) *	-0.22 (-0.08)	-3.33 (-1.57)	-3.43 (-2.02) **
Capital intensity	0.09 (3.26) ***	0.02 (0.10)	0.30 (2.35) **	0.20 (2.06) **
R-squared (within)	0.53	0.38	0.21	0.16
Number of observations	2,433	3,310	7,570	15,908

Note: The table shows the results of a fixed effects panel estimation, by age class (based on the date of creation): age <=5 years, 5 years < age <= 10 years, 10 years < age <= 20 years, > 20 years. 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.

According to Mina, Lahr and Hughes (2013), empirical work points at a pecking order of finance whereby firms will first of all use cash flow to finance new projects. If cash flow is not sufficient, firms will look for external financing. External equity appears to be the least preferred form of finance. For SMEs, retained earnings and the owner's private wealth are the main source of finance. Financial constraints are often seen as a major impediment for firms to invest in R&D activities. Liquidity, solvency, and profitability are therefore usually listed as determinants of firm-level R&D expenditures. As Table A3.1 shows, when included as control variable in the baseline estimation, the coefficients of liquidity, solvency, and profitability are not statistically significant except for one of the three alternative profitability variables which is significant but only at the 10% level. As including these variables reduces the number of observations, they are not included in further estimations. However, the financial indicators, rather than having an impact on R&D expenditures may affect the impact of public support to R&D. In annex 3, four tables report the results of the estimation of the baseline specification in which firms are grouped by quartile according to liquidity, solvency, profitability, and productivity.

Lahr and Mina (2021) show that the relationship between financial constraints, R&D and innovation is not straightforward. Using data from the UK Innovation Surveys, they do not find much evidence that past financial constraints affect R&D activities or innovation output. However, acknowledging the possible endogeneity of financial constraints, they find that new-to-market innovation may actually cause financial constraints. Farre-Mensa and Ljungqvist (2016) argue that empirical research proxies of financial constraints do not very well capture constraints, but rather reflect differences in the growth and financing policies of firms at different stages of their life cycles.

Table A3.4 shows that regional subsidies have a high positive impact on R&D expenditures of firms with low liquidity whereas the impact for firms with the highest liquidity is not statistically significant. On the other hand, the coefficient of the patent income deduction and EU funding is statistically significant negative for firms with the lowest liquidity, indicating crowding-out effects of these support schemes for liquidity-constrained firms. This result is in line with the finding by Acconcia and Cantabene (2018) that cash-constrained firms in Italy responded less to a R&D tax credit than firms with large cash holdings. Only for the partial exemption for researchers with a master's degree is the coefficient statistically significant at all levels of liquidity. Zavertiaeva, López-Iturriaga and Kumin (2016) provide evidence, for seven countries, that overconfident managers tend to spend inefficiently more on R&D and amplify the impact of financial determinants like liquidity or profitability on R&D intensity.

The results in Table A3.5, which shows the impact of public support by quartile of solvency, are rather like the results by quartile of liquidity, with a relatively large statistically significant positive coefficient for regional subsidies and even more so for the partial exemption for researchers with a master's degree for firms with low solvency. There are also indications of crowding out for the patent income deduction and EU funding for firms in the lowest quartile of solvency. The results seem to corroborate the finding by Bragoli et al. (2020) that above a certain debt (leverage) threshold, R&D investment decreases because of the higher probability of default.[30] The coefficient of the innovation bonus is statistically significant positive for firms with low solvency. The results reported in Table A3.6 do not reveal substantial heterogeneity of the impact of public support related to the profitability of firms. However, statistically significant indications of crowding out for the patent income deduction and the innovation income deduction are only found for firms with medium-high profitability (third quartile). Table A3.7 shows that some of the coefficients of the public support variables are highest for firms with low productivity (first quartile). This is the case for regional subsidies, the partial exemption for research cooperation, the partial exemption for Young Innovative Companies and the partial exemption for researchers with a master's degree. Indications of crowding-out effects of the patent income deduction and the innovation income deduction are found for firms with higher productivity levels.

The impact of public support for business R&D may also differ according to the sources of technology and knowledge, market demand characteristics and the potential of appropriability of the results of

[30] The U-shaped relationship between debt (leverage) and R&D investment proposed by Bragoli et al. (2020) is less apparent from the results in Table A3.5.

R&D activities. Pavitt (1984) proposed four distinct categories of industries along these lines. Tidd, Bessant and Pavitt (2005) introduced a fifth category, Information Intensive industries, defined as industries for which equipment that can process, and diffuse information is important for production and innovation. Bogliacino and Pianta (2015) found that Information Intensive sectors behave in a manner that is not statistically different from Scale Intensive sectors, which leads them to combine them in the category Scale and Information Intensive sectors:

- Science-Based sectors: innovation is based on advances in science and R&D,
- Specialized Suppliers: sectors producing machinery and equipment that is used in new processes for other industries,
- Scale and Information Intensive sectors: scale economies are relevant, and a certain rigidity of production processes exists, technological change is usually incremental. ICT equipment is important for production and innovation.
- Supplier-dominated sectors: traditional sectors in which small firms are prevalent and technological change is introduced through the inputs and machinery provided by suppliers from other industries.

Bodas Freitas et al. (2015) 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, such as higher additionality in low-tech industries (especially in countries with incremental support schemes). Table 17 shows the results of a separate panel estimation of the baseline specification for each of the four Pavitt categories proposed by Bogliacino and Pianta (2015). The table in Annex 2 lists NACE two-digit industries by Pavitt category.

The coefficient for regional subsidies is lowest in science-based industries and highest in supplier-dominated industries. There is no clear pattern for the partial exemption schemes. The coefficient of partial exemption for researchers with a PhD or civil engineering degree is only statistically significant positive in science-based industries. The negative coefficient of the innovation income deduction is only statistically significant for specialized suppliers and scale and information intensive industries. The Pavitt categories do not seem to provide clear-cut conclusions and the R-squared is substantially lower than in the other regressions with distinct groups of firms categorized by firm characteristics, other than the industry to which a firm belongs. This suggests that heterogeneity in the impact of public support is explained more by within-industry variance than by between-industry variance.

Table 17 Results of a fixed effects panel estimation, by Pavitt category

	Science-based	Specialized Suppliers	Scale and Information Intensive	Supplier-dominated
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.03 (3.24) ***	0.04 (2.66) ***	0.08 (4.04) ***	0.10 (5.76) ***
Partial exemption:				
Research cooperation	0.12 (3.33) ***	0.14 (3.14) ***	0.13 (2.30) **	0.12 (2.99) ***
Young Innovative Company	0.11 (4.61) ***	0.13 (3.03) ***	0.26 (2.07) **	0.09 (1.35)
PhDs and civil engineers	0.08 (2.96) ***	0.03 (1.31)	0.05 (1.52)	0.04 (1.20)
Master	0.11 (5.01) ***	0.09 (3.85) ***	0.17 (5.40) ***	0.19 (6.56) ***
Bachelor	0.00 (0.14)	0.07 (2.25) **	0.04 (1.03)	0.08 (2.01) **
CIT incentives:				
Tax credit R&D	-0.00 (-0.09)	-0.01 (-0.43)	-0.05 (-1.02)	0.10 (1.28)
Tax deduction R&D°	0.07 (2.94) ***	0.10 (2.16) **	0.05 (2.07) **	0.10 (2.62) ***
Patent income deduction	-0.01 (-0.26)	-0.02 (-0.80)	0.01 (0.20)	-0.03 (-0.93)
Innovation income deduction	-0.03 (-1.23)	-0.06 (-2.00) **	-0.07 (-1.79) *	-0.02 (-0.93)
Other funding:				
Innovation bonus	0.06 (1.51)	0.10 (2.17) **	0.10 (1.90) *	0.07 (1.70) *
EU funding	-0.02 (-0.95)	-0.02 (-0.89)	-0.02 (-0.66)	-0.06 (-1.67) *
Control variables:				
Turnover	0.14 (0.98)	0.00 (0.03)	0.21 (0.73)	0.16 (0.78)
Number of employees	1.17 (4.32) ***	1.23 (5.34) ***	0.85 (2.14) **	1.10 (3.76) ***
Age	-1.40 (-3.05) ***	-1.04 (-2.25) **	-1.81 (-2.43) **	-1.18 (-1.94) *
Capital intensity	0.12 (1.24)	0.12 (1.18)	-0.06 (-0.31)	0.33 (2.51) **
R-squared (within)	0.10	0.13	0.15	0.11
Number of observations	6,482	6,797	4,182	9,701

Note: The table shows the results of a fixed effects panel estimation, by Pavitt category using the classification provided by Bogliacino and Pianta (2015). The classification of NACE two-digit industries into Pavitt categories is listed in Annex 2. 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 18 shows the results of a panel estimation of the baseline specification in which industries are grouped by average market concentration, measured by the Herfindahl-Hirschman Index (HHI)[31], which sums the squared market shares of all firms within 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 (fourth) quartile grouping the two-digit industries, with the lowest (highest) average HHI over the period 2003-2019. The highest coefficients for the public support variables are found for industries with medium-low concentration (2nd quartile HHI).

[31] In their review of the literature on the link between market competition and R&D investment, Halpern and Muraközy (2015) point out that Herfindahl-Hirschman Index is probably not the best indicator of market competition, but it is the only possible indicator with the available firm-level data.

Table 18 Results of a fixed effects panel estimation, by degree of market concentration

	Low 1st quartile HHI	Medium-low 2nd quartile HHI	Medium-high 3rd quartile HHI	High 4th quartile HHI
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.04 (2.78) ***	0.09 (5.06) ***	0.05 (3.21) ***	0.08 (4.90) ***
Partial exemption:				
Research cooperation	0.09 (2.50) **	0.20 (4.30) ***	0.11 (2.29) **	0.12 (3.14) ***
Young Innovative Company	0.11 (4.72) ***	0.18 (2.81) ***	0.15 (1.89) *	0.05 (0.87)
PhDs and civil engineers	0.04 (1.44)	0.01 (0.33)	0.05 (1.92) *	0.06 (1.91) *
Master	0.14 (5.04) ***	0.16 (5.47) ***	0.14 (5.73) ***	0.08 (2.96) ***
Bachelor	0.00 (0.17)	0.22 (3.67) ***	0.00 (0.11)	0.04 (1.19)
CIT incentives:				
Tax credit R&D	-0.00 (-0.01)	0.00 (0.04)	0.03 (0.52)	-0.06 (-1.84) *
Tax deduction R&D°	0.13 (2.68) ***	0.09 (2.70) ***	0.06 (2.54) **	0.12 (3.11) ***
Patent income deduction	-0.05 (-1.36)	-0.06 (-1.56)	-0.04 (-2.27) **	-0.02 (-0.64)
Innovation income deduction	-0.04 (-1.41)	-0.04 (-0.76)	-0.04 (-1.70) *	-0.06 (-1.89) *
Other funding:				
Innovation bonus	0.16 (2.37) ***	0.02 (0.49)	0.08 (2.13) **	0.12 (2.54) **
EU funding	-0.05 (-2.21) **	-0.03 (-0.76)	-0.01 (-0.35)	-0.02 (-0.86)
Control variables:				
Turnover	-0.04 (-0.23)	0.22 (1.19)	-0.02 (-0.14)	0.27 (1.85) *
Number of employees	1.47 (4.83) ***	1.06 (3.75) ***	1.37 (4.47) ***	0.52 (2.04) **
Age	-1.60 (-2.96) ***	-1.17 (-2.00) **	-0.57 (-1.19)	-0.76 (-1.38)
Capital intensity	0.11 (1.09)	0.30 (2.50) **	0.11 (0.93)	0.26 (1.86) *
R-squared (within)	0.08	0.10	0.11	0.25
Number of observations	6,878	7,570	7,425	7,348

Note: The table shows the results of a fixed effects panel estimation, by degree of market concentration, measured by the Herfindahl-Hirschman Index (HHI). Industries are grouped by the average HHI, 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 (Low) grouping the industries with the lowest average market concentration and the fourth quartile (High) grouping the industries with the highest 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.

This seems to be in line with the inverted-U relationship between market concentration and innovation (effort) proposed by Aghion et al. (2005) where there is an optimal level of incentives for innovation at an intermediate level of market concentration, resulting from two opposing mechanisms, a negative (Schumpeterian) effect of competition on the incentives to innovate (especially for lagging firms) and a positive effect of competition that raises incentives among neck-and-neck competing incumbents to escape competition.

Especially for the tax incentives provided through corporate income taxation, market concentration reduces the impact of support, with statistically significant indications of crowding out for the tax credit, the patent income deduction, and the innovation income deduction for industries with medium-high and high market concentration.

As with the estimation by Pavitt industries, the estimations with industries grouped by market concentration explain less of the variance in R&D expenditures than estimations in which firms are grouped by firm-level characteristics other than industry affiliation. This points out the importance of within-industry heterogeneity in explaining R&D investment and the impact of public support.

Cusolito, Garcia-Marin and Maloney (2021) provide evidence for Chile that only for the 10% most productive firms increased competition has a positive impact on innovation whereas for the rest of the companies it tends to depress most measures of innovation. Eeckhout (2021) argues that through investment in R&D, marketing and new technologies, firms can attain a level of technological superiority that makes it hard for other firms to compete on price or for firms to enter the market. The statistically significant indications (at 10%) of crowding out for the R&D tax credit and the innovation income deduction and the strongly positive link between turnover and R&D expenditures in the most concentrated industries (4th quartile HHI), outline the risk that public support may reinforce a winners-take-most tendency, increase market concentration, widen the gap between frontier firms and laggards, and reduce business dynamism.

The final investigation of potential heterogeneity in the impact of public support for R&D considers the ownership of firms. Using the data on firm ownership of Belgian companies, provided by Hambÿe et al. (2022), which were used for Graph 17-Graph 19, Table 19 shows the results of a separate estimation of the baseline specification for each of three categories: domestic firms, firms that belong to a Belgian multinational group, and firms that belong to a foreign-controlled multinational group.

The impact of regional subsidies is statistically significant positive for all three groups. The coefficient of all five schemes of partial exemption is only statistically significant positive for domestic firms. There is robust evidence over the three groups of a statistically significant positive impact for the partial exemption for research cooperation and the partial exemption for researchers with a master’s degree. The indications of crowding out for the patent income deduction appear to apply to firms that belong to a multinational group (Belgian or foreign-controlled) and the indication for crowding out of the innovation income deduction to apply to firms that belong to a foreign-controlled multinational group (although this negative coefficient is only statistically significant at the 10% level).

According to Rodríguez-Pose and Wilkie (2016), direct support is more effective than tax benefits to attract R&D activities from foreign multinational enterprises in Europe. The statistically significant positive coefficient for regional subsidies and the statistically significant negative coefficient for the patent income deduction and the innovation income deduction, for firms that belong to a foreign multinational enterprise, seems to confirm this view. However, the coefficients of the partial exemption for firms involved in research cooperation and the partial exemption for R&D employees with a master’s degree are also statistically significant positive and larger than the coefficient of regional subsidies, suggesting that these schemes may be even more effective.

Table 19 Results of a fixed effects panel estimation, by firm ownership

	Domestic firm	Belongs to Belgian multinational group	Belongs to foreign-controlled multinational group
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.09 (8.18) ***	0.05 (3.46) ***	0.09 (4.56) ***
Partial exemption schemes:			
Research cooperation	0.20 (4.62) ***	0.12 (2.74) ***	0.11 (3.06) ***
Young Innovative Company	0.12 (4.93) ***	0.08 (1.66) *	0.20 (1.15)
PhDs and civil engineers	0.03 (1.67) *	0.03 (1.03)	0.05 (1.75) *
Master	0.13 (7.11) ***	0.11 (4.39) ***	0.16 (5.56) ***
Bachelor	0.05 (2.14) **	-0.02 (-0.65)	0.07 (1.81) *
Corporate income taxation incentives:			
Tax credit R&D	-0.00 (-0.01)	-0.00 (-0.04)	-0.04 (-1.23)
Tax deduction R&D°	0.13 (3.40) ***	0.07 (1.98) **	0.10 (4.00) ***
Patent income deduction	-0.00 (-0.01)	-0.05 (-2.12) **	-0.08 (-2.86) ***
Innovation income deduction	-0.01 (-0.47)	-0.06 (-1.61)	-0.08 (-1.89) *
Other funding:			
Innovation bonus	0.17 (4.50) ***	0.09 (2.06) **	0.11 (5.14)) ***
EU funding	-0.01 (-0.57) ***	-0.04 (-1.35)	-0.04 (-3.00) ***
Control variables:			
Turnover	0.14 (1.43)	-0.27 (-1.60)	-0.00 (-0.01)
Number of employees	1.26 (7.32) ***	1.50 (4.92) ***	1.03 (2.92) ***
Age	-1.66 (-5.84) ***	-0.78 (-1.34)	-0.15 (-0.25)
Capital intensity	0.22 (3.01) ***	0.06 (0.44)	0.11 (0.65)
R-squared (within)	0.14	0.28	0.27
Number of observations	18,308	5,679	5,234

Note: The table shows the results of a fixed effects panel estimation, for three groups according to firm ownership (data provided by Hambÿe et al. 2022): domestic firms, firms that belong to a Belgian multinational group and firms that belong to a foreign-controlled multinational group. 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.

4.1.2. Robustness of the baseline estimation

This section reports the results of alternative estimation procedures, to assess the robustness of the results of the fixed effects panel estimation of the baseline specification, as reported in section 4.1.1. Like the baseline estimation, the alternative estimations aim at providing an indication of the causal impact of public support for business R&D by tackling endogeneity, selection bias and other potential econometric issues.

a. Serial correlation and cross-sectional dependence

A first check of the robustness of the baseline estimation considers estimations that explicitly acknowledge serial correlation or cross-sectional dependence. The reported standard errors of the coefficient estimates of the baseline estimation are, in principle, robust to cross-sectional heteroskedasticity and within-panel (serial) correlation. Wursten (2018) points out that serial correlation in panel models has been largely ignored, although it could provide biased estimates, as shown by Pesaran and Smith (1995). Table 20 shows the results of a fixed effects panel estimation with a first-order autoregressive disturbance term, using the Stata procedure *xtregar*, and a fixed effects panel estimation with standard errors that are consistent for cross-sectional dependence, using the Stata procedure *xtscc*, proposed by Hoechle (2007). The coefficient estimates of the latter are the same as the baseline estimates, only the standard errors are different. The coefficient estimates of the serial correlation estimation differ from the baseline estimates. The null hypothesis of no serial correlation of any order, of a test that allows for gaps, as is the case in R&D Policy Mix panel, is clearly rejected.[32] The estimation with a first-order autoregressive disturbance term results in lower and less statistically significant coefficient estimates for the public support variables than in the baseline estimation. The negative coefficients of the income innovation deduction and EU funding are, contrary to the baseline estimates, not statistically significant in the estimation with a first-order autoregressive disturbance term. A disadvantage of this estimation is the loss of 23% of observations relative to the baseline estimation.

[32] The test uses xtistest, proposed by Wursten (2018).

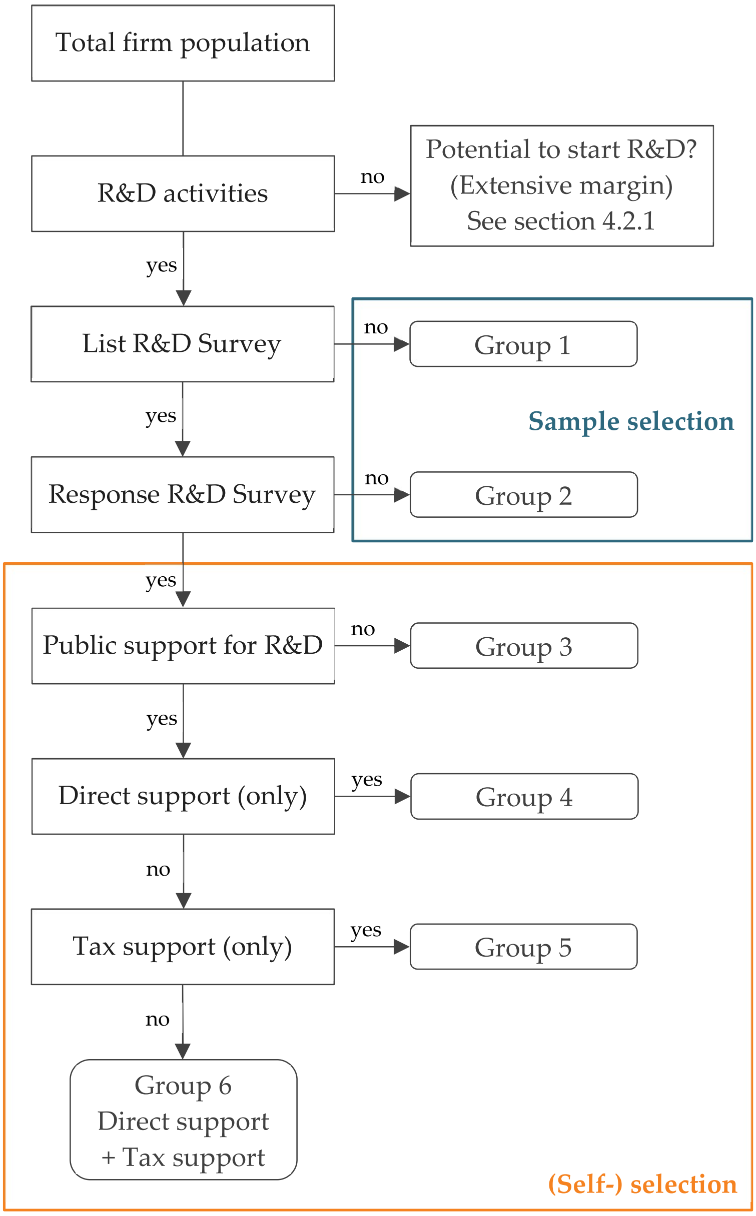
Table 20 Results of a fixed effects panel estimation allowing for first-order serial correlation and cross-sectional dependence

Dependent variable: (R&D expenditures net of public support)	First-order serial correlation	Cross-sectional dependence
Explanatory variables:		
Direct support:		
Regional subsidy	0.01 (1.69) *	0.08 (7.75) ***
Partial exemption schemes:		
Research cooperation	0.07 (3.33) ***	0.15 (10.18) ***
Young Innovative Company	0.07 (2.24) **	0.13 (6.60) ***
PhDs and civil engineers	0.05 (3.63) ***	0.04 (2.19) ***
Master	0.09 (7.52) ***	0.14 (9.06) ***
Bachelor	0.05 (2.58) ***	0.05 (2.99) ***
Corporate income taxation incentives:		
Tax credit R&D	0.00 (0.10)	-0.02 (-1.09)
Tax deduction R&D°	0.05 (2.07) **	0.12 (3.90) ***
Patent income deduction	0.00 (0.08)	-0.04 (-1.60)
Innovation income deduction	-0.02 (-0.91)	-0.05 (-2.91) ***
Other funding:		
Innovation bonus	0.04 (1.87) *	0.10 (10.86) ***
EU funding	-0.00 (-0.05)	-0.04 (-2.14) **
Control variables:		
Turnover	0.13 (2.14) **	0.07 (1.12)
Number of employees	0.91 (7.81) ***	1.12 (11.92) ***
Age	1.22 (3.83) ***	-1.20 (-9.42) ***
Capital intensity	0.21 (4.19) ***	0.17 (2.90) ***
R-squared	0.18	0.13
Number of observations	22,390	29,221

Note: The table shows the results of a fixed effects panel estimation that allows for first-order serial correlation and cross-sectional dependence using the xtregar and xtscc Stata procedures. The second column shows the results of a regression with first-order serial correlation of the disturbance term. The third column shows the results of a regression with Driscoll-Kraay standard errors, with a maximum lag of 4. Industry*year dummies are included but not reported. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%. °Data on the tax deduction for R&D investment is only available until 2012.

b. Selection model

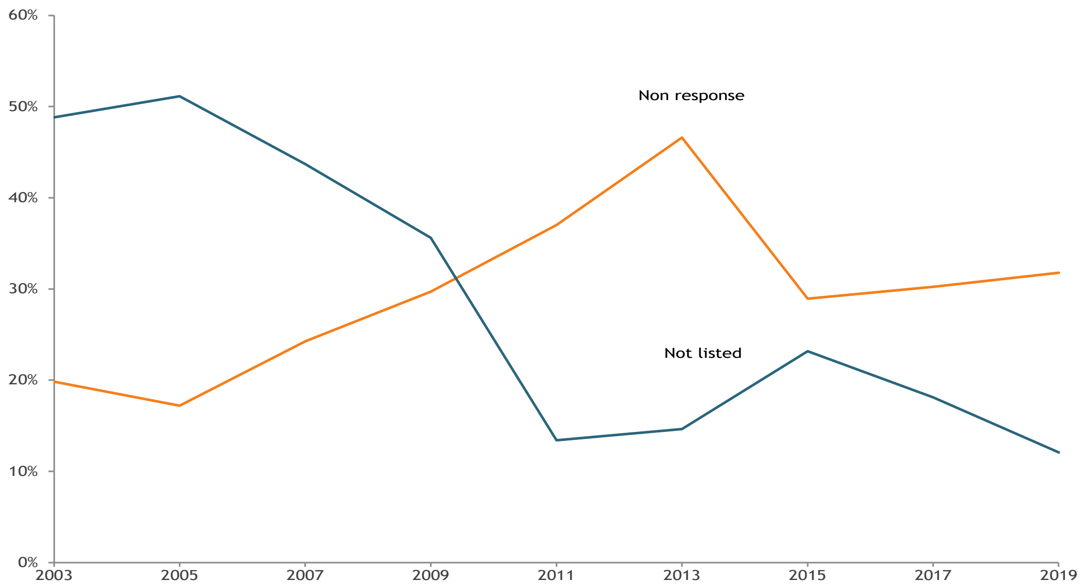
The estimation of the impact of public support on R&D expenditures, based on data from R&D surveys and other firm-level data, suffers from distinct selection issues that may result in biased estimates. The scheme below attempts to provide an overview of the selection issues.



Wooldridge (2010) points out that sample selection is only an issue once the population of interest has been carefully specified. For the estimation of input additionality, the population of interest can arguably be specified as the total population of firms with R&D activities in Belgium, rather than the total population of Belgian firms. Public support may aim to encourage firms that have not had any R&D activities in the past, to start doing R&D. This is the extensive margin, which is not considered in this section.[33] This may also include attracting R&D activities by foreign firms without any current economic activity.

If we consider the population of R&D active firms as the relevant population for an assessment of the input additionality of public support, a first selection issue arises as the R&D survey is sent to the firms that are listed in the repertory of known R&D active firms and to a sample of the total population of Belgian firms. Some R&D active firms may not be listed or sampled and therefore will not receive the R&D survey (group 1 in the scheme). Another selection issue is due to non-response, as only real responses on R&D expenditures are considered and firms that received the survey but did not respond will not be included for estimation (group 2 in the scheme). To provide an indication of the extent of these selection issues, the three following graphs show the share of firms that received public support for R&D and can therefore be assumed to have R&D activities, but that were not listed or that did not respond to the survey. Graph 30 shows the shares for firms that received direct support (regional subsidies), Graph 31 shows the shares for firms that benefitted from at least one of the five partial exemption schemes and Graph 32 shows the share for firms that used tax incentives provided through corporate income taxation. The three graphs clearly show that throughout the period of consideration, a very substantial share of firms that received public support for R&D is not included in the panel used to estimate the impact of support on R&D expenditures.

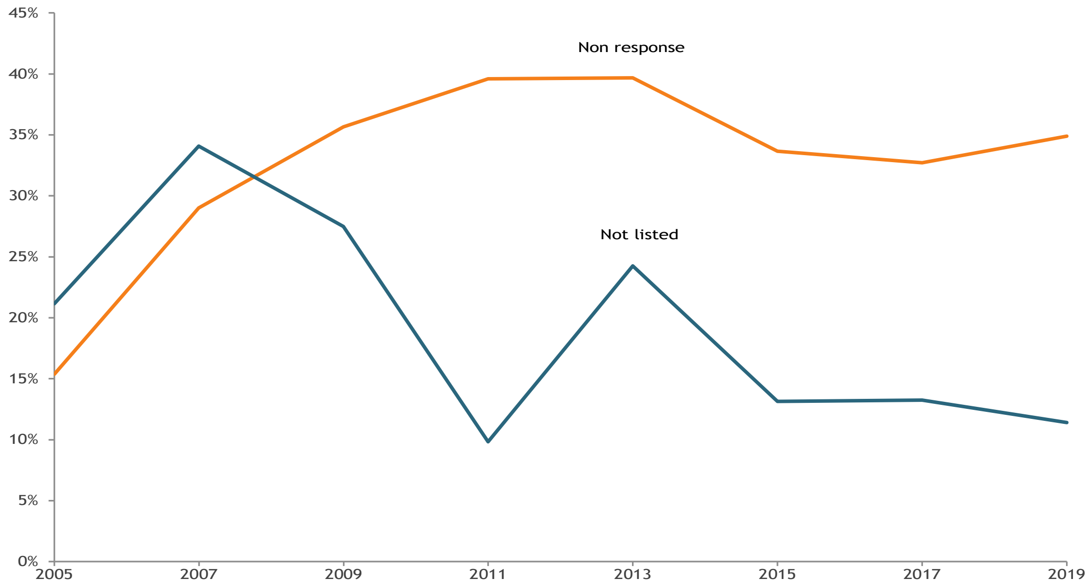
Graph 30 Share of firms that received regional subsidies but did not respond to or were not listed for the R&D Survey (2003-2019)



Note: The graph shows the evolution of the share of firms that received a regional subsidy but did not respond to the R&D Survey or were not in the list of companies that receive the R&D Survey. As the survey is biennial, the percentages are only shown for the odd years.

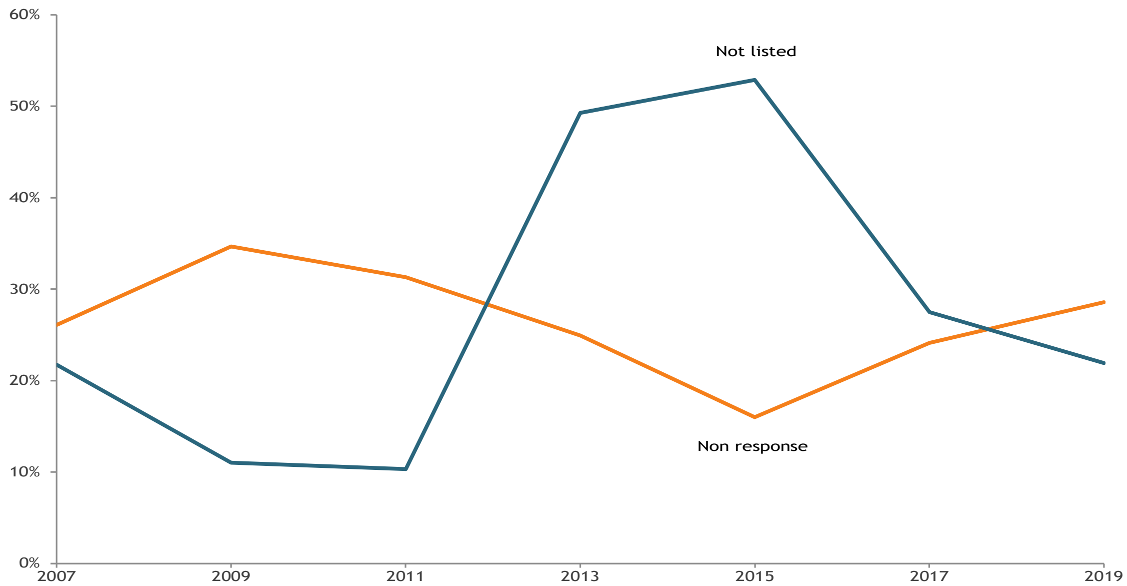
33 A firm that starts R&D would be included in the panel used for estimation if it reports R&D expenditures in its first year of R&D activities. However, the years before the start of R&D activities would only be included in the panel if the firm would have explicitly responded to the R&D survey that it had zero R&D expenditures. The problem in identifying firms that start doing R&D is further discussed in section 4.2.1.

Graph 31 Share of firms that received a partial exemption, but did not respond to, or were not listed for, the R&D Survey (2005-2019)



Note: The graph shows the evolution of the share of firms that received a partial exemption but did not respond to the R&D Survey or were not in the list of companies that receive the R&D Survey. As the survey is biennial, only the percentages are only shown for the odd years.

Graph 32 Share of firms that received a corporate income taxation (CIT) incentive, but did not respond to, or were not listed, for the R&D Survey (2007-2019)



Note: The graph shows the evolution of the share of firms that received a corporate income taxation incentive but did not respond to the R&D Survey or were not in the list of companies that receive the R&D Survey. As the survey is biennial, only the percentages are only shown for the odd years.

For regional subsidies and the partial exemption schemes, the share of firms that received support but that were not listed, or sampled for the R&D survey, decreased, whereas the share of firms that did not respond to the survey increased. For firms that received direct support, the share of non-listed firms dropped substantially. At the beginning of the period, the share of supported firms that were not listed was highest of the three main public support categories for regional subsidies whereas, at the end of the period, this share was lower than the share of firms benefitting from partial exemption or corporate income taxation incentives that were not listed. For firms that used at least one of the partial exemption schemes, the share of firms that did not respond to the survey more than doubled. Of the firms that benefitted from corporate income taxation incentives for R&D, almost half were not listed in the years 2013-2016 but this share dropped in 2017.

The large share of non-listed firms and firms that do not respond to the R&D survey not necessarily implies that the estimates of the baseline specification with a panel of only the firms that did respond to the R&D survey will be biased. This will only be the case if the latter group is not a random selection of the population of R&D active firms. The results reported in Table 21 clearly show that the group of firms that do respond to the R&D survey cannot be considered as a random sample of firms that receive public support. Especially small and young firms, firms that belong to a Belgian multinational group and firms that use partial exemption are not listed or sampled for the R&D survey. For non-response age not significant but size is (employees). Public support: when using CIT incentives less likely to be not listed or not to respond. For firms that do not respond to the R&D survey, the differences with the group of firms that do respond are less substantial. They tend to be smaller and belong to a Belgian or foreign-controlled multinational group.

The absence of group 1 and group 2 in the panel of firms that is used for estimation, can be considered as a sample selection issue, in line with the definition by Heckman (2010) of a distorted representation of the population of interest that results from the statisticians involved in the survey and/or from self-selection by the agents that are studied. The absence of these groups results in sampling on the response variable, which as Wooldridge (2010) points out, is more problematic than sampling based on an exogenous explanatory variable.

Another distinct selection issue does not result from data availability and sampling but from self-selection of firms in the use of public support. Regional subsidies are granted following a competitive procedure, based on the assessment of project proposals. The granting of subsidies is subject to selection by agencies and self-selection by companies. For tax incentives, the selection issue is less obvious although it is clear from the data that the group of firms that benefit from tax incentives is not a random selection from the population of R&D active firms. In the scheme presented above, four distinct groups of firms that do report R&D expenditures in the R&D survey can be distinguished, according to whether they receive public support and if so which type of support. The potential non-randomness of public support is not a sample selection issue in the strict sense. The Policy Mix data used in this report contain virtually all firms that receive public support for R&D. That this support is not necessarily distributed randomly, or proportionally to the R&D expenditures, does not result in a sampling problem.

This section reports the results of a two-stage estimation that allows to account for a potential selection bias, as proposed by Heckman (1979). In the first stage, a selection equation is estimated that considers variables that could explain why a firm belongs to a given selection of firms (groups of firms shown in the scheme above). From this estimation, inverse Mills ratios can be computed which are included in the second stage of the estimation, which consists in estimating the impact of public support on R&D

expenditures (baseline specification). The statistical significance of the inverse Mills ratios in the second-stage estimation provides an indication on the relevance of selection bias. Busom (2000) and Hussinger (2008) applied a two-stage selection model estimation to account for (self-)selection[34] in public support. This was also applied in the third evaluation of public support for business R&D in Belgium (Dumont 2019). In this section the distinction between sample selection in the strict sense, and (self-)selection/endogeneity of public support, is made by considering three alternative selection equations.

Table 21 shows the results of the estimation of a selection equation that considers three groups of firms that received public support for R&D: group 1 (not listed or sampled for R&D survey) and group 2 (non-response R&D survey) in the scheme above and a group with firms that received support and reported R&D expenditures (group 4, group 5 and group 6 in the scheme). This selection equation only considers sample selection resulting from the R&D survey and not (self-)selection in the use of public support. The coefficients in the table 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. In the estimation, the group of firms with reported R&D expenditures (in effect, the panel of firms used in the baseline estimation) is the benchmark group. As more than two groups are considered, the selection equation estimated with a multinomial logistic regression instead of a logistic regression with a binary variable.

Table 21 Estimation of characteristics of firms that are not in the sample used for the evaluation of public support, because they are not listed to receive, or did not respond to, the R&D Survey

Dependent variable:	Public support but not in list R&D Survey	No response R&D Survey
Explanatory variables:		
Regional subsidy	1.10 (24.44) ***	1.01 (3.17) ***
Partial exemption	1.16 (32.88) ***	1.01 (6.96) ***
CIT incentive	0.95 (-7.89) ***	0.96 (-12.19) ***
Liquidity	1.00 (0.74)	1.00 (0.71)
Profitability	0.99 (-0.16)	1.00 (1.00)
Turnover	1.10 (4.90) ***	1.01 (0.82)
Number of employees	0.67 (-15.60) ***	0.93 (-6.13) ***
Age	0.86 (-5.94) ***	1.00 (0.34)
Capital intensity	1.01 (0.53)	0.99 (-1.89) *
Belgian MNE group	1.19 (3.40) ***	1.10 (3.79) ***
Foreign MNE group	0.94 (-0.91)	1.07 (2.43) **
Share of observations	11.0%	36.3%
Number of observations: 68,580		
Pseudo R2: 0.05		

Note: The table shows the results of a multinomial logistic regression. The dependent variable is a categorical variable reflecting three possible situations in terms of public support for R&D: 1 (firm received support for R&D but is not in the list of firms to which the R&D Survey is send); 2 (firm received public support, is on the R&D Survey list but did not respond); 3 (firm responded to the R&D Survey and reported R&D expenditures). The table shows the results for the first two groups relative to the benchmark group (last group). 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 estimation considers region, industry, and year dummies (not reported). A measure of solvency (long-term financial independence) is excluded as it results in substantially less observations and its coefficient is not statistically significant for any of the groups. *, ** and *** denotes that the coefficient estimate differs from zero at a statistical significance level of respectively 10%, 5% and 1%.

[34] Busom (2000) considers the approach as a way to control for endogeneity of public support.

Conditional on other variables, firms that received direct support (regional subsidies) or a partial exemption, were more likely to be absent from the repertory or not sampled for the R&D survey whereas firms that benefit from corporate income taxation incentives were less likely to not be listed or sampled. Companies with many employees and old companies were more likely to appear in the repertory or be sampled for the R&D survey. Somewhat surprisingly, conditional on the other variables, companies with a large turnover and companies that belong to a Belgian multinational were more likely not to be listed or sampled for the R&D survey. For firms that did not respond to the R&D survey, the results are generally in line with the results of the non-listed/non-sampled firms but less pronounced. The most surprising result for this group is that firms that belong to a Belgian or a foreign-controlled multinational group appear to be less inclined to respond to the R&D survey.

The second selection equation that has been estimated considers only the (self-)selection of public support, using the four groups of firms for which data on R&D expenditures are available (group 3 up to group 6 in the scheme) and the third selection equation considers sample selection as well as (self-) selection of public support, using all six groups of the scheme above.

As they relate to, respectively, four and six categories, the results of the first-stage estimation of the second and the third selection equation are not reported but available upon request. The estimation of the selection equation reveals another selection issue. For a substantial share of firms that are not listed or sampled for the R&D survey or that do not respond, data are not available for some of the explanatory variables. As the groups of firms for which data for all variables are available may not be a random selection of the relevant category, the estimates of the selection equation may actually - somewhat ironically- suffer from a selection bias. Unfortunately, the lack of relevant data does not permit to say anything meaningful as to the extent of this bias.

Table 22 shows the results of the second-stage estimation of the impact of public support on R&D expenditures, which include inverse Mills ratios, derived from the first-stage estimation of the three alternative selection equations. As in each estimation the coefficient of at least two of these variables is statistically significant, the results suggest the need to account for the different selection issues. The three alternative specifications provide similar results on the impact of the public support instruments, especially for regional subsidies and the partial exemption schemes.

As to the corporate income taxation incentives, the only robust finding, over the three specifications, is the statistically significant positive coefficient of the tax deduction for R&D investment. When only accounting for (self-)selection of public support, the coefficient of the tax credit for R&D investment and the patent income deduction is statistically significant positive but this result is not confirmed when the two sample selection issues are accounted for. The negative coefficient of the innovation income deduction is only statistically significant when the sample selection issues and (self-)selection of public support is considered jointly (last column).

Table 22 Panel estimation accounting for sample selection and (self-)selection

	Sample selection Survey and Response	(Self-selection) Support	Sample selection Survey, Response and (self-)selection Support
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.08 (7.09) ***	0.04 (5.79) ***	0.07 (8.97) ***
Partial exemption schemes:			
Research cooperation	0.14 (5.81) ***	0.13 (5.78) ***	0.14 (6.13) ***
Young Innovative Company	0.12 (5.40) ***	0.18 (7.37) ***	0.13 (5.92) ***
PhDs and civil engineers	0.04 (2.65) ***	0.11 (7.32) ***	0.05 (3.72) ***
Master	0.13 (9.42) **	0.16 (11.85) ***	0.12 (9.78) ***
Bachelor	0.03 (1.86) *	0.05 (2.91) ***	0.03 (1.78) *
Corporate income taxation incentives:			
Tax credit R&D	0.04 (1.43)	0.08 (4.12) ***	0.02 (1.09)
Tax deduction R&D°	0.18 (6.31) ***	0.08 (4.89) ***	0.10 (5.65) ***
Patent income deduction	0.02 (0.74)	0.03 (2.25) **	-0.01 (-1.10)
Innovation income deduction	-0.01 (-0.31)	-0.02 (-1.24)	-0.05 (-2.49) **
Other funding:			
Innovation bonus	0.10 (4.48) ***	0.09 (4.42) ***	0.11 (5.07) ***
EU funding	-0.04 (-2.78) ***	-0.01 (-0.45)	-0.02 (-1.26)
Variables from selection equation:			
Inverse Mills 1	0.80 (2.72) ***	0.22 (15.72) ***	0.38 (8.98) ***
Inverse Mills 2	-0.58 (-2.30) ***	0.04 (2.48) **	-0.05 (-2.55) ***
Inverse Mills 3		0.04 (3.00) ***	0.02 (0.69)
Inverse Mills 4			-0.00 (-0.10)
Inverse Mills 5			0.01 (0.21)
Control variables:			
Liquidity	-0.01 (-1.17)	0.00 (0.26)	-0.01 (-0.82)
Profitability	-0.00 (-1.52)	0.00 (0.59)	-0.00 (-5.21) ***
Turnover	0.05 (0.59)	0.10 (1.08)	0.01 (0.06)
Number of employees	1.22 (8.25) ***	1.04 (6.56) ***	1.05 (7.01) ***
Age	-1.29 (-5.16) ***	-0.88 (-3.09) ***	-1.12 (-4.22) ***
Capital intensity	0.23 (3.64) ***	0.14 (2.16) **	0.20 (3.08) ***
R-squared (within)	0.13	0.16	0.14
Number of observations	25,787	20,655	23,931

Note: The table shows the results of the estimation of a selection model consisting of a selection equation and the main equation. The table shows the results of the (second-stage) equation in which inverse Mills variables, derived from the first-stage estimation of the selection equation, are included to account for (sample) selection issues related to the R&D Survey that is used for data on R&D expenditures and self-selection of public support. 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. °Data on the tax deduction for R&D investment is only available until 2012.

c. Instrumental variables estimation

In the evaluation of public support for business R&D, the possibility that the public support variables are endogenous needs to be acknowledged. If explanatory variables are endogenous (correlated with the error term), estimates may be substantially biased. The traditional approach to address endogeneity is through instrumental variables (IV) estimation. If a variable exists that is correlated with the potentially endogenous explanatory variable but not with the error term, this instrumental variable can be used to provide unbiased estimates of the endogenous variable. The main problem with IV estimation is the availability of a good instrumental variable, being a variable that is not correlated with the error term but that is also not weak, in effect, that is sufficiently correlated with the endogenous variable it is supposed to instrument. The use of weak instruments may result in a substantial loss of efficiency (high variance). In the evaluation of public support, instrumental variables need to be determined only by the government (agencies) and not by the firms that benefit from the support. So, instrumental variable estimation implies the availability of instruments for what are already government instruments (public support schemes). Table 23 shows the variables that are used as instruments for each of the public support schemes.

Table 23 List of instruments

Variable	Instrument
Regional subsidy	Total amount of support (net of support firm) by two-digit industry
Research cooperation	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	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	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	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
Bachelor	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	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. Consider applicable CIT rate (reduction from revenue year 2018 (taxation year 2019) onwards).
Tax deduction R&D	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.
Patent income deduction	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. Consider applicable CIT rate (reduction from revenue year 2018 (taxation year 2019) onwards).
Innovation income deduction	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. Consider applicable CIT rate (reduction from revenue year 2018 (taxation year 2019) onwards).
Innovation bonus	Total amount of support (net of support firm) by two-digit industry
EU funding	Total amount of support (net of support firm) by two-digit industry

As can be seen, for tax incentives, changes in the rate of exemption or deduction are used to create instrumental variables, assuming that these changes are not influenced by individual companies, in line with Chang (2012) and Rao (2016). For regional subsidies, the innovation bonus and EU funding, the total amount of support in the industry to which a firm belongs, is considered as instrumental variable, following arguments by Lichtenberg (1988), Wallsten (2000) and Clausen (2008).

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. Table 24 reports the results of a fixed effects as well as a random effects IV estimation in which the instruments listed in Table 23 are used.

Table 24 Results of instrumental variable estimation

Dependent variable: (R&D expenditures net of public support)	Fixed effects	Random effects
Explanatory variables:		
Direct support:		
Regional subsidy	0.18 (4.01) ***	0.27 (11.91) ***
Partial exemption schemes:		
Research cooperation	0.15 (3.53) ***	0.16 (5.72) ***
Young Innovative Company	0.11 (1.95) *	0.19 (6.80) ***
PhDs and civil engineers	0.05 (1.97) **	0.14 (8.63) ***
Master	0.11 (5.28) ***	0.19 (12.93) ***
Bachelor	0.05 (1.15)	0.03 (0.83)
Corporate income taxation incentives:		
Tax credit R&D	-0.03 (-0.88)	-0.02 (-0.69)
Tax deduction R&D°	0.14 (1.87) *	0.25 (4.11) ***
Patent income deduction	-0.06 (-1.97) **	-0.02 (-0.62)
Innovation income deduction	-0.06 (-1.10)	-0.01 (-0.13)
Other funding:		
Innovation bonus	0.09 (1.78) *	0.09 (2.43) **
EU funding	-0.08 (-1.49)	-0.12 (-2.63) ***
Control variables:		
Turnover	0.09 (1.13)	0.02 (0.54)
Number of employees	1.01 (8.31) ***	0.39 (6.32) ***
Age	-0.91 (-4.21) ***	-0.41 (-6.60) ***
Capital intensity	0.17 (3.44) ***	0.07 (2.53) **
Sargan (over-identification)	40.48 (0.00) ***	
Anderson (under-identification)	600.75 (0.00) ***	
Weak instrument (robust):		
Anderson-Rubin F	6.57 (0.00) ***	
Anderson-Rubin Chi2	167.16 (0.00) ***	
Stock-Wright	165.23 (0.00) ***	
R-squared	0.13	0.10
Number of observations	18,244	19,963

Note: The table shows the results of the second step of an instrumental variables estimation, using the instruments as listed in Table 23. The second column shows the results of a fixed effects estimation. The third column shows the results of an instrumental variables estimation with random effects, using the same list of instruments. Industry*year dummies are included but not reported. *, ** 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. °Data on the tax deduction for R&D investment is only available until 2012.

In addition to the variables listed in Table 23, the IV estimation also includes one-year lags of the public support variables.[35]

Qualitatively, fixed effects and random effects, provide similar results. The coefficients of the random effects estimation of the public support are generally higher than the coefficients from the fixed effects estimation. As in the baseline estimation, the coefficient is positive and statistically significant for regional subsidies, four of the five partial exemption schemes, the tax deduction for R&D investment and the innovation bonus. Contrary to the baseline estimation, the positive coefficient of the partial exemption for R&D personnel with a bachelor's degree is not statistically significant in the IV estimation. In contrast with the baseline estimation, the negative coefficients of the patent income deduction and the innovation income deduction are not statistically significant, except for the coefficient of the patent income deduction in the fixed effects IV estimation.

Table 24 reports the results of some tests of the validity of the instruments. The tests suggest that the instruments are not weak (not correlated with the variables they instrument) but the strong rejection of the null hypothesis of the Sargan over-identification test[36], which tests for the exogeneity of additional instrumental variables, casts substantial doubt on the validity of the instruments.

d. Dynamic panel estimation

The level of R&D expenditures of firms and the amount of public support received is often rather persistent, especially for firms with continuous R&D activities (for example, Arqué-Castells and Mohnen 2015; Busom, Corchuelo and Martínez-Ros 2017). Dynamic panel estimation permits to account for this persistence by including lags of the dependent variable. Within a Generalized Method of Moments (GMM) framework lagged values of potentially endogenous variables can be included as instruments. A GMM approach considers more moments than strictly necessary to provide estimates, which results in over-identification, which can be used for over-identification tests of instrument validity. Two alternative GMM approaches are considered, first difference GMM, as proposed by Arellano and Bond (1991), or system GMM, as proposed by Arellano and Bover (1995) and Blundell and Bond (1998).[37] Table 25 shows the results of a First Difference GMM estimation and Table 26 the results of a System GMM. The latter permits to distinguish between short-term and long-term estimates of the impact of public support. The First Difference GMM estimation clearly provides less statistically significant coefficient estimates. Only the positive coefficients of the partial exemption for Young Innovative Companies and the partial exemption for researchers with a bachelor's degree and the negative coefficient of EU funding are statistically significant. First Difference GMM estimation dramatically reduces the number of observations, which drop to 5,392, compared to 29,221 in the baseline estimation. The results of the System GMM estimation are more in line with the results of the baseline estimation and even more so with the results of the IV estimation. Again, in line with IV estimation, rejection of the Sargan over-identification test casts doubt on the validity of the instruments.

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35 This permits over-identification testing.

36 Murray (2006) argues that Sargan's over-identification test is suspect when all the instruments share a common rationale, which to some extent is the case in the instruments listed in Table 23. Murray (2010) points out that over-dentification tests are ambiguous, as rejection of the null hypothesis may suggest the lack of validity of the instruments, but it could also indicate that the responses of agents to government policies are heterogenous, for which this evaluation provides ample evidence.

37 The technical appendix in Dumont (2015) provides more technical details on these approaches.

Table 25 Results of dynamic panel estimation – First Difference GMM

Dependent variable: (R&D expenditures net of public support)	
Explanatory variables:	
Direct support:	
Regional subsidy	-0.01 (-1.01)
Partial exemption schemes:	
Research cooperation	-0.01 (-0.46)
Young Innovative Company	0.07 (2.34) **
PhDs and civil engineers	0.02 (0.88)
Master	0.03 (1.38)
Bachelor	0.03 (1.97) **
Corporate income taxation incentives:	
Tax credit R&D	-0.02 (-1.07)
Tax deduction R&D°	0.02 (1.19)
Patent income deduction	-0.00 (-0.29)
Innovation income deduction	-0.01 (-0.57)
Other funding:	
Innovation bonus	0.02 (0.92)
EU funding	-0.02 (-1.86) *
Lags of dependent variable	
Net R&D expenditures (t-1)	0.48 (15.77) ***
Net R&D expenditures (t-2)	-0.20 (7.21) ***
Net R&D expenditures (t-3)	0.11 (5.37) ***
Control variables:	
Turnover	0.02 (0.16)
Number of employees	0.75 (2.64) ***
Age	-0.15 (-0.40)
Capital intensity	0.12 (1.19)
Arellano-Bond test AR (1) -9.02 (0.00) ***	
Arellano-Bond test AR (2) 0.65 (0.52)	
Arellano-Bond test AR (3) -0.38 (0.70)	
Arellano-Bond test AR (4) -0.61 (0.54)	
Sargan (over-identification) 1631.76 (0.27)	
Hansen (over-identification) 1420.36 (0.99)	
Hansen test excluding group 1408.74 (0.99)	
Difference (H_0=exogeneity) 11.62 (0.56)	
Number of observations	5,392

Note: The table shows the results of a two-step difference GMM estimation. 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. °Data on the tax deduction for R&D investment is only available until 2012.

Table 26 Results of dynamic panel estimation – System GMM

	Short-term	Long-term
Dependent variable:		
(R&D expenditures net of public support)		
Explanatory variables:		
Direct support:		
Regional subsidy	0.03 (3.85) ***	0.13 (3.88) ***
Partial exemption:		
Research cooperation	0.03 (2.12) **	0.13 (2.10) **
Young Innovative Company	0.09 (4.62) ***	0.40 (4.56) ***
PhDs and civil engineers	0.08 (6.73) ***	0.36 (6.98) ***
Master	0.07 (6.55) ***	0.30 (6.52) ***
Bachelor	0.00 (0.00)	0.00 (0.00)
Corporate income taxation incentives:		
Tax credit R&D	-0.00 (-0.21)	-0.03 (-0.47)
Tax deduction R&D°	0.04 (2.19) **	0.17 (2.23) **
Patent income deduction	0.01 (0.67)	0.03 (0.67)
Innovation income deduction	-0.04 (-3.22) ***	-0.15 (-3.14) ***
Other funding:		
Innovation bonus	0.00 (0.25)	0.02 (0.25)
EU funding	-0.02 (-1.61)	-0.08 (-1.58)
Lags of dependent variable		
Net R&D expenditures (t-1)	0.80 (52.56) ***	
Net R&D expenditures (t-2)	-0.19 (-7.43) ***	
Net R&D expenditures (t-3)	0.15 (7.69) ***	
Control variables:		
Value added	-0.05 (-0.54)	
Number of employees	0.17 (1.40)	
Age	-0.11 (-1.40)	
Capital intensity	0.05 (0.81)	
Arellano-Bond test AR (1) -10.84 (0.00) ***		
Arellano-Bond test AR (2) 0.57 (0.57)		
Arellano-Bond test AR (3) 0.46 (0.65)		
Arellano-Bond test AR (4) -0.73 (0.47)		
Sargan (over-identification) 2257.63 (0.00) ***		
Hansen (over-identification) 1756.93 (0.88)		
Hansen test excluding group 1446.50 (0.99)		
Difference (H_0=exogeneity) 310.42 (0.00)		
Number of observations 8,225		

Note: The table shows the results of a two-step system GMM. 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. Year dummies are included but not reported. °Data on the tax deduction for R&D investment is only available until 2012.

In contrast with the results of the IV estimation, the negative coefficient of the innovation income deduction is statistically significant, in the short-term and the long-term. Especially the long-term coefficient is substantial.

e. Error-correction model (ECM)

Regressions in which time series of variables are used, as is the case in panel regressions, may suffer from spurious correlation, correlation that does not reflect a causal relationship between variables but rather the fact that time series of economic variables are often non-stationary. An error-correction approach establishes whether there exists a stationary long-term relationship between the dependent and the explanatory variables, called cointegration relationship. If so, deviations (errors) from the long-term relationship will be temporary. More details on ECM are provided in the technical appendix of Dumont (2015). To assess the existence of a cointegration relationship, the order of integration of the time-series variables needs to be determined, using panel unit root tests. Table 27 shows the results of panel unit root tests for R&D expenditures and the distinct public support variables. A variable is said to be integrated of order zero (I(0)) if its level is stationary. If the level is not stationary but the first difference is, it is integrated of order 1 (I(1)) and if the level nor the first difference is stationary but the second difference is, the order of integration is two (I(2)). The results in Table 27 suggest that none of the variables is stationary in level or in first difference and that only R&D expenditures, regional subsidies and the three schemes of partial exemption based on the educational degree have an order of integration of two.

Table 27 Panel unit root tests

	Level test - I(0)	First difference test - I(1)	Second difference test - I(2)
R&D expenditures (net of support)	2552.76 (1.00)	2119.33 (1.00)	3184.09 (0.00) ***
Regional subsidy	2030.91 (1.00)	1716.63(1.00)	2470.93 (0.00) ***
Research cooperation	421.69 (1.00)	655.09 (1.00)	762.45 (1.00)
Young Innovative Company	189.06 (1.00)	216.50 (1.00)	189.81 (1.00)
PhDs and civil engineers	2178.43 (1.00)	2221.42 (1.00)	2778.98 (0.00) ***
Master	2336.67 (1.00)	2001.04 (1.00)	3432.41 (0.00) ***
Bachelor	96.27 (1.00)	894.86 (1.00)	2719.95 (0.00) ***
Tax credit R&D	353.87 (1.00)	428.82 (1.00)	610.77 (1.00)
Tax deduction R&D	348.42 (1.00)	392.19 (1.00)	447.97 (1.00)
Patent income deduction	312.86 (1.00)	357.85 (1.00)	679.99 (1.00)
Innovation income deduction	75.19 (1.00)	289.08 (1.00)	640.96 (1.00)
Innovation bonus	453.01 (1.00)	741.18 (1.00)	1131.03 (1.00)
EU funding	216.92 (1.00)	377.87 (1.00)	586.19 (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.

The fact that none of the corporate income taxation incentives have the same order of integration as R&D expenditures is problematic as this is a necessary condition for the existence of a cointegration relationship. Keeping in mind this important caveat, Table 28 shows the results of a single-equation ECM estimation and, alternatively, a two-step ECM estimation.

Table 28 Results of a panel error-correction model estimation

Dependent variable: (R&D expenditures net of public support)	Single-equation ECM	Two-step ECM
Explanatory variables:		
Direct support:		
Regional subsidy	0.01 (2.24) **	-0.00 (-0.16)
Partial exemption schemes:		
Research cooperation	0.06 (4.30) ***	0.05 (3.56) ***
Young Innovative Company	0.07 (3.38) ***	0.06 (2.80) ***
PhDs and civil engineers	0.03 (2.93) ***	0.03 (3.03) ***
Master	0.07 (6.38) ***	0.05 (5.64) ***
Bachelor	0.02 (1.65) *	0.03 (2.30) **
Corporate income taxation incentives:		
Tax credit R&D	0.01 (0.67)	-0.00 (-0.22)
Tax deduction R&D°	0.05 (4.05) ***	0.02 (1.97) **
Patent income deduction	-0.01 (-0.78)	-0.021 (-0.60)
Innovation income deduction	-0.04 (-3.26) ***	-0.02 (-2.31) **
Other funding:		
Innovation bonus	0.06 (3.78) ***	0.04 (2.79) ***
EU funding	-0.02 (-2.59) ***	-0.01 (-1.86) *
Error-correction term	-0.47 (-46.26) ***	-0.00 (-0.18)
Control variables:		
Turnover	0.03 (0.51)	0.06 (2.05) **
Number of employees	0.60 (5.52) ***	0.03 (0.58)
Age	-0.59 (-2.81) ***	-0.06 (-1.46)
Capital intensity	0.10 (2.15) **	0.04 (2.09) **
R-squared (within)	0.32	
Number of observations	19,047	17,990

Note: The table shows the results of a single-equation error-correction model (ECM) estimation and the second step of a two-step Engle-Granger error-correction model estimation. 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. °Data on the tax deduction for R&D investment is only available until 2012.

The results of the two alternative ECM estimations are very similar except that the coefficient of regional subsidies is negative, though not statistically significant, in the two-step ECM estimation but statistically significant positive in the single-equation ECM estimation. The results of the ECM estimations are also rather like the results of the baseline estimation, except that the negative coefficient of the patent income deduction is not statistically significant in the two alternative ECM estimations. The negative coefficient of the innovation income deduction is statistically significant in both estimations.

f. First Difference estimation

A final robustness estimation consists of a panel estimation where not the level of R&D expenditures is considered as dependent variable, but the growth in R&D expenditures. As R&D expenditures need to be reported by firms in consecutive years to compute growth and there are many gaps in the panel, the number of observations decreases substantially when considering first differences. As first differencing eliminates firm-level fixed effects, Table 29 shows the results of a pooled OLS estimation.

Table 29 Results of a first difference estimation - Pooled OLS

Dependent variable: Growth in R&D expenditures net of public support	
Explanatory variables:	
Direct support:	
Regional subsidy	0.01 (1.07)
Partial exemption schemes:	
Research cooperation	0.06 (3.67) ***
Young Innovative Company	0.08 (3.87) ***
PhDs and civil engineers	0.04 (3.68) ***
Master	0.05 (5.60) ***
Bachelor	0.03 (2.26) **
Corporate income taxation incentives:	
Tax credit R&D	-0.01 (-0.37)
Tax deduction R&D°	0.03 (2.37) **
Patent income deduction	0.00 (0.14)
Innovation income deduction	-0.03 (-2.73) ***
Other funding:	
Innovation bonus	0.04 (3.02) ***
EU funding	-0.02 (-2.68) **
Control variables:	
Turnover	0.04 (1.56)
Number of employees	0.05 (1.31)
Age	-0.08 (-2.58) ***
Capital intensity	0.02 (1.10)
Number of observations	19,047

Note: The table shows the results of a Pooled OLS estimation with variables considered in first differences. 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. °Data on the tax deduction for R&D investment is only available until 2012.

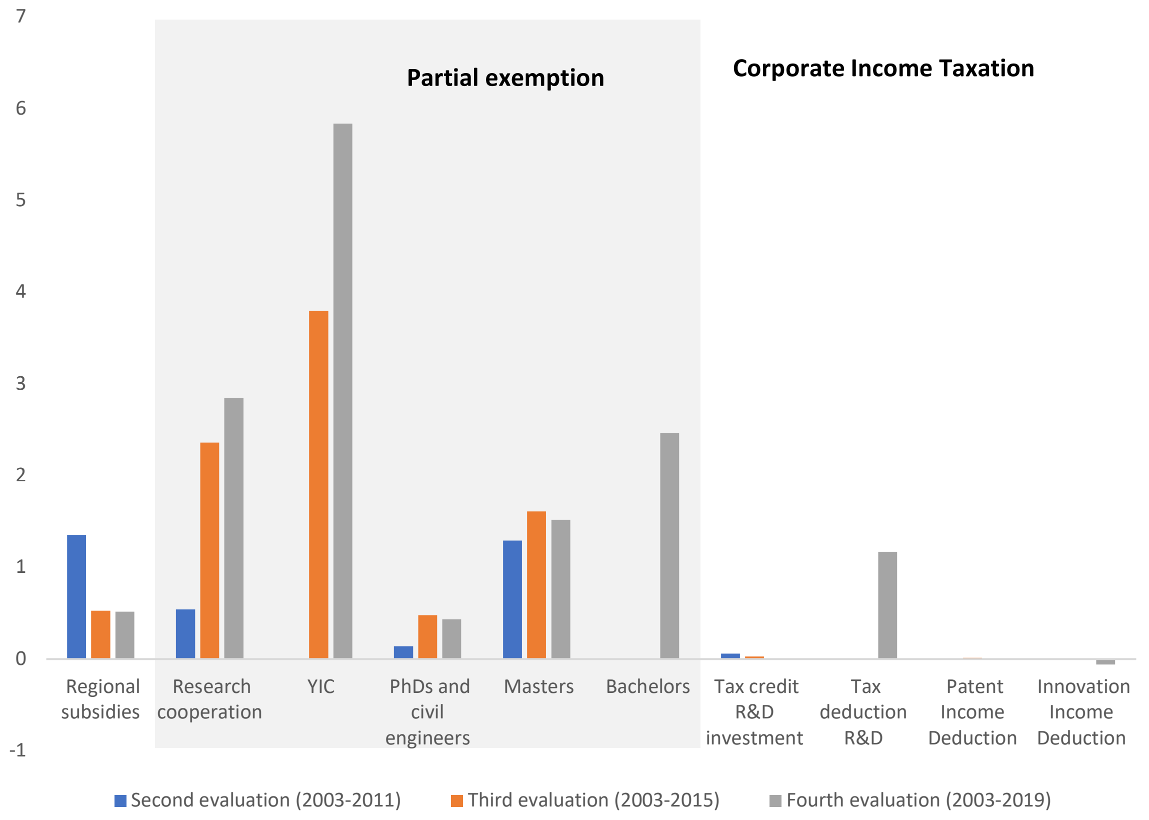
The results of the first difference estimation are very similar to the results of the ECM estimations. The coefficient of regional subsidies is positive but not statistically significant. The fact that the estimate of the coefficient of regional subsidies is lower and less significant when using first differences, or when using lags, may to some extent be explained by the finding in Table 13 that the baseline estimate of this coefficient is substantially larger for non-persistent R&D firms than for persistent R&D firms and that observations of non-persistent R&D performers are likely to be disproportionately dropped due to first differencing or including lagged variables.

4.1.3. Bang for the Buck

As the dependent variable and the public support variables are expressed in logs, the coefficient estimates can be interpreted in elasticity terms. Because R&D expenditures are considered net of the total amount of public support, a statistically significant positive coefficient provides an indication of additionality whereas a statistically significant negative coefficient provides an indication of crowding out.

An alternative and intuitively more straightforward indicator of the impact of public support is the Bang for the Buck (BFTB), which denotes how much euro in additional R&D expenditures results from one euro in public support.

Graph 33 Average Bang for the Buck by public support instrument - Second, Third and Fourth evaluation



Note: The graph shows the average Bang for the Buck based on alternative estimates of the coefficients of the different public support instruments for the second evaluation, covering the period 2003-2011, the third evaluation, covering the period 2003-2015 and the current (fourth) evaluation, covering the period 2003-2019.

The BFTB can be computed by multiplying the elasticity estimates with the ratio of the average net R&D expenditures to the average amount of support received by firms. As R&D expenditures are considered after subtracting the total amount of support, a BFTB greater than zero indicates net additionality and a negative BFTB indicates crowding out. Graph 33 compares the average BFTB, for each public support scheme, over all alternative estimations, to the average BFTB, over all estimations in the two previous evaluations (Dumont 2015, 2019). As the alternative estimations that have been used to check the robustness of the baseline estimation differ between the second, third and fourth evaluation, the comparison should be interpreted with some caution.

The three evaluations provide statistical evidence of net additionality for regional subsidies and the schemes of partial exemption. For regional subsidies, the BFTB based on the estimates of the second evaluation was higher than the BFTB based on the estimates of the third and fourth evaluation, with a similar BFTB for the last two evaluations. The BFTB for the partial exemption for research cooperation and for Young Innovative Companies increased over the three consecutive evaluations whereas for the partial exemption for PhDs and civil engineers and the partial exemption for masters, the BFTB is slightly lower in the fourth evaluation than in the third evaluation, but slightly higher than the BFTB based on the estimates of the second evaluation.

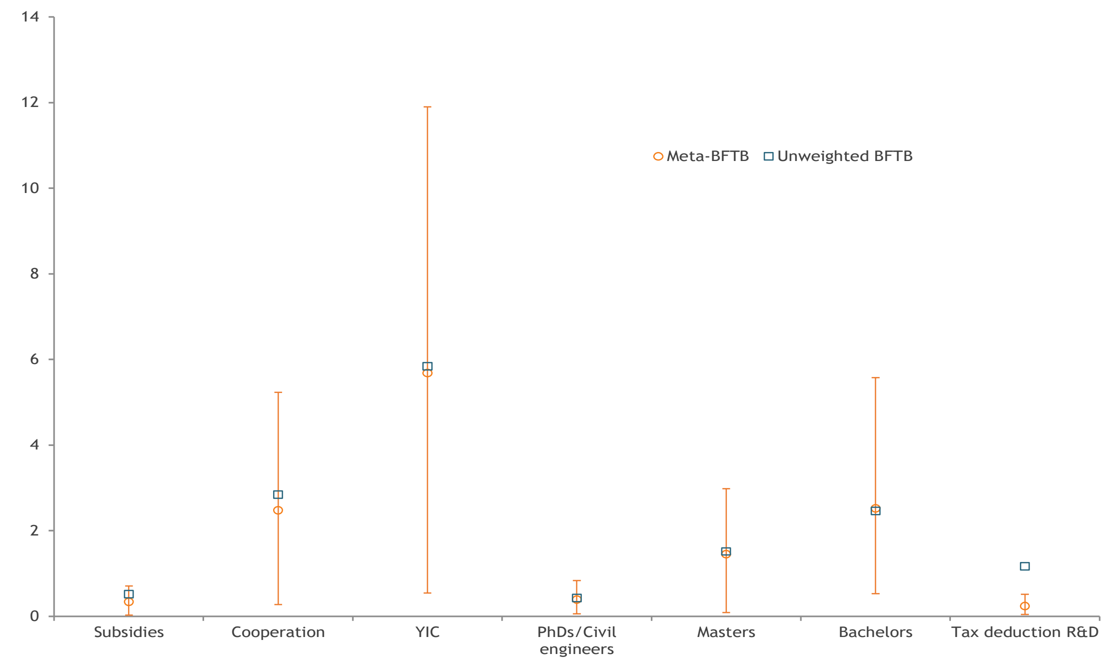
For the tax credit for R&D investment and the patent income deduction none of the evaluations provides an indication of additionality. Whereas a small positive average BFTB for the tax credit for R&D was found in the second evaluation (0.06), the BFTB in the third evaluation was even lower (0.02) and the BFTB based on the estimates of the fourth evaluation was equal to 0.00. For the patent income deduction there was no estimate of the BFTB in the second evaluation. The average BFTB for this tax incentive based on the estimates of the third evaluation was 0.01 and based on the estimates of the fourth evaluation 0.00.

The BFTB, based on the estimates of this (fourth) evaluation, for the partial exemption for researchers with a bachelor's degree, for the tax deduction for R&D investment and for the innovation income deduction are shown in Graph 33 but cannot be compared with the second and third evaluation as they were previously not, or only partially, included. The innovation income deduction and EU funding (not shown in Graph 33), which are for the first time considered in this evaluation, are the first schemes of public support for which an average negative BFTB is found, indicating partial crowding out.

The average BFTB shown in Graph 33 is an unweighted average of the Bang for the Buck based on the alternative estimations without acknowledging the accuracy of the estimates. To provide a BFTB that does acknowledge the variance of estimates, a meta-analysis was carried out for each public support scheme, which provides a BFTB that is weighted by the accuracy of the estimates. A meta-analysis usually estimates a weighted average of effect size over distinct studies, with weights determined by the information provided by a study, rather than over distinct estimations within the same study. As the estimates concern the same target population and the same public support schemes, a common true effect size is assumed for all estimators. The meta-analysis considers common (fixed) effect and not fixed or random effects. Borenstein, Hedges and Rothstein (2007) provide a good overview of meta-analysis. The forest plots in Annex 4 provide an overview of the meta-analysis for each public support scheme. For the meta-analysis, the baseline estimates and 15 alternative estimates that have been reported in section 4.1.2 are considered. The forest plots show the estimate of the BFTB, with a 95% confidence interval, based on each of the 16 coefficient estimates and the estimated standard deviation and the resulting overall BFTB estimate. A forest plot shows the weights attributed to each estimate, based on the variance. Graph 34 shows the meta-BFTB (overall effect size in the forest plots in Annex 4) and the unweighted BFTB for the public support schemes for which the BFTB is found to be positive. The positive BFTB for the innovation bonus, based on a relatively small number of observations, is not shown in Graph 34 because of its extreme value (meta-BFTB = 10.77 and unweighted BFTB = 9.59). Graph 35 shows the meta- and the unweighted BFTB for the public support schemes for which the BFTB is found to be negative.

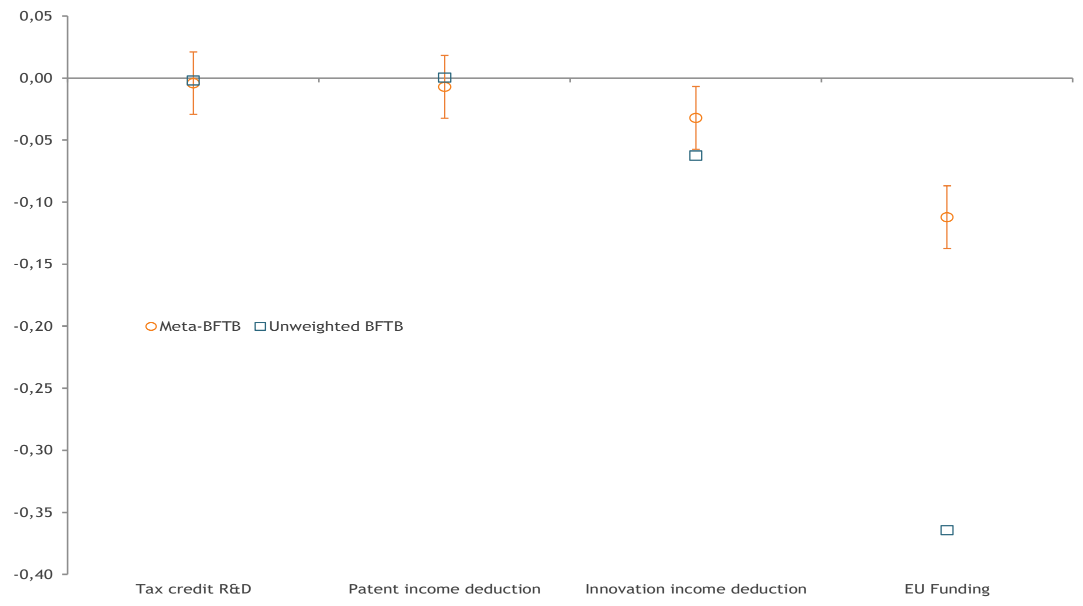
The meta-BFTB is smaller than the unweighted BFTB for all support schemes with a positive BFTB, except for the partial exemption for researchers with a bachelor's degree, suggesting that positively biased estimates also tend to have higher variance. The difference between the meta-BFTB and the unweighted BFTB is not substantial, except for the tax deduction for R&D investment. For all support schemes in Graph 34, the 95% confidence interval lies entirely above zero, supporting the conclusion of net additionality.

Graph 34 Meta-BFTB and unweighted average BFTB – positive values fourth evaluation



Note: In the graph the orange circles show the weighted Bang for the Buck (meta-BFTB), based on 16 alternative estimates of the coefficients of the different public support instruments as reported before, resulting from a meta-analysis that accounts for the variance of the estimates and an unweighted average BFTB (blue squares). This graph considers support schemes for which the BFTB is positive. Given the extreme high value (meta-BFTB= 10.77, unweighted average BFTB 9.59), the BFTB for the innovation bonus is not shown. The error bar denotes the confidence interval (95% significance level).

Graph 35 Meta-BFTB and unweighted average BFTB – zero or negative values fourth evaluation



Note: In the graph the orange circles show the weighted Bang for the Buck (meta-BFTB), based on 16 alternative estimates of the coefficients of the different public support instruments as reported before, resulting from a meta-analysis that accounts for the variance of the estimates and an unweighted average BFTB (blue squares). This graph considers the support schemes for which the BFTB is negative or based on non-significant coefficients. The error bar denotes the confidence interval (95% significance level).

For the support schemes with a negative BFTB, the meta-BFTB is more negative than the unweighted BFTB for the tax credit for R&D investment and for the patent income deduction but less negative for the innovation income deduction and EU funding. For the latter two schemes, negatively biased estimates appear to have higher variance and the difference between the meta-BFTB and the unweighted BFTB is more substantial than for the tax credit for R&D investment and for the patent income deduction. The fact that companies combine several support schemes may result in high collinearity between some support variables. Bilateral correlations between all individual support schemes indicate that there is a relatively high correlation between the amount of partial exemption for R&D personnel with a PhD or civil engineering degree and respectively, the amount of the R&D tax credit (0.68) and the amount of the patent income deduction (0.63). The correlation between the amount of partial exemption for R&D personnel with a bachelor's degree and the amount of the patent income deduction is also rather high (0.58). Collinearity can result in higher standard errors of coefficient estimates and thus lower statistical significance. The low statistical significance of the coefficients of the R&D tax credit and the patent income deduction could therefore, to some extent, be explained by the strong correlations of these tax incentives with some of the partial exemption schemes. However, strong collinearity generally affects standard errors but not the coefficient estimates, which for both CIT incentives are close to zero. Moreover, collinearity is also more problematic when the number of observations is small which is not the case in most estimations.[38] This seems to suggest that multicollinearity probably does not explain the low statistical significance of the estimates for the R&D tax credit and the patent income deduction. The 95% level confidence interval of the meta-BFTB of the innovation income deduction and EU funding lies entirely below zero, supporting the conclusion of crowding out. The latter conclusions can certainly not be explained by multicollinearity as this tends to reduce statistical significance and moreover these support variables are not highly correlated with the other support variables.

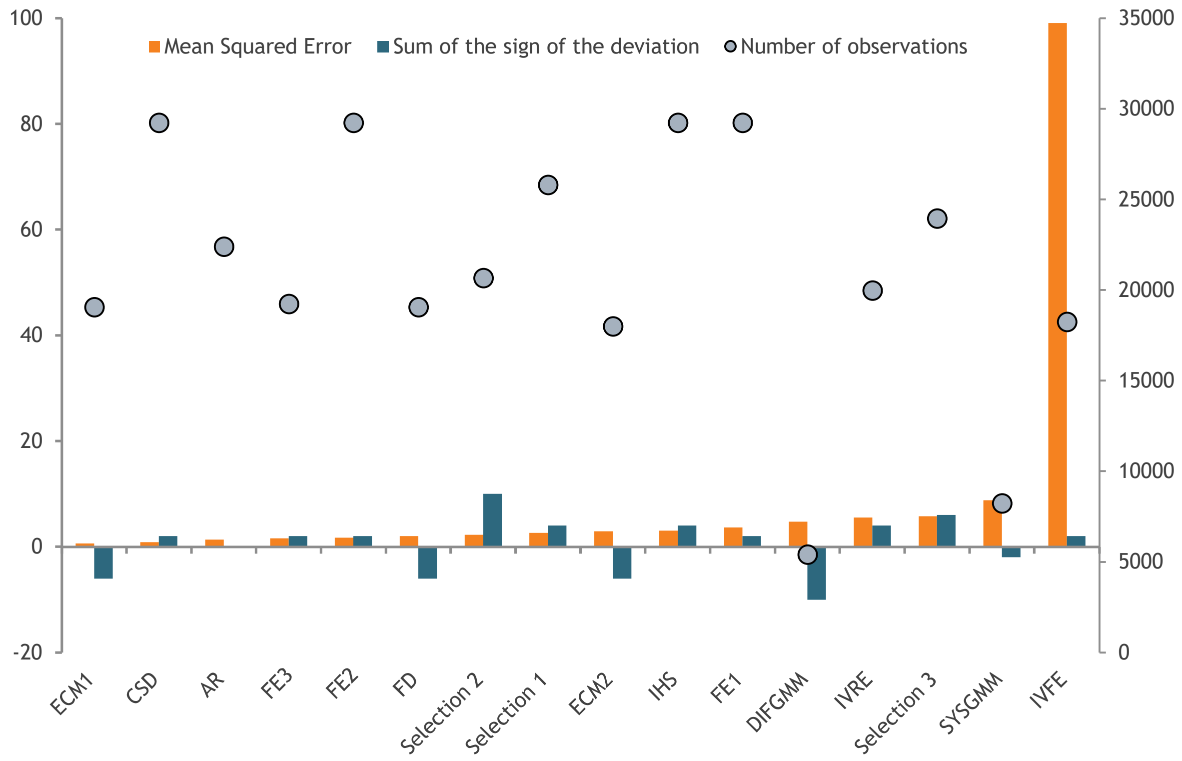
A meta-analysis also permits to assess which of the 16 alternative estimation procedures tend to deviate most from the overall meta-result. The funnel plots in Annex 5 show the overall result (red vertical line) and three confidence intervals (1%, 5% and 10% significance level) for each public support scheme. The blue bulbs show the estimates from the alternative estimation procedures. The plot shows the effect size (in this case the estimated BFTB) on the x-axis and the standard error of the estimate on the y-axis. Funnel plots are mostly used in meta-analysis to investigate whether there are indications of a potential publication bias, suggested by asymmetrical funnel plots. However, as Sterne and Harbord (2004) point out that asymmetry in funnel plots can be caused by several other factors than publication bias, funnel plots should be considered more as a tool to examine the tendency of small studies to provide larger treatment effects than as a tool to diagnose specific types of bias. As used in this evaluation, considering alternative within-study estimates, a funnel plot provides indications of which estimation procedures deviate most from the meta-BFTB estimate.

Graph 36 provides an overview of the bias of the alternative estimation procedures with respect to the overall meta-BFTB estimate. More details on the different estimation procedures used for the meta-analysis are provided in Annex 4. The 16 alternative estimation procedures are ranked in increasing

[38] High collinearity could also result in small changes in the data leading to large variation in estimates and coefficients having the "wrong" sign or implausible values. Testing for multicollinearity and possible solutions when collinearity is perceived as problematic imply some degree of arbitrariness (Greene 2000, pp. 256-259). The solution that consists in dropping a highly collinear variable is not appropriate for one of the support variables as this would likely introduce an omitted variable bias.

order of the mean squared error, computed as the average of the squared difference between the BFTB estimate and the meta-BFTB. The mean squared error is displayed by the orange bars. The blue bars show the sum of the sign of the deviation, with a positive sign equalling +1 and a negative sign equalling -1. This sum provides an indication of whether a given estimation procedure tends to over- or underestimate the BFTB, without considering the extent of the deviation. The second selection model (third column in Table 22), which accounts for (self-)selection in public support, tends to overestimate the BFTB in the greatest number of estimates whereas the First Difference GMM estimation tends to underestimate the BFTB in the greatest number of estimates. The single-equation Error-Correction Model, the panel estimation accounting for serial correlation and cross-sectional dependence and the baseline estimation with industry-year dummies perform best in terms of the mean squared errors. The single-equation Error-Correction Model, which has the smallest mean squared error has a slight tendency to underestimate the BFTB.

Graph 36 Mean squared error and sign of the bias of different estimates relative to estimate meta-BFTB



Note: The graph shows the mean squared error of the difference between the BFTB estimate of each estimation procedure and the meta-BFTB estimate (orange bars). The blue bars show the sum of the times that each estimation overestimates (+1) or underestimates (-1) the meta-BFTB. The grey bulbs show the number of observations (displayed on the right y-axis). A description of the abbreviated estimation procedures is provided at the beginning of Annex 4.

Estimation procedures with many observations do not necessarily perform better than procedures with fewer observations although the two GMM procedures, which have the fewest number of observations, are among the procedures with the highest mean squared error. Estimation procedures using instrumental variables have high mean squared errors which probably reflects the low quality of the instruments. The fact that the mean squared error of the fixed effects IV estimation is dramatically larger than the mean squared error of the random effects IV estimation seems to underscore the argument of Griliches and Hausman (1986) and Lichtenberg (1988) that a fixed effects estimation may magnify measurement errors of independent variables (for example, weak instrumental variables), if the errors are not time-invariant.

Graph 36 indicates that the baseline estimation with industry-year dummies performs reasonably well, both in terms of the mean squared error and the sum of the sign of deviation from the meta-BFTB estimate.

The BFTB of some partial exemption schemes is rather high compared with estimates for other countries. In the OECD cross-country project MicroBeRD, Belgium has the highest BFTB (implied incrementality ratio of 3.5) for tax incentives, out of a group of seven participating countries (Appelt et al. 2020, page 62). In MicroBeRD the implied incrementality ratio provides an estimate of the joint impact of all partial exemption schemes and the tax credit for R&D investment combined.

4.2. Behavioural additionality

Section 4.1 assesses the input additionality of public support to business R&D in Belgium, in effect, the extent to which support stimulates firms to invest more in R&D than they would in the absence of public support. This section considers the potential impact of public support on the behaviour of firms, in terms of firms that decide to start R&D activities (section 4.2.1), the distribution of R&D expenditures between basic research, applied research and experimental development (section 4.2.2) and the skill composition of R&D personnel (section 4.2.3).

4.2.1. Starting R&D activities

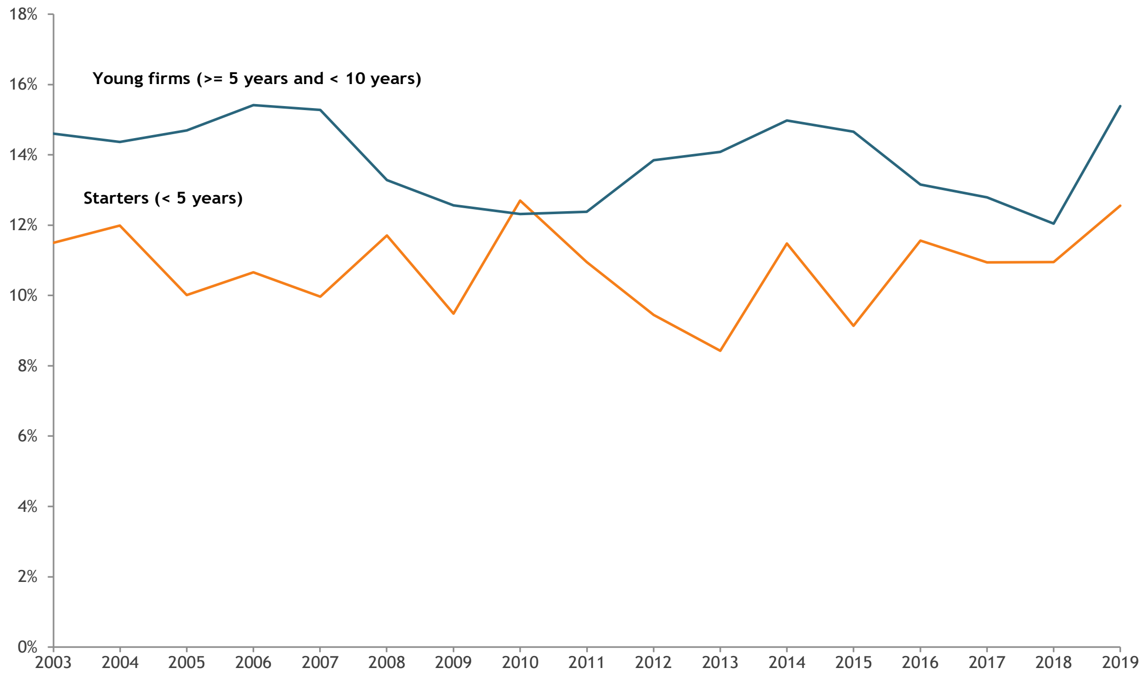
The estimation of input additionality reported in section 4.1 considers the extent to which public support stimulates firms to invest more in R&D activities, the intensive margin. Although firms that start doing R&D may also be included in the panel, the distinction between firms starting R&D activities and R&D active firms raising, or lowering, their R&D expenditures is not made explicitly. Public support may aim at increasing the number of R&D active firms, the extensive margin. Coad, Mathew and Pugliese (2020) argue that, as firms without the necessary management capabilities may find it hard to benefit from R&D, not all firms should invest in R&D and that from a policy perspective it may not be worthwhile to encourage firms without sufficient management capabilities to invest in R&D.[39]

This section reports the results of an assessment of the potential impact of public support on the decision of firms without any past R&D experience, to start doing R&D. The available data pose a severe problem to identify firms that start with R&D activities. A real R&D starter is a firm with R&D activities in the initial year and no R&D expenditures in the past. With the data at hand, this implies that a firm reports non-zero R&D expenditures in a year and explicitly reports zero expenditures in the previous year(s). With the biennial R&D survey this could be the case of a firm that starts with R&D in the final year of the survey and reports zero R&D expenditures in the previous year (first year of the survey). If it starts R&D and reports non-zero R&D expenditures in the first year of the survey, it will also need to have reported non-zero R&D expenditures in the previous R&D survey to be sure that the firm did not have

[39] Coad, Mathew and Pugliese (2020) use data on Indian firms but argue that the conclusion may hold for developing as well as developed countries.

R&D activities in the past. If it is a real R&D starter this is not very likely as it would not have been in the list of R&D performers and not very probable be in the sample of from the total firm population to which the survey is send. Using a strict definition of R&D starters is not feasible as this results in insufficient starters to identify the potential impact of public support on the decision to start R&D. For the estimation, the starting year of R&D activities is therefore determined by the first year for which non-zero R&D expenditures are reported. Given that the R&D survey is biennial, there is a zig-zag pattern in the R&D starters with a higher number of firms defined as starters in the odd years than in the even years. Graph 37 shows the evolution of the share of R&D active firms that have been active for less than five years and the share that have been active for five years or more but less than 10 years. The share of starters was reasonably stable around 11% over the period 2003-2019 whereas the share of young firms decreased slightly, except in the last year.

Graph 37 Share of R&D firms that are starters (less than 5 years old) or young (5 years or more but less than 10)



Note: The graph shows the share of firms that have reported R&D expenditures (only real responses considered) that are starters (less than 5 years old) or young (5 years or more but less than 10 years old. The age of firms is based on the date of creation.

For the estimation of the potential impact of public support to start R&D, the relevant population are firms without any R&D activities. Table 30 shows the results of a logit estimation of the impact of public support on the probability that a non-R&D active firm will start R&D activities. The dependent variable is binary, equalling 0 for a non-R&D active firm that remains non-R&D active and equalling 1 for a firm that was previously non-R&D active but that starts R&D (first year with reported R&D expenditures). The table shows the results of an estimation that considers all available years and the results of an estimation that only considers the odd years (final year of biennial R&D survey), which allows to capture more real R&D starters and avoids the zig-zag pattern in the number of identified starters. As contrary to the estimation of input additionality, non-R&D firms are considered, the number of observations is much larger. In both estimations, all coefficients of the public support variables are positive and statistically significant (at least at the 10% level). In both estimations the highest coefficient is found for regional subsidies. Other support schemes with large coefficients are the partial exemption for Young Innovative Companies and the innovation income deduction. The results seem to suggest that all public support schemes significantly increase the probability that a firm will start R&D activities. However, a more trivial explanation is that, by definition, a firm needs to have R&D activities to be eligible to receive public support for R&D. Firms that start R&D activities may benefit from public support in the initial year of their R&D activities, even if the support is not the main reason to start R&D. Firms that do not start R&D cannot benefit from public support. Even if only a modest share of R&D starters receives public support in the initial year, in the estimation this will result in positive coefficients of the public support variables. The estimation does not allow for a causal interpretation as this relates to the factors that play a role in the decision of firms to start R&D, which cannot be established with the data at hand.

Table 30 Results of a logit estimation of starting R&D

Dependent variable: (Start R&D: No= 0/Yes= 1)	All years	Odd years
Explanatory variables:		
Direct support:		
Regional subsidy	4.05 (58.30) ***	4.29 (37.61) ***
Partial exemption schemes:		
Research cooperation	2.69 (13.58) ***	2.66 (6.71) ***
Young Innovative Company	4.04 (24.19) ***	3.90 (13.86) ***
PhDs and civil engineers	1.07 (9.39) ***	0.34 (1.62) ***
Master	2.82 (34.17) ***	2.90 (19.31) ***
Bachelor	0.60 (3.04) ***	0.87 (3.42) ***
Corporate income taxation incentives:		
Tax credit R&D	1.35 (5.31) ***	0.99 (2.44) ***
Tax deduction R&D°	3.41 (9.14) ***	3.05 (3.51) ***
Patent income deduction	2.08 (8.08) ***	2.26 (5.26) ***
Innovation income deduction	3.55 (6.84) ***	4.00 (6.38) ***
Other funding:		
Innovation bonus	2.26 (12.03) ***	0.94 (1.87) *
EU funding	2.12 (5.28) ***	1.48 (2.44) **
Control variables:		
Turnover	0.03 (2.31) **	0.03 (1.13)
Number of employees	0.42 (20.19) ***	0.34 (8.61) ***
Age	-0.26 (-14.92) ***	-0.41 (-12.99) ***
Capital intensity	0.00 (0.40)	-0.01 (-0.30)
Pseudo R-squared	0.38	0.37
Number of observations	887,899	454,551

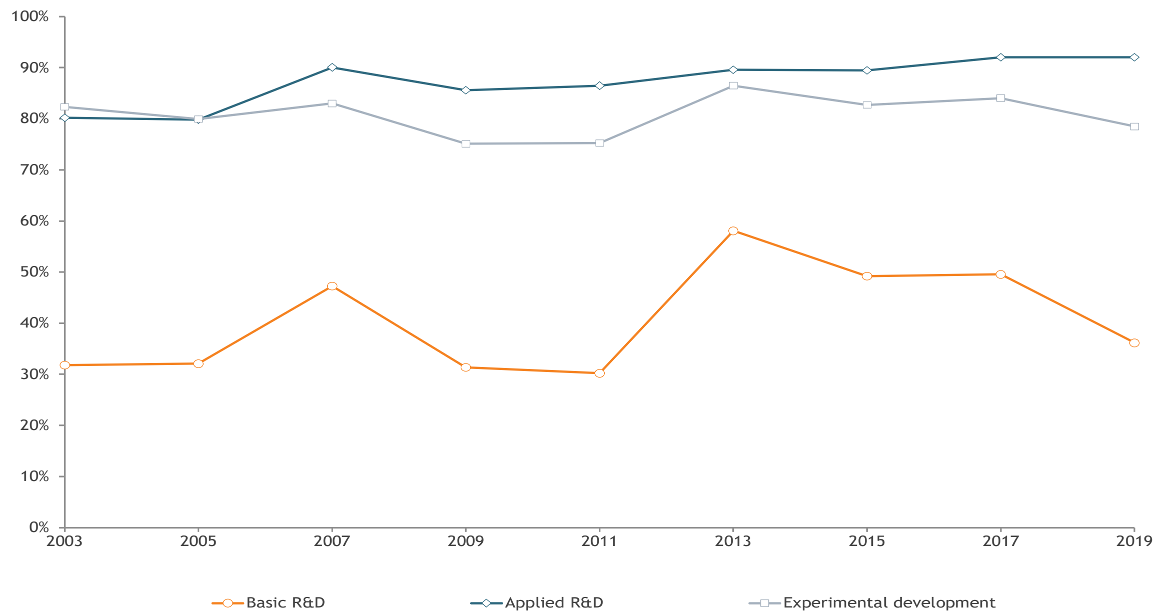
Note: The table shows the results of a logit estimation with a binary dependent variable that equals 1 if a firm started doing R&D and 0 if not. The variables reflecting public support are also binary and equal 1 if the firm received support and 0 if not. The estimation includes industry dummies. *, ** and *** denotes that the coefficient estimate differs from zero through that specific support scheme at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity. °Data on the tax deduction for R&D investment is only available until 2012.

Public support is often justified to attract R&D activities of foreign companies that were previously not active in any way (R&D, production, distribution, or logistics). Using data on R&D activities of MNEs in Europe over the period 2000-2012, Knoll et al. (2021) find evidence that tax incentives indeed tend to raise R&D investment in MNE affiliates in the country with (more generous) tax incentives but that this is mainly due to lower R&D investment in affiliates in other countries so that tax incentives do not increase R&D investment globally. A more encompassing issue in an international context is the link between R&D activities and other activities within global value chains and whether by increasing public support for R&D a country may specialize in R&D activities without necessarily increasing other value-generating activities. Biatour, Dumont and Kegels (2020) investigate the link between R&D and other economic activities for the four most R&D intensive industries in Belgium. For Manufacture of pharmaceutical products and preparations there are indications of specialization in R&D and partial decoupling between R&D and production and indications of co-location of R&D and production for the three other industries. The data used for this evaluation do not permit to assess the potential impact of public support on the decision of foreign companies without any activities in Belgium to start R&D activities and potentially also start other activities such as production.

4.2.2. R&D orientation

Public support for R&D activities may affect the distribution of R&D expenditures over the three categories: basic research, applied research and experimental development. Graph 38 shows the evolution over the period 2003-2019 of the share of firms that reported non-zero R&D expenditures, by main category. As the R&D survey is biennial the breakdown by category applies only to the odd years. The introduction of the tax incentives for R&D, mostly between 2005 and 2007, coincides with an increase in the share of R&D active firms that report non-zero expenditures for basic and applied research and only a slight increase in the share of firms that report non-zero expenditures in experimental development. Between 2007 and 2009 the share decreased for all three categories, especially for investment in basic research.

Graph 38 Share of firms doing basic R&D, applied R&D and experimental development (2003-2019)

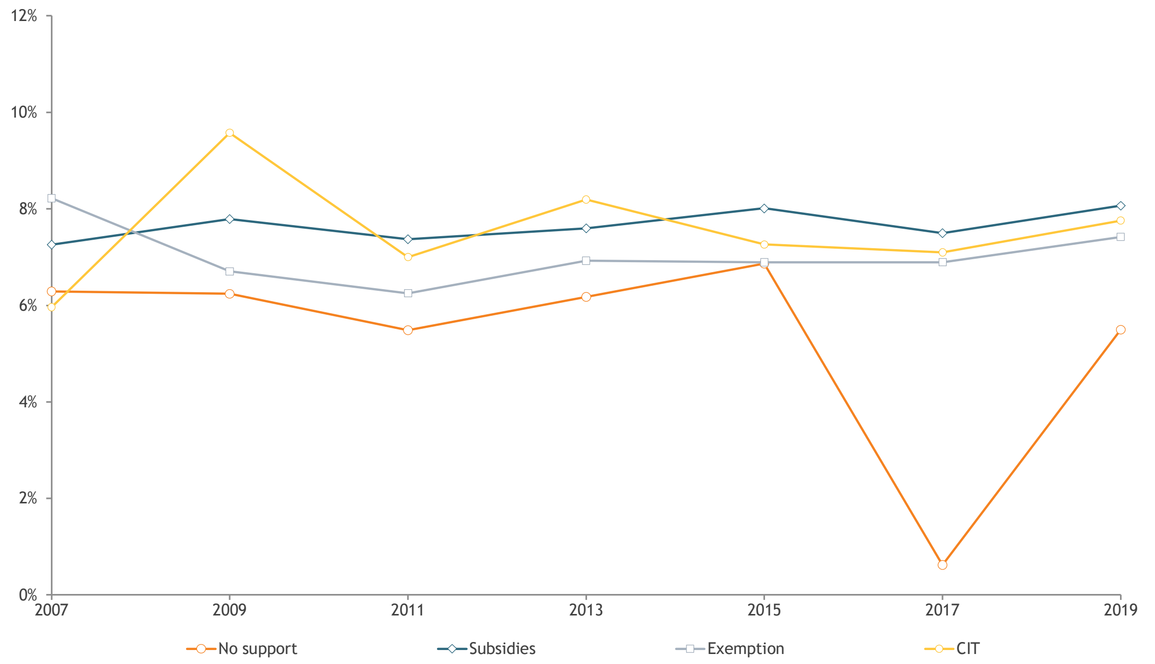


Note: The graph shows the share of firms that responded to the questions with regard to the type of R&D activities, that reported doing basic R&D, applied R&D and experimental development. As the R&D Survey is biennial, only the odd years are considered.

After 2009, the share of firms that invested in applied research increased gradually but continuously until the end of the period. The share of firms that invested in basic research and experimental development increased substantially in 2013 but decreased afterwards, especially for investment in basic research. In 2019, 92% of firms that answered the question on the breakdown of R&D by category invested in applied research, 79% in experimental development and only 36% invested in basic research.

Graph 39 shows the evolution of the share of R&D active firms (reported non-zero R&D expenditures) that invested in basic research, with firms grouped by the type of public support that they received (no support, regional subsidies, partial exemption, and corporate income taxation incentives). Graph 40 shows the evolution of the share of R&D active firms that invested in applied research and Graph 41 the share of R&D active firms that invested in experimental development, both, as in Graph 38, by the type of public support received by the firms. Given data availability, the period considered for Graph 39-Graph 41 is 2007-2019.

Graph 39 Average share of R&D expenditures for basic research by public support type (2007-2019)



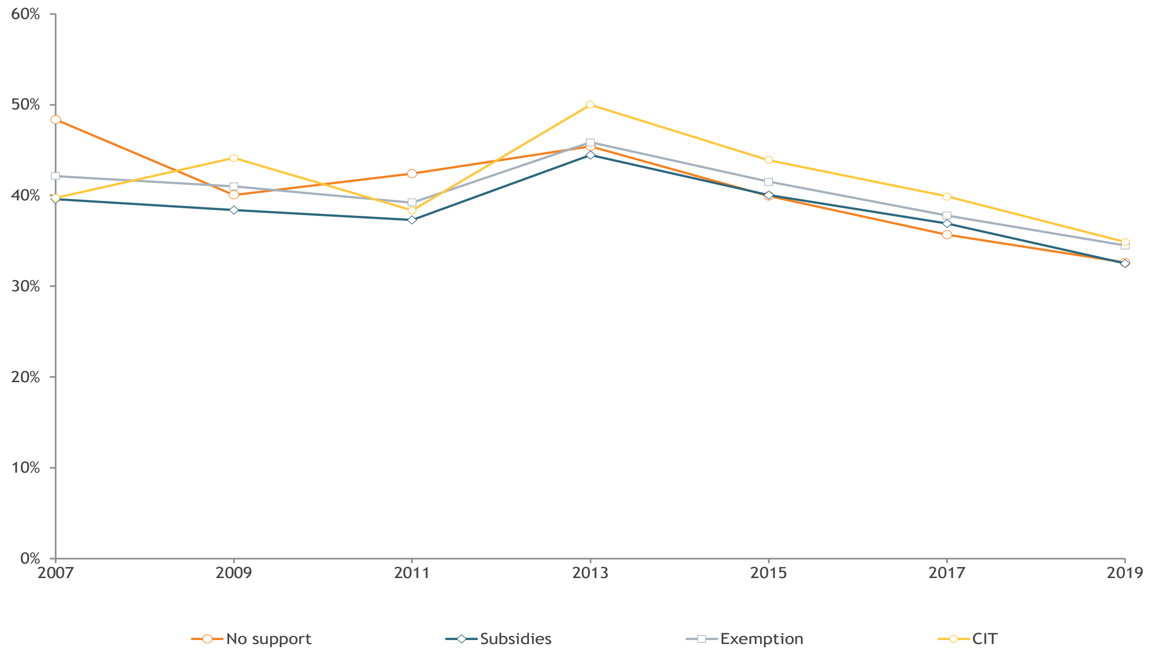
Note: The graph shows the share of R&D expenditures spent on basic research for firms that received no public support and firms that received support through one of the three main support mechanisms (regional subsidies, partial exemption, corporate income taxation (CIT) incentives). As the R&D Survey is biennial, only the odd years are considered.

Over the period 2007-2019, of the four categories of public support, R&D active firms that did not receive any public support for R&D were least likely to invest in basic research whereas in four out of the seven years considered, firms that received direct support (regional subsidies) were most likely to invest in basic research although the difference with the two other support categories is not substantial. In 2017 and 2019 the difference, in terms of investing in basic research, between firms with public support and those that did not receive any support, increased whereas the shares of the three support categories converged. The shares of firms investing in applied research (Graph 40) and in experimental development (Graph 41) are very equivalent for the four categories of public support.

Graph 40 Average share of R&D expenditures for applied research by public support type (2007-2019)

Note: The graph shows the share of R&D expenditures spent on applied research for firms that received no public support and firms that received support through one of the three main support mechanisms (regional subsidies, partial exemption, corporate income taxation (CIT) incentives). As the R&D Survey is biennial, only the odd years are considered.

Graph 41 Average share of R&D expenditures for experimental development by public support type (2007-2019)



Note: The graph shows the share of R&D expenditures spent on experimental development for firms that received no public support and firms that received support through one of the three main support mechanisms (regional subsidies, partial exemption, corporate income taxation (CIT) incentives). As the R&D Survey is biennial, only the odd years are considered.

From 2013 onwards, firms that received corporate income taxation incentives for R&D appear to be somewhat less likely than other firms to invest in applied research and more likely to invest in experimental development. Given the focus of direct support, relative to tax support, on research activities, firms that receive direct support tend to invest somewhat more in basic and applied research than firms receiving tax support (partial exemption or corporate income taxation incentives) and somewhat less in experimental development.

Arora, Belenzon and Patacconi (2018) provide evidence for the US that large firms tend to shift their R&D activities away from basic research to product development and commercialization. In Belgium, the decrease in investment in basic research of large companies appears to be only relative to medium-sized and small companies, as the share of large R&D active companies that invest in basic research was higher at the end of the period than at the beginning. It was just that the share of small and medium-sized R&D active companies that invested in basic research increased more substantially.

The three graphs in Annex 6 compare the evolution of the distribution of R&D expenditures over the three categories (basic research, applied research and experimental development) between SMEs (less than 250 FTE employees) and large companies. Except for the year 2013, over the period 2003-2019, SMEs spent relatively more on basic and applied research and relatively less on experimental development. The share of R&D expenditures spent on basic research appears to be relatively stable, both for SMES and large companies. For both size categories the main shift in R&D expenditures is away from experimental development to applied research.

The three graphs in Annex 7 compare the evolution of the distribution of R&D expenditures over the three categories between young firms (less than 10 years after creation) and old companies (10 years or more after creation). The evolution in the shares and distinction between young and old firms is similar to the shares and the distinction between SMES and large firm although the share of R&D expenditures allocated to basic research by young firms decreased substantially. Using data of Spanish manufacturing firms over the period 2004–2015, Coad, Segarra-Blasco and Teruel (2021) find substantial heterogeneity in R&D strategies and do not find much support for the general assumption that young firms invest relatively more in basic research and old firms invest relatively more in applied research. For Belgium, the graphs in Annex 7 show that young firms invested relatively more in basic research, and relatively less in experimental development than old firms. However, towards the end of the period the difference between both age groups disappeared because of a sharp decrease in investment in basic research of young firms and a sharp decrease in investment in experimental development of old companies. For both age groups, the shares of R&D expenditures oriented towards applied research increased substantially and converged to each other.

Table 31 shows the results of three estimations with alternatively the share of R&D oriented towards one of the three R&D categories as dependent variable. Given the biennial responses in the R&D survey the panel is transformed by dropping even years and considering the odd years in succession. Whereas previous evaluations provided indications that some partial exemption resulted in a shift away from research activities to experimental development, there is now only one statistically significant coefficient for the public support variables, indicating that regional subsidies result in a shift away from experimental development. The fact that there are fewer statistically significant effects of public support on the shares of R&D expenditures oriented to one of the three R&D categories, suggests that the impact of public support on R&D behaviour weakens over time.

Table 31 Results of panel fixed effects estimation – impact on the type of R&D activities

	Basic research	Applied research	Experimental development
Dependent variable: Share in total R&D expenditures			
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.01 (1.28)	0.01 (1.26)	-0.02 (-3.11) ***
Partial exemption schemes:			
Research cooperation	0.00 (0.11)	0.00 (0.08)	-0.01 (-0.72)
Young Innovative Company	-0.02 (-0.39)	-0.01 (-0.56)	-0.03 (-1.22)
PhDs and civil engineers	-0.00 (-0.18)	0.00 (0.32)	0.00 (0.43)
Master	-0.00 (-0.15)	-0.01 (-1.35)	0.00 (0.05)
Bachelor	-0.01 (-0.54)	-0.01 (-0.99)	-0.00 (-0.34)
Corporate income taxation incentives:			
Tax credit R&D	-0.02 (-0.78)	0.01 (0.72)	0.00 (0.08)
Tax deduction R&D°	0.01 (0.40)	0.02 (1.32)	-0.02 (-0.61)
Patent income deduction	-0.01 (-0.40)	0.02 (1.16)	-0.02 (-1.56)
Innovation income deduction	-0.00 (-1.28)	0.02 (1.48)	-0.03 (-1.61)
Other funding:			
Innovation bonus	0.00 (0.07)	-0.02 (-1.15)	-0.01 (-0.47)
EU funding	-0.01 (-0.27)	-0.00 (-0.37)	0.00 (0.28)
Control variables:			
Turnover	0.13 (0.80)	-0.09 (-1.79) *	0.13 (1.54)
Employees	-0.17 (-0.87)	-0.03 (-0.31)	-0.10 (-0.90)
Age	-0.23 (-1.15)	0.04 (0.36)	-0.01 (-0.11)
Capital intensity	0.13 (1.89) *	0.04 (1.14)	-0.04 (-1.41)
R-squared (within)	0.18	0.07	0.07
Number of observations	5,220	9,221	8,881

Note: The table shows the results of a fixed effects estimation with the share of each type of R&D activities in R&D expenditures as dependent variable (logit-transformed). The panel is transformed, using only odd years without imputation for even years. Industry and 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. °Data on the tax deduction for R&D investment is only available until 2012.

4.2.3. Skill composition R&D personnel

Public support may affect the skill composition of R&D personnel. Some support schemes explicitly benefit specific educational groups, such as the partial exemption for R&D employees with a PhD or civil engineering degree, for R&D employees with a master's degree and R&D employees with a bachelor's degree. Table 32 shows the results of a panel estimation in which, respectively, the share of R&D personnel with a PhD and the share of R&D personnel with a university degree is considered as the dependent variable. This information is provided by the R&D survey. As the information relates to the odd years of the biennial R&D survey, only these years are considered. The panel is transformed by dropping even years and considering odd years in succession. The breakdown of R&D personnel by educational degree do not perfectly match the educational categories of the three partial exemption schemes based on the educational degree of R&D personnel. Few of the coefficients of the public support variables are statistically significant. The partial exemption for R&D employees with a bachelor's degree and the innovation bonus appear to have resulted in an increase of the share of R&D personnel with a university degree (master or bachelor) and the tax deduction for R&D investment had a negative impact on the share of R&D personnel with a PhD.

Table 32 Results of a panel fixed effects estimation - impact on the skill composition of R&D personnel

Dependent variable: (Share in the total number of researchers)	PhD	University degree (Master and Bachelor)
Explanatory variables:		
Direct support:		
Regional subsidy	-0.01 (-0.80)	0.00 (0.65)
Partial exemption schemes:		
Research cooperation	-0.01 (-0.75)	0.00 (0.15)
Young Innovative Company	0.01 (0.39)	0.01 (0.75)
PhDs and civil engineers	0.01 (0.97)	0.00 (0.53)
Master	0.00 (0.56)	-0.01 (-0.83)
Bachelor	0.01 (0.94)	0.04 (3.60) ***
Corporate income taxation incentives:		
Tax credit R&D	-0.00 (-0.07)	-0.01 (-1.09)
Tax deduction R&D°	-0.02 (-2.02) **	-0.00 (-0.34)
Patent income deduction	0.01 (1.00)	0.00 (0.22)
Innovation income deduction	-0.01 (-0.70)	0.02 (1.60)
Other funding:		
Innovation bonus	-0.01 (-1.17)	0.02 (1.70) *
EU funding	-0.00 (-0.42)	0.01 (0.82)
Control variables:		
Turnover	0.01 (0.12)	0.02 (0.57)
Number of employees	-0.15 (-1.55)	0.04 (0.50)
Age	-0.20 (-1.66) *	0.03 (0.27)
Capital intensity	0.01 (0.20)	0.01 (0.38)
Pseudo R-squared	0.24	0.43
Number of observations	3,133	5,461

Note: The table shows the results of a fixed effects estimation with the share of researchers with a PHD or a master's/bachelor's degree in the total number of researchers (FTE) as dependent variable. The panel is transformed, using only odd years without imputation for even years. The estimation includes industry-year dummies. *, ** and *** denotes that the coefficient estimate differs from zero through that specific support scheme at a statistical significance level of respectively 10%, 5% and 1%. The t-values, shown in brackets, are robust to heteroskedasticity. °Data on the tax deduction for R&D investment is only available until 2012.

In the first two evaluations, similar estimations provided several statistically significant coefficients of the partial exemption schemes, with the intuitively right sign, in effect, the schemes increased the shares in R&D personnel of the educational groups that they benefit. In the previous (third) evaluation, fewer of these coefficients were statistically significant. The fact that in this (fourth) evaluation the coefficient of partial exemption, in the estimation with the share of R&D personnel with a university degree as dependent variable, for R&D personnel with a bachelor's degree, which was introduced as recently as 2018, is the only statistically significant coefficient of the five partial exemption schemes, seems to confirm that the impact of public support and more specifically of the partial exemption schemes based on the educational degree of R&D personnel decreases over time, in line with the results for the impact of public support on the type of R&D activities (section 4.2.2).

Goolsbee (1998) argued that if the supply of high-skilled workers is inelastic, part of an increase in R&D expenditures due to public support may be explained by a rise in remuneration of researchers. He provides indications for the U.S. that estimates of the efficiency of public support to R&D may be overestimated by 30 to 50%, by ignoring the impact on the wages of researchers. Lokshin and Mohnen (2013) provide more recent evidence of an impact of public support on the wages of researchers in the Netherlands. Dumont, 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 A3.3 in Annex 3 shows the results of an estimation of the impact of public support on the average wage of employees. The table reports results of estimations, alternatively without and with the share of researchers with a PhD and the share of researchers with a university degree included. Only one coefficient in the three alternative estimations is statistically significant positive, and even only at 10%. The coefficient, of the partial exemption for R&D employees with a master's degree, is moreover very small. The coefficient of the tax deduction for R&D investment is statistically significant negative in all three estimations and the coefficient of the partial exemption for R&D employees with a bachelor's degree and the coefficient of EU funding is statistically significant negative in one of the three alternative estimations. The results provide few indications of a positive impact of public support on the average wage of employees.

4.3. Output additionality

In providing public support to business R&D, the aim of governments is not to raise R&D investment as such but rather to stimulate R&D investment that would not occur without support, and which contributes to innovation and economic growth. Instead of looking at the impact of public support on R&D expenditures (input additionality), this section assesses the impact on indicators of the potential results of R&D activities (output additionality). A complication in the assessment of the impact of public support on output is that there are many alternative output indicators but often no clear indications as to which indicators law makers had in mind when introducing public support. Both the direct impact of own R&D activities and the impact of R&D of companies on the rest of the economy need to be considered. Although potential credit constraints that can hamper investment in R&D by companies may warrant to look at the direct impact of R&D financed with public support, the main argument to provide public support to business R&D relies on the assumed existence of a positive indirect impact of R&D activities on the rest of the economy (spillovers).

As with the estimation of input additionality, the estimation of output additionality is subject to selection issues. If the best performing firms are more likely to receive public support, given well-known persistence in firm performance, estimates of the impact of support on firm performance may be substantially biased if this selection issue is not accounted for. The selection issue seems to apply especially to tax incentives provided through corporate income taxation, as only profitable firms can benefit from them[40] and even more so to the patent income deduction and the innovation income deduction. The

[40] Firms without profits can use the tax credit for R&D investment, which is paid out after four consecutive years of insufficient taxable profits.

latter tax deductions can - by definition- only be used by companies that have a current income resulting from past R&D activities, and the larger this income is, the larger the benefit from the tax deduction. An estimated positive "impact" of R&D financed with the patent income deduction, or the innovation income deduction, may therefore simply reflect that good performance is a necessary condition to use these tax deductions.

There are several ways to quantify firm performance, and it is not straightforward to determine which indicator is most relevant to assess the results of R&D activities. R&D investment may result in the introduction of new products or services, in more efficient production or in the optimization of organizational processes. The biennial Community Innovation Survey, introduced in 1992, provides direct information on innovation in EU Member States. In the survey, companies are asked whether they introduced new or improved goods or services and whether these were new to the company or new to the market. In addition to a binary response the companies are also asked to estimate the percentage of their turnover that results from new or improved goods. The survey also contains questions regarding process innovation. The main disadvantage of the CIS survey is that most questions are binary (yes/no) and that the survey is based on a sample of the total population and therefore only provides partial information for the panel of R&D active firms. The CIS data are anyway not available in the current version of the R&D Policy Mix database.

From a review of the literature between 1980 and 2015, Dziallas and Blind (2019) discern 82 unique indicators of innovation. In terms of financial performance, they list return on investment in innovation, R&D costs/revenue, profit margin measures, new-to-market and new-to business sales, and percentage of innovations that met financial benefit projections. The authors argue that although innovation is very important for the success of a company, the part of the success that can be attributed to innovation is difficult to determine.

According to Stevens and Burley (1997), only about 1% of small R&D projects can be considered successful whereas for projects closer to the actual development of products, they consider the odds of success to be between 1 in 7 up to 1 in 10. Estimates of the average return to R&D may fail to reflect the disproportionate contribution of a small number of very successful projects. A meta-regression based on 65 studies, by Ugur et al. (2016), indicates that estimates of the private and social return to R&D differ substantially across studies and is smaller than what is reported in previous reviews. Møen and Thorsen (2017) argue that although most economists have a prior belief that returns to R&D are positive and possibly large, the estimation of the return to R&D is subject to substantial issues related to measurement, selection, choice of functional form, and appropriate lag length. The results of their meta-analysis suggest that there is a positive publication bias in the literature on returns to R&D. Bloom et al. (2020) provide firm-level and industry-level evidence that the productivity of R&D effort appears to be decreasing over time, but they point out that measurement issues for inputs and output warrant caution in interpreting the results.

Hervás-Oliver et al. (2021) argue that EU innovation policies, evidenced by the 3% R&D target in Europe 2020, tend to be research-driven although it is well known that most SMEs depend on non-R&D activities for their innovation, for example by investing in managerial innovation and by relying on external collaboration with and knowledge from suppliers, customers, or competitors.

The impact of R&D on firm performance is mostly estimated by considering an intermediate output indicator such as patents or final output indicators such as growth in sales or value added, changes in profitability or productivity or changes in other financial indicators (liquidity, solvency).

Coad, Mathew and Pugliese (2020) point out that empirical studies provide conflicting conclusions as to the impact of R&D on firm performance and argue that the mixed evidence could be explained by the failure to account for the fact that the innovation capabilities of firms may at the same time influence the decision to invest in R&D and the expected benefits of R&D activities. As mentioned before, they conclude that firms without sufficient capabilities should not be stimulated to invest in R&D as they would probably not benefit from their R&D activities.

Whereas positive R&D spillovers are often assumed as a justification for public support to business R&D, product market rivalry could result in overinvestment in R&D if innovators succeed in capturing market share from other firms without generating much social benefit (business-stealing effect), as argued by Van Reenen (2022). Guerrero, Heijs and Huergo (2022) find evidence of business stealing in Spain, especially for knowledge intensive industries. Van Reenen (2022) considers three possible ways to estimate spillovers, using case studies, estimation within a production function framework, and analysis based on patent citations, and discusses the advantage and limitations of the three alternative approaches. As Van Reenen (2022) points out, an important challenge of this approach is to determine the channel through which spillovers operate. Given data availability, this evaluation opts for a production (cost) function approach and an estimation with the number of patents as dependent variable.

Arqué-Castells and Spulber (2022) point out the distinction between technology transfer and knowledge spillovers and argue that it is crucial for policy makers to know whether one dominates the other. If spillovers dominate technology transfer, strong intellectual property rights and public support to business R&D (subsidies and tax incentives) are warranted, to align private investment in R&D with the social optimal level. However, if technology transfer dominates spillovers, subsidizing R&D may be harmful as they tend to reinforce the dominant position of superstar firms, which are able to internalize the spillovers from their R&D activities. They also point out that estimations of spillovers that do not account for technology transfer may provide upward-biased estimates.

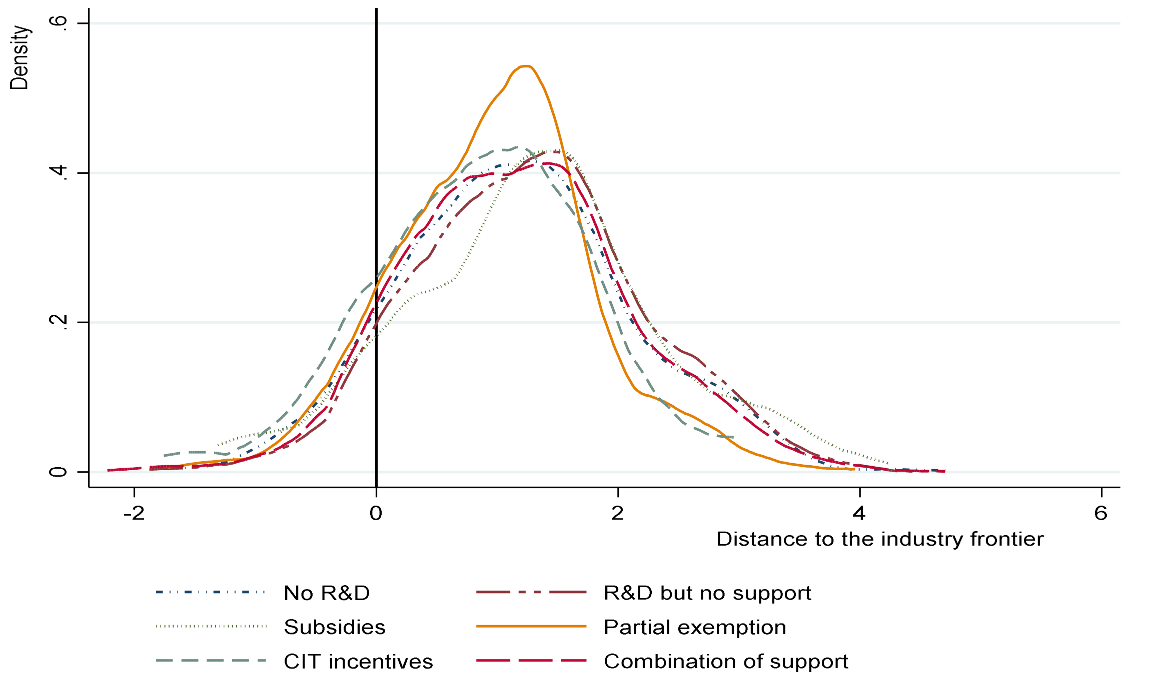
To assess the output additionality of public support to business R&D in Belgium, several indicators of firm performance are considered as dependent variable. Given the importance to account for (self-) selection in public support, a two-step selection model is considered which considers past firm performance as potential determinant for receiving public support. In the estimation, a distinction is made between the impact of R&D investment financed by firms and the impact of R&D investment financed through public support. Tassey (2007) and Mohnen (2022) argue that public support may stimulate development projects with only potentially marginal return. The distinction between self-financed R&D and subsidized R&D permits to evaluate the specific impact of R&D investment financed through public support.

To evaluate potential spillovers from R&D financed through public support, the sum of R&D expenditures of different groups of firms are considered. In terms of public support, five group are considered, firms that do not receive support, firms that only receive direct support (regional subsidies), firms that only benefit from partial exemption, firms that only use corporate income taxation incentives and finally, firms that combine at least two of the three main support categories. A further distinction is between R&D performed by firms within the same two-digit NACE industry (intra-industry) and R&D performed by firms in other industries (inter-industry).

To control for potential voluntary technology transfer, firms without R&D are grouped into firms with low tangible investment (bottom 50%) and firms with high tangible investment (top 50%). This is obviously a very crude way to account for technology transfer but is feasible with the available data.

The first indicator of firm performance that is considered is productivity.[41] Graph 42 compares, for the year 2019, productivity of firms without R&D to productivity of R&D active firms, with the latter group broken down by the type of public support that is received. Rather than the level of productivity, the level of productivity relative to the industry frontier is considered.

Graph 42 Distance to the industry productivity frontier by public support category (2019)



Note: The graph shows the distribution of the distance to the industry frontier in 2019 for firms that received no public support, for firms that received support only through one of the three main support mechanisms (regional subsidies, partial exemption, corporate income taxation (CIT) incentives) and for firms that combined at least two of the three main support groups. The distance to the frontier of a firm is defined as the 90th percentile of the log of labour productivity (turnover per FTE employee) in the two-digit NACE industry of the firms minus the log of labour productivity of the firm. The distance to the frontier for firms above the 90th percentile is negative.

The distance to the industry frontier is defined as the 90th percentile productivity level minus the productivity level of the firm. This definition implies that 10% of the firms with productivity above the 90th percentile will have a negative distance to the industry frontier and that the lower the productivity

[41] Schankerman (1981) pointed at the impact of double counting of research labour and capital, on the estimation of the return to R&D, as researchers and R&D capital are counted in the capital and labour input of a company but also in R&D expenditures. Using firm-level data for the US, Schankerman finds that double counting results in a downward bias of the estimate of the return to R&D. Bartelsman et al. (1996) provide evidence for The Netherlands that double counting of the factor input of R&D results in the underestimation of the return to R&D. Due to a lack of the necessary information, factor inputs can unfortunately not be adjusted for double counting in this evaluation.

of the firms the larger its distance to the industry frontier will be. For Graph 42 labour productivity is used, defined as turnover over the FTE number of employees.

Graph 42 shows that firms without R&D activities are generally less far away from the industry frontier than firms with R&D that do not receive any public support for R&D and R&D active firms that receive direct support (regional subsidies). Firms that receive subsidies have the highest distance to the industry frontier, which appears to refute the claim that agencies tend to pick winners (at least not in terms of productivity). Somewhat surprisingly, firms that only use corporate income taxation incentives or only benefit from partial exemption tend to have higher productivity relative to the industry frontier than firms that combine at least two of the three main support categories.

Table 33 shows the results of an estimation of the direct impact, with a distinction by type of public support, and the indirect impact (spillovers) of R&D expenditures on labour productivity. The reported results include inverse Mills variables, based on results from an estimation of a selection equation that accounts for alternative selection issues, as previously done for the estimation of input additionality (section 4.1.2.b). A one-year lag of productivity is included as potential determinant in the selection equation.

To account for a delay in the results from R&D activities, R&D expenditures of firms (self-financed or financed through public support) are included with a one-year lag and the spillover variables with a two-year lag. These are arguably short lags to fully account for the delay in the results from R&D. Including longer lags results in substantial loss of observations due to the inconstancy of responses to the R&D survey, possible leading to a selection bias. As the public support schemes appear to differ in the extent to which they stimulate basic research, applied research and experimental development, differentiation in lag length seems warranted. This can result in an intractable large number of potentially relevant combinations of different lags. Some estimations with more and longer lags provide similar or less statistically significant estimates as those reported in tables 33 and 34.[42]

Table 34 shows the results of estimations in which productivity growth is considered as dependent variable instead of the level of labour productivity as in Table 33. These estimations include the distance to the industry efficiency frontier, which is defined (as for graph 42) as the 90th percentile level of labour productivity of the industry to which a firm belongs, minus the productivity level of the firm.

This estimation includes a firm's distance to the industry frontier, the coefficient of which is statistically significant and substantially positive in all estimations, indicating that, conditionally on the other explanatory variables, firms tend to have higher productivity growth the further away they are from the industry frontier (conditional convergence).

Only in the estimations that consider (self-)selection of public support, the impact of R&D that is self-financed by firms contributes to productivity in a statistically significant way.

[42] These estimates are not reported but available upon request.

Table 33 Results of panel estimation of the impact of public support on labour productivity (turnover)

	Sample selection Survey and Response	(Self-selection) Support	Sample selection Survey, Response and (self-)selection Support
Dependent variable: labour productivity			
Explanatory variables:			
Firms without R&D - low tangible investment	0.00 (0.12)	0.00 (0.58)	0.01 (1.13)
Firms without R&D - high tangible investment	-0.07 (-1.07)	-0.04 (-0.72)	-0.00 (-0.05)
R&D expenditures financed by firm	-0.00 (-0.32)	0.08 (13.45) ***	-0.00 (-0.14)
R&D expenditures financed by public support:			
Regional subsidies	-0.00 (-2.90) ***	0.29 (13.92) ***	0.41 (16.95) ***
Research cooperation	0.01 (1.64) *	-0.00 (-0.05)	-0.00 (-1.43)
Young Innovative Company	0.00 (0.15)	-0.00 (-0.64)	-0.01 (-1.04)
PhDs and civil engineers	-0.00 (-0.15)	-0.01 (-3.12) ***	-0.01 (-2.41) **
Master	0.00 (2.08) **	-0.01 (-4.02) ***	-0.01 (-3.93) ***
Bachelor	-0.00 (-0.05)	-0.00 (-0.35)	-0.00 (-0.25)
Tax credit R&D	-0.00 (-0.45)	0.09 (8.97) ***	0.07 (5.92) ***
Tax deduction R&D°	0.00 (0.32)	0.10 (10.73) ***	0.07 (6.66) ***
Patent income deduction	0.00 (0.93)	0.09 (9.15) ***	0.07 (5.92) ***
Innovation income deduction	0.00 (0.25)	0.06 (6.42) ***	0.05 (5.06) ***
Innovation bonus	-0.00 (-0.07)	0.00 (1.05)	0.00 (1.06)
EU Funding	-0.00 (-1.07)	-0.00 (-0.52)	0.00 (0.60)
R&D expenditures of other firms (spillovers):			
Intra-industry firms without public support	-0.01 (-2.44) **	-0.01 (-1.80) *	-0.01 (-1.89) *
Intra-industry regional subsidies only	0.00 (0.51)	-0.00 (-0.08)	-0.00 (-0.70)
Intra-industry partial exemption only	0.00 (0.09)	-0.00 (-0.05)	0.00 (1.11)
Intra-industry CIT incentives only	-0.00 (-0.10)	-0.00 (-0.34)	0.00 (0.04)
Intra-industry combined support	0.02 (3.28) ***	0.02 (3.31) ***	0.01 (2.62) ***
Inter-industry firms without public support	0.00 (0.22)	0.01 (0.55)	-0.00 (-0.10)
Inter-industry regional subsidies only	-0.00 (-0.63)	-0.00 (-0.41)	-0.00 (-0.25)
Inter-industry partial exemption only	-0.00 (-1.12)	-0.00 (-0.95)	-0.00 (-1.44)
Inter-industry CIT incentives only	0.00 (0.37)	-0.00 (-0.34)	-0.00 (-0.02)
Inter-industry combined support	-0.01 (-0.66)	-0.01 (-1.07)	-0.00 (-0.31)
R-squared (within)	0.09	0.30	0.40
Number of observations	10,095	10,074	10,095

Note: The table shows the results of a fixed effects panel regression, using labour productivity as dependent variable. Labour productivity is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The tax deduction for R&D investment is not considered as the data is only available until 2012. The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). Firms that have no R&D expenditures are split in two groups through a dummy variable that reflects whether the firm belongs to the bottom 50% or to the top 50% in terms of fixed assets investment. For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Industry and year dummies are included. The estimates reported result from the estimation of the main equation of a selection model that includes inverse Mills variables, derived from the estimation of a selection equation that accounts for the respective selection issues. The selection equation includes the lag of labour productivity, in addition to other variables. *, ** 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 34 Results of panel estimation of the impact of public support on labour productivity growth

	Sample selection Survey and Response	(Self-selection) Support	Sample selection Survey, Response and (self-)selection Support
Dependent variable: Labour productivity growth			
Explanatory variables:			
Distance to the industry frontier (t-1)	0.49 (14.89) ***	0.70 (16.91) ***	0.98 (20.01) ***
Firms without R&D - low tangible investment	0.01 (0.75)	0.01 (0.90)	0.01 (1.29)
Firms without R&D - high tangible investment	-0.03 (-0.39)	-0.00 (-0.00)	0.05 (0.81)
R&D expenditures financed by firm	0.00 (0.20)	0.09 (8.23) ***	0.00 (1.51)
R&D expenditures financed by public support:			
Regional subsidies	-0.00 (-0.92)	0.31 (8.38) ***	0.61 (11.99) ***
Research cooperation	-0.00 (-0.07)	-0.01 (-1.12)	-0.01 (-2.11) **
Young Innovative Company	0.01 (1.47)	0.01 (0.66)	-0.00 (-0.39)
PhDs and civil engineers	0.00 (1.19)	-0.01 (-1.75) *	-0.01 (-1.75) *
Master	0.00 (1.80) *	-0.01 (-3.82) ***	-0.01 (-4.24) ***
Bachelor	-0.00 (-0.55)	-0.00 (-0.76)	-0.00 (-0.70)
Tax credit R&D	-0.01 (-1.33)	0.09 (6.84) ***	0.07 (4.90) ***
Tax deduction R&D°	0.00 (0.06)	0.11 (6.80) ***	0.09 (5.30) ***
Patent income deduction	-0.01 (-2.32) **	0.09 (6.75) ***	0.07 (5.15) ***
Innovation income deduction	-0.00 (-0.85)	0.06 (5.33) ***	0.06 (4.53) ***
Innovation bonus	0.00 (0.57)	0.01 (1.28)	0.00 (1.01)
EU Funding	0.00 (0.65)	0.00 (0.61)	0.01 (1.53)
R&D expenditures of other firms (spillovers):			
Intra-industry firms without public support	0.01 (1.22)	0.02 (1.92) *	0.02 (2.05) **
Intra-industry regional subsidies only	0.00 (0.60)	0.00 (0.28)	-0.00 (-0.28)
Intra-industry partial exemption only	-0.00 (-1.57)	-0.00 (-2.00) **	-0.00 (-1.41)
Intra-industry CIT incentives only	-0.00 (-1.78) *	-0.01 (-2.04) **	-0.01 (-2.18) **
Intra-industry combined support	-0.00 (-0.19)	-0.01 (-0.85)	-0.01 (-1.15)
Inter-industry firms without public support	-0.01 (-0.45)	-0.01 (-0.69)	-0.02 (-2.45) **
Inter-industry regional subsidies only	-0.00 (-1.26)	-0.00 (-1.08)	-0.00 (-1.47)
Inter-industry partial exemption only	0.00 (0.92)	0.00 (1.37)	0.00 (1.30)
Inter-industry CIT incentives only	0.00 (1.36)	0.00 (1.10)	0.00 (1.12)
Inter-industry combined support	-0.00 (-0.38)	-0.00 (-0.16)	0.01 (1.44)
R-squared (within)	0.29	0.40	0.48
Number of observations	10,199	10,178	10,199

Note: The table shows the results of a fixed effects panel regression, using labour productivity growth as dependent variable. Labour productivity is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The tax deduction for R&D investment is not considered as the data is only available until 2012. The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). Firms that have no R&D expenditures are split in two groups through a dummy variable that reflects whether the firm belongs to the bottom 50% or to the top 50% in terms of fixed assets investment. For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Industry and year dummies are included. The estimates include inverse Mills variables, derived from the estimation of a selection equation that accounts for the respective selection issues. The selection equation includes the lag of labour productivity, in addition to other variables. *, ** 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 indicate that accounting for (self-)selection of public support seems more important than accounting for sample selection due to the list of recipients of the R&D survey and non-response. Two of the three alternative estimations provide indications of a substantial positive impact of regional subsidies on productivity. This is also true in the estimation of the impact on productivity growth, which controls for the distance to the industry frontier. In the estimation of the impact on productivity (Table 33), the coefficient of regional subsidies is statistically significant negative when only sample selection due to the list of recipients of the R&D survey and non-response is considered in the selection equation

The statistically significant positive coefficients of regional subsidies are rather large suggesting a substantial impact of direct support on productivity and productivity growth.

As shown in Graph 42, the distribution of the distance to the industry frontier of firms receiving regional subsidies was the furthest away from the industry frontier, indicating that agencies do not seem to be biased in favour of highly productive firms. The coefficient of the distance to the industry frontier in Table 34 provides indications that firms with initial low productivity witness higher productivity growth than firms with initial high productivity. Controlling for this conditional convergence, regional subsidies appear to support R&D activities with a substantial positive impact on productivity growth.

There are no indications of a positive impact on productivity, or on productivity growth, for R&D expenditures financed through the partial exemption schemes. Some coefficients are statistically significant negative, especially for the partial exemption for researchers with a master's degree. This suggests that R&D financed through the partial exemption from payment of the withholding tax, for which robust indications of input additionality are found, tend to support marginal projects as argued by Tassey (2007) and Mohnen (2022).

In contrast, the corporate income taxation incentives, for which, apart from the tax deduction for R&D investment, estimations provide few indications of input additionality, seem to support R&D activities with a positive impact on productivity and productivity growth. Of the four corporate income taxation incentives, the tax deduction for R&D investment, with robust indications of input additionality, has the largest positive impact on productivity and productivity growth and the income innovation deduction, for which there are robust indications of crowding out, has the lowest impact. As pointed out before, only profitable firms can use tax incentives provided through corporate income taxation and current income from past R&D activities is a necessary condition to benefit from the patent income deduction and the innovation income deduction. This warrants substantial caution in the interpretation of the results on the impact of own R&D supported with public support, if the support is based on income rather than on R&D expenditures and is larger the larger the income is.

The results for spillovers, which from a policy perspective are the most relevant output variables, are rather mixed and depend on whether the productivity level or productivity growth is considered. In the productivity level estimation (Table 33) all three alternative selection models, provide a statistically significant negative coefficient for intra-industry spillovers from R&D performed by firms that do not receive public support. This could point out that the R&D activities of non-supported firms aim at imitation or absorption of the knowledge resulting from R&D by other firms and that this generates business-stealing effects. However, in the productivity growth estimation (Table 34) the coefficient of intra-industry spillovers from non-supported firms is statistically positive in the two selection models that account for (self-)selection of public support.

R&D by firms that combine at least two of the main support categories appear to have a positive impact on the productivity of other firms in the same industry (intra-industry combined support) but this result is not confirmed for productivity growth, as in this estimation the coefficients are negative (but not statistically significant). In the productivity growth estimation, some statistically significant negative coefficients seem to indicate business-stealing effects of R&D performed by firms, in the same industry, that only benefit from partial exemption or only use corporate income taxation incentives and of R&D performed by firms, in other industries, that do not receive public support.

The statistically significant coefficients of spillover variables are not very substantial, compared to the impact from own R&D. Moreover, the coefficients are sometimes negative, indicating the possibility of business stealing and are not very robust.

All estimations reported in this section come with the important caveat that they do not consider potential spillovers from foreign R&D. Eberhardt, Helmers and Strauss (2013) argue that ignoring spillovers may bias estimates of the private return to R&D. In their seminal paper on international R&D spillovers by Coe and Helpman (1995), of the group of 22 countries considered, Belgium is the country with the largest elasticity of total factor productivity with respect to foreign R&D (in 1990). This can be explained by the finding of the authors that the impact of foreign R&D is more beneficial the more open a country is to international trade (considered as the channel for spillovers). In 1990, Belgium by far had the highest import share of the 22 countries. Dieppe and Mutl (2013) provide an overview of the conflicting conclusions of estimations of international R&D spillovers and argue for the need to distinguish between technology transfer and synergies in R&D (cf. recent argument by Arqué-Castells and Spulber (2022)).

It would be feasible to construct stocks of foreign R&D, which are generally used to estimate international spillovers. These stocks would however be the same for all firms. For firm-specific R&D stocks information is needed with respect to the channel of spillovers that is assumed. Firm-specific bilateral import shares could, for example, be used to weight R&D expenditures of other countries. This information is however not available in the data at hand. The inclusion of foreign R&D spillovers, which, especially for a small open economy as Belgium, is warranted for unbiased estimates of the return to R&D as well as unbiased estimates of domestic spillovers, is therefore beyond the scope of the current evaluation.

Table 35 shows the results of the impact of self-financed R&D and R&D financed with direct support, on labour productivity, with a breakdown of regional subsidies by category along three dimensions, as in Table 7 up to Table 9. The coefficients of the variables denoting tax benefits are included in the estimation but not reported. Estimations in which the spillover variables from R&D financed through direct support are broken down by the distinct direct support categories, provide no statistically significant coefficients[43], in line with the lack of statistical significance of the coefficients of the spillover variables from R&D financed through direct support (Table 34).

43 The results are not reported but available upon request.

The estimation includes inverse Mills variables from the estimation of a selection equation that accounts for (self-)selection of public support.

The coefficients of the four categories denoting the distance to the market are all statistically significant positive with the highest coefficient for the R&D category. The coefficient of both bottom-up and thematic projects is also statistically significant with a larger coefficient for bottom-up projects.

Table 35 Results of panel estimation of the impact of public support on labour productivity with breakdown of direct support by category

	Distance to market	Thematic/Bottom-up	Cooperation
Dependent variable: Labour productivity			
Explanatory variables:			
R&D expenditures financed by firm	0.02 (6.09) ***	0.04 (6.94) ***	0.01 (4.93) ***
R&D expenditures financed by public support:			
Research	0.04 (5.69) ***		
Development	0.04 (5.96) ***		
Research and Development	0.06 (7.41) ***		
Feasibility study/SME support	0.03 (5.60) ***		
Bottom-up		0.14 (6.73) ***	
Thematic		0.11 (4.78) ***	
No R&D cooperation			0.03 (6.20) ***
R&D cooperation			0.03 (6.38) ***
R-squared (within)	0.14	0.19	0.12
Number of observations	10,074	10,074	10,074

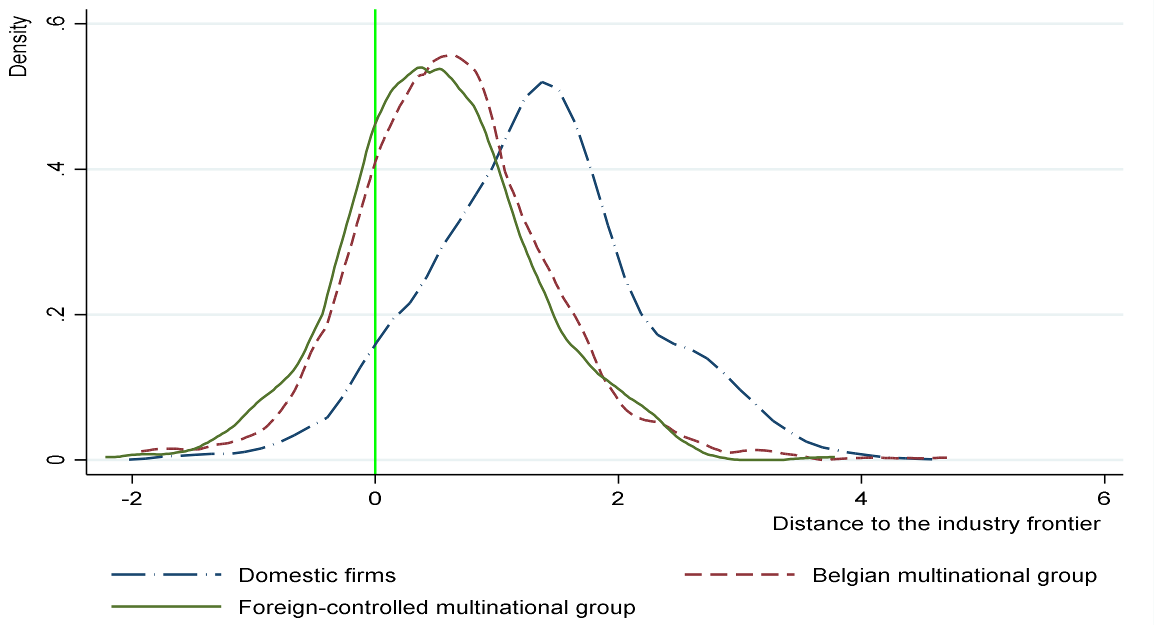
Note: The table shows the results of a fixed effects panel regression with direct support broken down by category along three dimensions: distance to the market, thematic-bottom-up and cooperation. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection equation 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.

Whether regional subsidies involve research cooperation or not does not seem to have an impact on labour productivity.

As with the estimation of input additionality, potential heterogeneity in the impact of public support on output is investigated through separate estimations for distinct groups. In these estimations inverse Mills variables resulting from the estimation of a selection equation that accounts for (self-) selection of public support are included.

A first characteristic that could provide different results across firms is ownership. Graph 43 shows the distribution of the distance to the industry frontier in 2019 for domestic firms, firms that belong to a Belgian multinational group and firms that belong to a foreign-controlled multinational group. As before, information on firm ownership is provided by Hambÿe et al. (2022). The distribution of firms that belong to a Belgian multinational group is similar, though indicating slightly lower productivity, to the distribution of firms that belong to a foreign-controlled multinational group. A disproportionate large share (in effect, more than 10%) of firms that belong to a multinational group, have productivity above the 90th percentile. The distribution of domestic firms is located far to the right of the industry frontier indicating that within industries most domestic firms are substantially less productive than firms that belong to a multinational group.

Graph 43 Distance to the industry productivity frontier by firm ownership (2019)



Note: The graph shows the distribution of the distance to the industry frontier in 2019 for domestic firms, firms that belong to a Belgian-controlled multinational group and firms that belong to a foreign-controlled multinational group (data provided by Hambÿe et al. 2022). The distance to the industry frontier of a firm is defined as the 90th percentile of the log of labour productivity (turnover per FTE employee) in the two-digit NACE industry of the firms minus the log of labour productivity of the firm. The distance to the frontier for firms above the 90th percentile is negative.

Table 36 shows the results of separate estimations by ownership group of output additionality. Lenihan et al. (2022) point out that supporting R&D activities of subsidiaries of foreign-controlled multinationals poses the risk that the results from supported R&D may not be exploited in the host country. They provide indications that this does not appear to be the case in Ireland, as grants and tax credits for R&D have a positive impact on R&D expenditures (input additionality) but also on the performance (output additionality) of the subsidiaries of foreign-controlled multinationals.

As with the estimations of input additionality by distinct firm groups, separate estimations of output additionality generally provide a better fit, which indicates the need to account for substantial heterogeneity in the impact of public support over several firm characteristics. In contrast with the results in Table 33, the coefficients of tangible investment of firms without R&D are statistically significant negative for domestic firms and firms that belong to a Belgian multinational group. Sampson (2022) proposes a taxonomy of global value chains based on whether the headquarters of a multinational enterprise promotes technology diffusion and imitation in the host country (inclusive) or not (exclusive).

For all three groups, the coefficient of self-financed R&D is statistically significant positive and indicates a higher return to own R&D than the results for the whole panel reported in Table 33. The coefficient is substantially larger for domestic firms than for firms that belong to a multinational group.

Table 36 Results of panel estimation of the impact of public support on labour productivity, by firm ownership

	Domestic firm	Belongs to a Belgian multinational group	Belongs to a foreign-controlled multinational group
Dependent variable: Labour productivity			
Explanatory variables:			
Firms without R&D - low tangible investment	-0.25 (-4.09) ***	-0.23 (-2.32) **	-0.12 (-0.90)
Firms without R&D - high tangible investment	-0.23 (-3.58) ***	-0.22 (-2.25) **	-0.17 (-1.35)
R&D expenditures financed by firm	0.33 (18.79) ***	0.22 (9.27) ***	0.22 (9.45) ***
R&D expenditures financed by public support:			
Regional subsidies	0.78 (18.56) ***	0.46 (10.86) ***	0.38 (8.24) ***
Research cooperation	-0.01 (-0.85)	-0.01 (-0.35)	0.00 (1.67) *
Young Innovative Company	0.00 (0.15)	-0.01 (-1.54)	0.01 (0.62)
PhDs and civil engineers	-0.01 (-3.45) ***	-0.01 (-1.54)	0.00 (1.21)
Master	-0.01 (-2.81) ***	-0.01 (-1.95) *	0.00 (0.56)
Bachelor	-0.00 (-0.06)	-0.00 (-0.22)	-0.00 (-0.04)
Tax credit R&D	0.07 (7.24) ***	0.03 (3.85) ***	0.04 (4.32) ***
Tax deduction R&D°	0.08 (8.60) ***	0.03 (3.61) ***	0.05 (5.85) ***
Patent income deduction	0.05 (6.30) ***	0.03 (5.03) ***	0.04 (5.63) ***
Innovation income deduction	0.04 (4.09) ***	0.02 (2.85) ***	0.02 (2.94) ***
Innovation bonus	0.01 (1.15)	0.00 (0.22)	0.00 (0.63)
EU Funding	-0.00 (-0.19)	0.00 (0.67)	-0.00 (-1.55)
R&D expenditures of other firms (spillovers):			
Intra-industry no support	-0.00 (-0.77)	-0.00 (-0.69)	-0.01 (-1.43)
Intra-industry regional subsidies only	0.00 (0.30)	0.00 (0.04)	0.00 (0.29)
Intra-industry partial exemption only	0.00 (0.40)	0.00 (1.06)	-0.01 (-4.11) ***
Intra-industry CIT incentives only	0.00 (1.71) *	-0.01 (-1.41)	-0.00 (-1.37)
Intra-industry combined support	0.00 (0.41)	0.02 (2.10) **	0.03 (3.02) ***
Inter-industry no support	-0.19 (-1.10)	-0.11 (-1.02)	-0.01 (-2.27) **
Inter-industry regional subsidies only	0.00 (0.36)	-0.00 (-0.72)	-0.00 (-0.67)
Inter-industry partial exemption only	-0.00 (-0.18)	-0.00 (-1.95) *	-0.00 (-0.56)
Inter-industry CIT incentives only	-0.00 (-1.06)	0.00 (0.98)	0.00 (1.39)
Inter-industry combined support	-0.18 (-1.70) *	0.09 (0.96)	0.00 (0.97)
R-squared (within)	0.56	0.44	0.51
Number of observations	5,799	2,315	2,083

Note: The table shows the results of a fixed effects panel regression for alternatively domestic firms, firms that belong to a Belgian multinational group and firms that belong to a foreign-controlled multinational group (data provided by Hambÿe et al. 2022). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection equation 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.

Regional subsidies are, as in Table 33 and Table 34, found to have a large positive impact on productivity, with the largest impact for domestic firms and the lowest, though still substantial, impact for firms that belong to a foreign-controlled multinational group.

The lack of a positive impact on productivity of the partial exemption schemes is confirmed for all three groups. For the partial exemption for researchers with a master's degree, the coefficient is even statistically significant negative for domestic firms and firms that belong to a Belgian multinational group. For domestic firms the coefficient for the partial exemption for researchers with a PhD or civil engineering degree is also statistically significant negative.

The positive impact of R&D financed through corporate income taxation incentives is confirmed for all three groups. For all four incentives, the impact is larger for domestic firms than for firms that belong to a multinational enterprise group.

Crescenzi, Dyèvre and Neffke (2022) report evidence that subsidiaries of foreign multinationals have a positive impact on local innovation, measured by US patents granted between 1975 and 2015, through knowledge spillovers to domestic firms but also by attracting new foreign firms. However, technology leaders generate fewer spillovers than technologically less advanced multinationals, participate in fewer technological alliances and exchange fewer workers with local firms. The results in Table 36 provide some, but not very strong, evidence of R&D spillovers. For domestic firms only the coefficient of intra-industry spillovers from R&D by firms that only use corporate income taxation incentives is positive and statistically significant and even then, only at 10%. The coefficient is moreover negligible. R&D activities of firms that combine at least two of the three main support categories has a substantially negative impact on productivity of firms in other industries, although the coefficient is only statistically significant at 10%.

There are statistically significant indications of spillovers from R&D activities by firms that benefit from at least two support categories, on the productivity of firms that belong to a multinational group in the same industry. Domestic firms benefit from R&D activities, especially those that are self-financed or that are financed through regional subsidies, but they do not seem to be able to benefit from R&D activities of other firms. This could be explained by the large productivity gap that appears to exist between domestic firms and firms that belong to a multinational group as shown in Graph 43, which suggests that domestic firms may lack the capacity to absorb spillovers. However, it could also indicate that the technologically more advanced subsidiaries of multinationals try to avoid knowledge to flow to non-affiliated local companies (cf. Crescenzi, Dyèvre and Neffke 2022).

Table 37 shows the results of three separate estimations of output additionality by firm size. The return to self-financed R&D is largest for firms with less than 50 employees and smallest - though still considerable- for the largest firms (250 or more employees). The coefficient for R&D financed through regional subsidies is again found to be larger than the coefficient of self-financed R&D, and also decreases with firm size.

The coefficient of R&D financed through the partial exemption for researchers with a master's degree is statistically significant negative for all three firm size groups.

Table 37 Results of a panel estimation of the impact of public support on labour productivity, by firm size

	Less than 50 employees	Between 50 and 250 employees	250 or more employees
Dependent variable: Labour productivity			
Explanatory variables:			
Firms without R&D - low tangible investment	-0.20 (-3.31) ***	-0.17 (-2.52) **	0.03 (0.31)
Firms without R&D - high tangible investment	-0.19 (-2.90) ***	-0.18 (-2.59) ***	0.03 (0.29)
R&D expenditures financed by firm	0.36 (23.02) ***	0.27 (13.96) ***	0.20 (6.77) ***
R&D expenditures financed by public support:			
Regional subsidies	0.90 (24.35) ***	0.59 (11.81) ***	0.43 (6.77) ***
Research cooperation	-0.02 (-2.49) **	0.01 (2.46) ***	-0.00 (-0.28)
Young Innovative Company	-0.01 (-1.28)	-0.00 (-0.41)	-0.00 (-0.11)
PhDs and civil engineers	-0.01 (-2.91) ***	-0.00 (-0.50)	-0.01 (-2.16) **
Master	-0.02 (-4.12) ***	-0.01 (-2.04) **	-0.01 (-2.77) ***
Bachelor	-0.00 (-0.23)	0.01 (2.09) **	-0.00 (-0.30)
Tax credit R&D	0.07 (6.52) ***	0.05 (5.04) ***	0.03 (3.32) ***
Tax deduction R&D°	0.09 (9.20) ***	0.05 (6.39) ***	0.04 (3.89) ***
Patent income deduction	0.07 (9.04) ***	0.04 (5.06) ***	0.03 (3.88) ***
Innovation income deduction	0.06 (4.88) ***	0.03 (2.92) ***	0.01 (2.77) ***
Innovation bonus	0.01 (1.36)	-0.00 (-0.11)	0.00 (0.17)
EU Funding	0.01 (1.28)	-0.00 (-0.91)	-0.00 (-0.89)
R&D expenditures of other firms (spillovers):			
Intra-industry no support	-0.00 (-0.26)	-0.01 (-1.15)	-0.00 (-0.46)
Intra-industry regional subsidies only	0.00 (0.61)	-0.00 (-1.03)	0.00 (0.22)
Intra-industry partial exemption only	-0.00 (-0.49)	-0.00 (-1.13)	0.00 (0.91)
Intra-industry CIT incentives only	0.00 (1.28)	-0.01 (-3.34) ***	-0.00 (-0.13)
Intra-industry combined support	-0.00 (-0.04)	0.01 (1.76) *	0.01 (0.64)
Inter-industry no support	-0.10 (-0.59)	0.00 (0.03)	-0.00 (-0.27)
Inter-industry regional subsidies only	-0.00 (-0.49)	0.00 (1.31)	0.00 (0.14)
Inter-industry partial exemption only	0.00 (0.47)	-0.00 (-0.99)	-0.00 (-1.30)
Inter-industry CIT incentives only	-0.00 (-1.18)	0.01 (3.19) ***	0.00 (0.35)
Inter-industry combined support	-0.08 (-0.84)	-0.00 (-0.03)	-0.00 (-0.83)
R-squared (within)	0.61	0.55	0.46
Number of observations	5,647	3,174	1,376

Note: The table shows the results of a fixed effects panel regression for firms grouped by size (number of FTE employees). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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.

In the group of firms with between 50 and 250 employees the coefficient is statistically significant positive for the partial exemption for research cooperation and the partial exemption for R&D employees with a bachelor's degree.

The coefficients of all four corporate income taxation incentives are statistically significant positive for all three firm size groups. The size of the coefficient again decreases with firm size.

There are no indications of positive spillovers for any firm size group except for spillovers from R&D of firms that have only benefited from corporate income taxation incentives on labour productivity of firms in other industries (inter-industry), in the intermediate size group (between 50 and 250 employees).

In this firm size group, R&D performed by firms that have only benefited from corporate income taxation incentives on the other hand have a statically significant negative impact on labour productivity of firms in the same industry. The impact of R&D financed with public support in at least two of the three main categories also has a positive impact on labour productivity of firms in the same industry, but this effect is only statistically significant at 10%.

Table 38 shows the results of an estimation in which firms are grouped by age (based on the date of creation), firms up to 9 years old and firms that started 10 years or more ago. The return to self-financed R&D is substantial for both age groups but slightly higher for young firms. The impact of R&D financed through regional subsidies on labour productivity is again larger than the impact of self-financed R&D, for both age groups, with a more considerable impact for young firms than for firms of 10 years or more. The only coefficient of the five partial exemption schemes that is statistically significant is the negative coefficient of the partial exemption for R&D employees with a master's degree for old firms. The coefficients of all four corporate income taxation incentives are statistically significant positive for both age groups, but larger for young firms than for old firms. For old firms, the coefficient of the innovation bonus is also statistically significant positive but only at 10%. In contrast with the impact of own R&D (self-financed or financed through public support), no coefficient of the spillovers variables is statistically significant for young firms. For old firms, the impact of R&D of firms that combine at least two of the three main support categories, on labour productivity of firms in the same industry is statistically significant positive.

Arora, Fosfuri and Roende (2022) argue that start-ups are more apt to solve technical challenges whereas incumbents are better at solving commercial challenges and that start-ups that are active in fields where technical and commercial challenges are comparable in size, are less likely to capture a substantial fraction of the value that they create. The authors consider that this may explain why start-ups in IT and life sciences appear to be successful whereas start-ups in deep-tech sectors (new materials, automation, and eco-innovations) are struggling. The results in Table 38 indicate that young firms succeed in generating a higher return to self-financed R&D and R&D financed through regional subsidies or corporate income taxation incentives than old firms, but they do not seem to be able to absorb knowledge generated by other firms. Crowley and Jordan (2022) provide evidence for Sweden that the relationship between start-ups, knowledge spillovers and innovation effort is complicated. They find a negative correlation between new business formation at municipal level and firm-level R&D expenditures. Geographical proximity is often seen as an essential factor for knowledge flows, but Crowley and Jordan (2022) point out that proximity also increases the risk of knowledge leakage. A local increase in the creation of new firms may therefore reduce the incentives of incumbents to invest in R&D. This could explain the negative correlation at a local level between start-up creation and R&D effort. To benefit from knowledge of other firms, co-location may not be a sufficient condition. Local labour mobility, networks and joint ventures may be necessary.

Table 38 Results of panel estimation of the impact of public support on labour productivity, by firm age

Dependent variable: Labour productivity	Less than 10 years old	10 years or more
Explanatory variables:		
Firms without R&D - low tangible investment	-0.53 (-2.30) **	-0.17 (-3.55) ***
Firms without R&D - high tangible investment	-0.50 (-2.21) **	-0.18 (-3.59) ***
R&D expenditures financed by firm	0.31 (7.89) ***	0.27 (18.02) ***
R&D expenditures financed by public support:		
Regional subsidies	0.78 (9.41) ***	0.58 (16.47) ***
Research cooperation	-0.01 (-0.62)	-0.00 (-0.18)
Young Innovative Company	0.00 (0.34)	-0.00 (-0.26)
PhDs and civil engineers	0.00 (0.52)	-0.00 (-1.41)
Master	-0.00 (-0.16)	-0.01 (-2.94) ***
Bachelor	-0.00 (-0.31)	0.00 (1.44)
Tax credit R&D	0.09 (6.06) ***	0.05 (8.04) ***
Tax deduction R&D°	0.09 (6.32) ***	0.05 (9.79) ***
Patent income deduction	0.06 (3.50) ***	0.04 (8.93) ***
Innovation income deduction	0.07 (4.48) ***	0.02 (4.58) ***
Innovation bonus	0.01 (0.86)	0.01 (1.89) *
EU Funding	-0.00 (-0.24)	0.00 (0.90)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	-0.01 (-0.30)	-0.00 (-1.21)
Intra-industry regional subsidies only	-0.00 (-0.24)	0.00 (0.24)
Intra-industry partial exemption only	-0.01 (-0.49)	-0.00 (-0.12)
Intra-industry CIT incentives only	0.01 (0.95)	-0.00 (-0.17)
Intra-industry combined support	0.00 (0.12)	0.01 (2.02) **
Inter-industry no support	-0.26 (-0.49)	0.00 (0.64)
Inter-industry regional subsidies only	0.00 (0.22)	-0.00 (-0.67)
Inter-industry partial exemption only	0.01 (0.67)	-0.00 (-0.97)
Inter-industry CIT incentives only	-0.00 (-0.57)	0.00 (0.14)
Inter-industry combined support	-0.24 (-1.10)	-0.01 (-0.83)
R-squared	0.59	0.45
Number of observations	1,067	9,130

Note: The table shows the results of a fixed effects panel regression for firms grouped by firm age (based on date of creation). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 negative correlation between start-up creation and R&D effort appears to be mitigated by the scale of knowledge generating activities, which according to the authors could be explained by the fact that a larger number of local firms, including start-ups, increases the value of the absorptive capacity that results from own R&D. Crowley and Jordan (2022) state that the non-linear relationship implies that there is an optimal level of business creation, in effect, that not only can there be too few start-ups but, contrary to the common opinion, also too many. The indications in Table 38 that young firms succeed in generating a high return from their own R&D is obviously a positive result but as the rationale for public support to business R&D relies on the existence of positive spillovers, the lack of evidence of R&D spillovers from other firms to young firms is problematic. It could be that young firms benefit from foreign R&D spillovers and that, in the absence of any foreign R&D variables in the estimation, the estimated high return to own R&D captures the absorptive capacity effect required to benefit from these spillovers. As mentioned before, due to a lack of firm-specific data on potential spillover channels, the estimation of foreign R&D spillovers is beyond the scope of this evaluation, but certainly warrants future investigation.

Using data for Spain, Labeaga et al. (2021) find evidence that persistence in the use of tax credits is positively correlated with the number of product innovations, but only for SMEs. To assess the potential different impact between firms that do R&D on an ongoing basis and firms without persistent R&D activities, Table 39 shows the results of a separate regression for non-persistent R&D active firms and persistent R&D active firms. As with the separate regressions for input additionality (reported in Table 13), non-persistent R&D firms are defined as firms with less than eight years for which non-zero R&D expenditures are reported, and persistent R&D firms as firms with eight up to 17 years of reported non-zero R&D expenditures (only real responses to the R&D survey are considered). As in previous results, the return to self-financed R&D and R&D financed through direct support (regional subsidies) is statistically significant positive and considerable for both groups of firms, with slightly larger coefficients for non-persistent R&D firms. The indications of a negative return to R&D financed with partial exemption appear to apply to firms without persistent R&D activities whereas the statistically significant positive coefficients for the corporate income taxation incentives are very similar for both groups.

There are no indications of statistically significant spillovers for non-persistent R&D firms whereas the coefficient of intra-industry spillovers from firms that combine at least two of the main three support categories is statistically significant positive for persistently R&D active firms. This finding suggests that persistent R&D activities are necessary to be able to absorb spillovers from R&D activities of other firms.

In a recent survey of the literature on the role of intellectual property rights in promoting innovation, Mezzanotti & Simcoe (2022) observe that patenting is concentrated in a rather limited share of R&D firms. The firms that do patent account for the bulk of R&D expenditures. Patenting is mainly concentrated in large firms active in high-tech industries. Generally, firms consider patents to be less important than trade secrets, trademarks, and copyrights to appropriate the benefits of their innovation activities.

Matching data from United States Patent and Trademark Office (USPTO) patents to data on product introductions in the US consumer goods sector, Argente et al. (2020) find that although patent filing by firms is positively correlated with product innovation, at least half of product innovation and sales growth comes from firms that never patent. They also provide evidence that market leaders use their patents to limit competition. In line with the finding by Mezzanotti & Simcoe (2022) that especially large firms patent, Argente et al. (2020) point out that the private value of patents is high for large firms as they seem to allow them to protect large market shares of existing products.

Table 39 Results of panel estimation of the impact of public support on labour productivity, by R&D persistence

Dependent variable: Labour productivity	Non-persistent R&D	Persistent R&D
Explanatory variables:		
Firms without R&D - low tangible investment	-0.13 (-2.42) **	-0.46 (-4.80) ***
Firms without R&D - high tangible investment	-0.13 (-2.45) **	-0.43 (-4.38) ***
R&D expenditures financed by firm	0.28 (15.99) ***	0.27 (15.48) ***
R&D expenditures financed by public support:		
Regional subsidies	0.63 (12.96) ***	0.58 (15.54) ***
Research cooperation	-0.02 (-1.89) *	0.00 (0.72)
Young Innovative Company	-0.01 (-0.96)	0.01 (1.39)
PhDs and civil engineers	-0.01 (-3.29) ***	-0.00 (-1.01)
Master	-0.02 (-3.54) ***	-0.00 (-1.30)
Bachelor	0.01 (1.35)	0.00 (0.09)
Tax credit R&D	0.03 (2.06) ***	0.05 (8.35) ***
Tax deduction R&D°	0.05 (4.90) ***	0.05 (9.43) ***
Patent income deduction	0.04 (4.30) ***	0.04 (8.19) ***
Innovation income deduction	0.03 (2.65) ***	0.02 (3.79) ***
Innovation bonus	0.01 (1.15)	0.00 (1.43)
EU Funding	0.00 (0.35)	0.00 (0.04)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	-0.01 (-0.76)	-0.00 (-0.43)
Intra-industry regional subsidies only	-0.00 (-0.32)	0.00 (0.83)
Intra-industry partial exemption only	0.00 (0.12)	-0.00 (-0.45)
Intra-industry CIT incentives only	-0.00 (-0.88)	0.00 (0.66)
Intra-industry combined support	0.01 (0.79)	0.01 (2.27) **
Inter-industry no support	-0.21 (-1.05)	0.00 (0.06)
Inter-industry regional subsidies only	0.00 (0.64)	-0.00 (-1.56)
Inter-industry partial exemption only	-0.00 (-0.38)	-0.00 (-1.11)
Inter-industry CIT incentives only	0.00 (0.97)	-0.00 (-0.69)
Inter-industry combined support	-0.11 (-0.82)	-0.01 (-0.91)
R-squared	0.43	0.52
Number of observations	5,140	5,057

Note: The table shows the results of a fixed effects panel regression for firms grouped by persistence in reported R&D expenditures. As in Table 13, firms with less than 8 years for which non-zero R&D expenditures are reported are considered for non-persistent R&D and firms with 8 up to 17 years of reported non-zero R&D expenditures as persistent R&D. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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.

To assess possible differences in output additionality and spillovers, between firms that patent and firms that do not patent, Table 40 shows the results of a separate regression for each group. With the patent data that is available, a non-patenting firm is defined as a firm without any patent granted in Belgium or any patent application at the European Patent Office in the period 2003-2019 whereas a firm is defined as a patenting firm if it has at least one Belgian patent granted or at least one EPO application. Given data availability a caveat applies to the definition of non-patenting firms as they may have USPTO patents, for which no firm-level information is available in the current data set, or have patents granted before 2003. Self-financed R&D and R&D financed with direct support are again found to have a statistically significant positive impact on labour productivity, both for non-patenting and patenting firms, with larger coefficients for non-patenting firms, confirming that firms can obtain a substantial return to their R&D activities, without any patent. The statistically significant negative coefficient for R&D financed through some of the partial exemption schemes, found for the total panel of firms, only appears to apply to patenting firms, for the partial exemption for R&D employees with a PhD or civil engineering degree or a master’s degree. The coefficients of all four corporate income taxation incentives are statistically significant positive for both patenting and non-patenting firms. The significant coefficient of R&D financed through the patent income deduction for non-patenting firms seems dubious but could be explained by the fact that USPTO patents and patents granted before 2003 are not considered for the definition of a non-patenting firm. The coefficient of all four corporate income taxation incentives is larger for non-patenting firms than for patenting firms. Intra-industry spillovers of firms that combine at least two of the three main public support categories are statistically significant positive for both groups of firms although the coefficient is larger for patenting firms than for non-patenting firms and the coefficient for non-patenting firms is only significant at 10%. The result suggests that large dominant firms use their patents to limit spillovers to smaller non-patenting firms or at least that they seem to benefit more from R&D by other firms in their industry than non-patenting firms.

Table 41 shows the results of separate regressions of output additionality by Pavitt industry category. As before, the high positive return to self-financed R&D and R&D financed with direct support, is confirmed for all four Pavitt categories, with the largest coefficients for supplier-dominated industries and the lowest coefficients for scale intensive industries. Whereas again some of the coefficients of R&D financed with partial exemption are statistically significant negative, especially in science-based industries, some of the coefficients are statistically significant positive, in contrast with the result of the total panel. This is, for example, the case for the partial exemption for research cooperation in supplier-dominated industries and for the partial exemption for Young Innovative Companies in supplier-dominated industries and specialized supplier industries. Except for the coefficient of the innovation income deduction in supplier-dominated industries, the coefficients of all four corporate income taxation incentives are statistically significant positive.

The results for the spillover variables are more heterogenous across the four Pavitt categories. In both science-based industries and supplier-dominated industries, two coefficients are statistically significant positive and one statistically significant negative but there is no overlap between the two Pavitt categories as to which coefficients are statistically significant. In supplier-dominated industries there are indications of positive spillovers from R&D of firms that combine at least two of the three public support categories on labour productivity of firms in the same industry but negative spillovers from R&D of firms that combine at least two of the three public support categories of firms in other industries.

Table 40 Results of a panel estimation of the impact of public support on labour productivity, by patent activity

Dependent variable: Labour productivity	Firms without patents	Firms with patents
Explanatory variables:		
Firms without R&D – low tangible investment	-0.16 (-3.22) **	-0.45 (-3.31) ***
Firms without R&D – high tangible investment	-0.16 (-3.20) ***	-0.44 (-3.21) ***
R&D expenditures financed by firm	0.29 (17.20) ***	0.25 (11.57) ***
R&D expenditures financed by public support:		
Regional subsidies	0.64 (15.57) ***	0.52 (13.43) ***
Research cooperation	0.00 (0.81)	0.00 (0.01)
Young Innovative Company	0.01 (0.25)	0.00 (0.25)
PhDs and civil engineers	0.00 (0.25)	-0.01 (-2.17) **
Master	-0.00 (-0.49)	-0.01 (-2.10) **
Bachelor	0.00 (0.49)	0.00 (0.50)
Tax credit R&D	0.05 (5.92) ***	0.04 (6.69) ***
Tax deduction R&D°	0.07 (10.08) ***	0.04 (6.53) ***
Patent income deduction	0.05 (6.53) ***	0.04 (6.59) ***
Innovation income deduction	0.05 (5.27) ***	0.01 (2.21) **
Innovation bonus	0.01 (1.43)	0.00 (1.01)
EU Funding	0.00 (0.16)	0.00 (0.05)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	-0.00 (-0.80)	-0.01 (-1.00)
Intra-industry regional subsidies only	0.00 (0.25)	-0.00 (-0.03)
Intra-industry partial exemption only	-0.00 (-1.42)	0.00 (1.07)
Intra-industry CIT incentives only	0.00 (1.05)	-0.00 (-1.01)
Intra-industry combined support	0.01 (1.80) *	0.02 (2.00) **
Inter-industry no support	0.00 (0.45)	0.04 (0.42)
Inter-industry regional subsidies only	-0.00 (-0.06)	-0.00 (-0.86)
Inter-industry partial exemption only	0.00 (0.50)	-0.01 (-1.82) *
Inter-industry CIT incentives only	-0.00 (-0.81)	0.00 (0.84)
Inter-industry combined support	-0.00 (-0.67)	-0.49 (-0.48)
R-squared	0.48	0.50
Number of observations	7,679	2,518

Note: The table shows the results of a fixed effects panel regression for firms grouped by patent activity: firms with no Belgian or European patent during the period 2003-2019 and firms with at least 1 patent during this period. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 41 Results of a panel estimation of the impact of public support on labour productivity, by Pavitt category

	Science-based	Specialized Suppliers	Scale Intensive	Supplier-dominated
Dependent variable Labour productivity				
R&D expenditures financed by firm	0.29 (12.81) ***	0.29 (12.97) ***	0.13 (4.45) ***	0.32 (13.32) ***
R&D expenditures financed by public support:				
Regional subsidies	0.64 (13.21) ***	0.63 (11.25) ***	0.30 (5.23) ***	0.69 (10.71) ***
Research cooperation	-0.01 (-1.70) *	-0.01 (-1.86) *	-0.00 (-0.79)	0.01 (2.83) ***
Young Innovative Company	-0.01 (-1.30)	0.02 (2.17) **	-0.02 (-0.86)	0.03 (3.60) ***
PhDs and civil engineers	-0.01 (-1.74) *	-0.01 (-1.64) *	0.01 (1.64) *	-0.00 (-1.03)
Master	-0.01 (-2.71) ***	-0.00 (-0.72)	-0.01 (1.06)	-0.00 (-0.99)
Bachelor	0.00 (0.64)	0.00 (0.27)	-0.01 (-0.87)	0.01 (1.51)
Tax credit R&D	0.05 (5.15) **	0.04 (2.93) ***	0.02 (2.70) ***	0.09 (7.19) ***
Tax deduction R&D°	0.06 (7.32) ***	0.05 (6.13) ***	0.03 (3.97) ***	0.09 (7.17) ***
Patent income deduction	0.03 (4.27) ***	0.04 (5.62) ***	0.03 (2.45) **	0.07 (7.17) ***
Innovation income deduction	0.02 (2.56) **	0.03 (3.94) ***	0.01 (1.99) *	0.02 (1.53)
Innovation bonus	-0.00 (-0.31)	0.00 (0.84)	0.01 (1.65) *	0.01 (1.86) *
EU Funding	0.01 (1.65) *	-0.01 (-1.57)	-0.01 (-1.76) *	0.00 (0.31)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	-0.01 (-0.37)	-0.02 (-1.01)	-0.01 (-0.51)	-0.02 (-1.38)
Intra-industry regional subsidies only	-0.01 (-1.21)	0.00 (0.38)	0.01 (1.23)	0.00 (0.39)
Intra-industry partial exemption only	0.02 (2.00) **	-0.00 (-0.89)	-0.00 (-0.72)	0.00 (0.26)
Intra-industry CIT incentives only	0.00 (0.66)	0.00 (1.55)	-0.00 (-0.15)	-0.00 (-0.47)
Intra-industry combined support	0.02 (1.43)	0.00 (0.20)	-0.00 (-0.01)	0.03 (3.05) ***
Inter-industry no support	0.29 (0.79)	-0.25 (-0.76)	0.01 (0.98)	0.04 (2.44) **
Inter-industry regional subsidies only	0.01 (2.12) **	-0.00 (-0.30)	-0.01 (-0.98)	-0.00 (-0.41)
Inter-industry partial exemption only	-0.02 (-2.16) **	0.00 (0.11)	0.00 (0.46)	-0.00 (-1.25)
Inter-industry CIT incentives only	-0.00 (-0.47)	-0.00 (-1.50)	0.00 (0.43)	0.00 (0.28)
Inter-industry combined support	0.07 (0.62)	-1.03 (-1.56)	0.07 (0.37)	-0.05 (-3.48) ***
R-squared (within)	0.53	0.48	0.31	0.53
Number of observations	2,483	2,323	1,525	3,334

Note: The table shows the results of a fixed effects panel regression by Pavitt category (see Annex 2 for a list of two-digit NACE industries by category). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 latter result suggests that R&D activities of suppliers may weaken the bargaining position of firms in supplier-dominated industries. In science-based industries, firms appear to benefit most from R&D of firms in the same industry which only use partial exemption as public support and R&D of firms, in other industries, that use regional subsidies but receive no tax support.

In Table 18, the potential role of market concentration in input additionality is investigated by considering separate regressions for each quartile of industries, ranked in increasing order of the Herfindahl-Hirschman indicator, a proxy measure of market concentration (the higher the indicator, the higher market concentration and the lower competition is assumed to be). Table 42 considers the same quartiles to assess potential differences in output additionality and spillovers by level of market concentration. The statistically significant indications of a substantial return to self-financed R&D and R&D financed with regional subsidies is confirmed for all quartiles of market concentration. The return to own R&D clearly decreases with increasing market concentration. Only for the partial exemption for R&D employees with a master’s degree in the two highest quartiles of market concentration, the coefficient is statistically significant negative. The coefficients of all four corporate income taxation incentives are statistically significant in all four quartiles with the smallest coefficients in the most concentrated industries. Only in industries with medium-high market concentration (third HHI quartile) are there indications of statistically significant positive spillovers, in effect, spillovers of R&D by firms in the same industry that only benefit from partial exemption or that combine at least two of the three main public support categories. This result could be indicative of the inverted-U relationship between competition and innovation, proposed by Aghion et al. (2005), that results from too much competition discouraging laggard firms to invest in innovation activities and a lack of sufficient competition that takes the pressure off frontier firms to keep investing in innovation. The statistically significant negative coefficient in highly concentrated industries, of R&D by firms in the same industry, that do not receive any public support, may point at the incentive for imitation by entrants (and laggards), encouraged by potentially high post-entry rents. The estimates of spillovers provide statistically significant opposite signs for industries with medium-high market concentration (third quartile HHI), in effect, positive intra-industry spillovers and negative inter-industry spillovers. Leppälä (2020) points out that few studies consider both intra- and inter-industry knowledge spillovers. The theoretical model proposed by the author shows that the impact of product variety and market concentration on R&D effort and industry output depends on the rate of both types of spillovers as well as on the degree of product differentiation and that the combination of intra- and inter-industry spillovers can also result in an inverted-U relationship between competition and innovation. As variety and concentration can have opposite effects on innovation and output, the model also indicates that the choice of the output measure is not trivial. For certain parameters, the model predicts that concentration may increase R&D effort but decrease industry output.

Table 42 Results of a panel estimation of the impact of public support on labour productivity, by degree of market concentration

	Low 1st quartile HHI	Medium-low 2nd quartile HHI	Medium-high 3rd quartile HHI	High 4th quartile HHI
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.32 (11.50) ***	0.28 (9.99) ***	0.27 (12.41) ***	0.22 (8.92) ***
R&D expenditures financed by public support:				
Regional subsidies	0.66 (10.64) ***	0.63 (8.84) ***	0.64 (12.15) ***	0.49 (9.42) ***
Research cooperation	-0.00 (-0.53)	0.01 (1.49)	-0.00 (-0.86)	-0.00 (-0.37)
Young Innovative Company	0.00 (0.39)	0.01 (0.61)	-0.01 (-1.25)	0.00 (0.14)
PhDs and civil engineers	-0.01 (-1.50)	-0.00 (-1.00)	-0.00 (-0.07)	-0.00 (-0.33)
Master	-0.01 (-1.04)	-0.01 (-1.07)	-0.01 (-2.50) **	-0.01 (-1.86) *
Bachelor	0.01 (1.71) *	-0.01 (-1.52)	0.01 (1.02)	-0.00 (-0.54)
Tax credit R&D	0.04 (3.05) ***	0.07 (5.64) ***	0.06 (5.68) ***	0.03 (4.08) ***
Tax deduction R&D°	0.06 (5.38) ***	0.07 (7.24) ***	0.06 (5.69) ***	0.04 (4.43) ***
Patent income deduction	0.06 (6.43) ***	0.06 (5.66) ***	0.05 (4.57) ***	0.03 (4.38) ***
Innovation income deduction	0.04 (4.45) ***	0.01 (0.93)	0.01 (0.80)	0.03 (4.01) ***
Innovation bonus	0.00 (0.39)	0.01 (1.49)	0.00 (0.08)	0.01 (1.43)
EU Funding	0.00 (0.23)	0.00 (0.22)	0.00 (0.54)	-0.03 (-1.03)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	-0.02 (-0.42)	-0.02 (-0.81)	-0.01 (-0.33)	-0.01 (-1.94) *
Intra-industry regional subsidies only	-0.01 (-0.23)	0.00 (0.22)	-0.01 (-0.81)	0.00 (0.59)
Intra-industry partial exemption only	0.04 (0.77)	0.01 (1.58)	0.01 (1.78) *	-0.00 (-0.73)
Intra-industry CIT incentives only	0.01 (1.14)	0.01 (1.08)	-0.00 (-0.51)	0.00 (0.27)
Intra-industry combined support	-0.04 (-0.85)	0.01 (0.73)	0.03 (2.21) **	0.01 (1.54)
Inter-industry no support	-0.86 (-1.84) *	0.07 (0.25)	-0.29 (-0.53)	0.00 (0.05)
Inter-industry regional subsidies only	0.01 (0.67)	-0.00 (-0.30)	0.01 (1.39)	-0.00 (-0.63)
Inter-industry partial exemption only	-0.04 (-0.85)	-0.01 (-1.76) *	-0.01 (-2.04) **	-0.00 (-1.42)
Inter-industry CIT incentives only	-0.01 (-1.12)	-0.01 (-1.36)	0.00 (0.48)	0.00 (0.53)
Inter-industry combined support	-0.54 (-1.13)	0.33 (1.29)	0.10 (0.71)	0.00 (0.58)
R-squared (within)	0.48	0.48	0.52	0.46
Number of observations	2,534	2,663	2,629	2,371

Note: The table shows the results of a fixed effects panel regression by quartile of market concentration (measured by the Herfindahl-Hirschman Index - HHI). Industries are grouped by the average HHI, computed as the sum of the squared market shares of firms within the industry. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 43 shows the results of separate regressions for firms grouped by quartile of the distance to the industry frontier, measured as the difference between the industry-year 90th percentile labour productivity level and the labour productivity level of a firm. The high positive return to self-financed R&D and R&D financed with regional subsidies is confirmed for all four quartiles but the relationship, between the return and the distance to the industry frontier is U-shaped with higher returns for the most productive firms and even more so for the least productive firms, relative to firms at a medium-low or medium-high distance to the industry frontier. The large coefficients for firms that are furthest away from the industry frontier indicate that laggard firms can catch up through R&D activities. Laggard firms also have the largest return to R&D financed with corporate income taxation incentives. The most productive firms do not seem to benefit from positive spillovers but are negatively affected by R&D in the same industry of firms that do not receive any public support for their R&D activities, which may suggest that these activities imply more imitation than innovation and therefore result in business stealing. The coefficient of intra-industry spillovers of firms that do not receive any public support is also statistically significant negative for the second and third quartile of the distance to the industry frontier. The impact of intra-industry spillovers of firms that combine at least two of the three main public support categories is only statistically significant positive for firms with a medium-low and medium-high distance to the industry frontier. For firms at a medium-high distance to the industry frontier, inter-industry spillovers from R&D by firms that combine at least two of the three main public support categories are also statistically significant positive and rather substantial. On the other hand, for this group of firms, the coefficients of two inter-industry spillovers, are statistically significant negative. Finally, for the least productive firms, only the coefficient of R&D by firms in the same industry that received direct support (regional subsidies) but no tax support, is statistically significant positive.

Spillovers are often argued to be localized (Crowley and Jordan 2022) which obviously raises the question which geographical level can be considered as ‘local’. Estimations in which, alternatively, the three Belgian regions and the 43 administrative districts (see Graph 9), are considered as geographical areas to compute intra-region (intra-district) and inter-region (inter-district) spillover variables (similar to industry spillovers but using the region/district code rather than the NACE code) provide no statistically significant coefficient for any spillover variable, except for two when productivity growth is considered but even then the coefficients are only significant at 10%.[44] According to Arqué-Castells and Spulber (2022) localized spillovers tend to capture market transfers more than non-market knowledge flows although they point out the difficulty in distinguishing between effects resulting from market transactions and spillovers, in the strict sense of non-market externalities.

To prevent readers from getting lost in the multitude of estimations, summarizing the conclusions regarding R&D spillovers on productivity, there are indications of positive spillovers from R&D of other firms but also indications of a negative impact, which hints at business-stealing effects and potential overinvestment in R&D. The magnitude of estimated spillovers is generally rather small and there is substantial heterogeneity across firms and industries. The most robust result appears to be a positive impact of R&D performed by firms that combine at least two of the three main public support categories (subsidies, partial exemption, and corporate income taxation incentives) on the productivity of other firms.

44 These results are not reported but available upon request.

Table 43 Results of panel estimation of the impact of public support on labour productivity, by distance to the industry frontier

	Low distance 1st quartile DTF	Medium-low distance 2nd quartile DTF	Medium-high distance 3rd quartile DTF	High distance 4th quartile DTF
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.16 (9.33) ***	0.08 (5.94) ***	0.07 (6.09) ***	0.25 (8.95) ***
R&D expenditures financed by public support:				
Regional subsidies	0.34 (9.23) ***	0.17 (6.47) ***	0.18 (7.11) ***	0.55 (8.41) ***
Research cooperation	-0.00 (-0.76)	0.00 (0.41)	-0.00 (-1.04)	0.00 (0.40)
Young Innovative Company	-0.01 (-1.38)	-0.00 (-0.58)	-0.00 (-0.19)	-0.00 (-0.08)
PhDs and civil engineers	-0.01 (-1.83) *	0.00 (0.00)	-0.00 (-1.05)	-0.00 (-0.39)
Master	-0.01 (-2.67) ***	0.00 (0.20)	-0.00 (-0.35)	-0.01 (-1.47)
Bachelor	0.01 (1.50)	-0.00 (-1.25)	-0.00 (-0.63)	-0.01 (-1.12)
Tax credit R&D	0.02 (4.70) ***	0.02 (4.03) ***	0.01 (2.83) ***	0.07 (6.14) ***
Tax deduction R&D°	0.02 (4.54) ***	0.01 (3.14) ***	0.02 (4.63) ***	0.06 (4.42) ***
Patent income deduction	0.02 (4.41) ***	0.01 (4.29) ***	0.02 (4.25) ***	0.05 (4.44) ***
Innovation income deduction	0.02 (3.30) ***	0.01 (1.87) *	0.01 (1.03)	0.03 (1.47)
Innovation bonus	0.00 (0.24)	0.00 (0.51)	0.01 (1.70) *	0.00 (0.94)
EU Funding	0.00 (0.91)	-0.00 (-0.66)	-0.00 (-0.58)	-0.00 (-0.13)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	-0.01 (-1.67) *	-0.02 (-2.61) ***	-0.02 (-2.26) **	-0.00 (-0.51)
Intra-industry regional subsidies only	0.00 (0.33)	-0.00 (-0.20)	0.01 (1.42)	0.01 (2.13) **
Intra-industry partial exemption only	-0.00 (-1.18)	-0.01 (-2.80) ***	0.01 (1.61)	0.00 (0.11)
Intra-industry CIT incentives only	-0.01 (-1.53)	-0.00 (-0.34)	0.00 (0.69)	0.00 (1.18)
Intra-industry combined support	0.01 (1.25)	0.03 (3.92) ***	0.02 (1.95) *	0.00 (0.44)
Inter-industry no support	0.09 (1.01)	-0.08 (-1.06)	-0.38 (-2.18) **	-0.14 (-0.53)
Inter-industry regional subsidies only	-0.00 (-0.60)	0.00 (0.46)	-0.00 (-1.38)	-0.00 (-1.13)
Inter-industry partial exemption only	-0.00 (-0.66)	0.00 (0.78)	-0.01 (-3.17) ***	0.00 (0.15)
Inter-industry CIT incentives only	0.00 (1.17)	0.00 (0.58)	-0.00 (-0.05)	-0.00 (-1.41)
Inter-industry combined support	-0.08 (-1.02)	0.08 (1.14)	0.17 (1.89) *	-0.05 (-0.38)
R-squared (within)	0.45	0.36	0.31	0.47
Number of observations	2,684	2,839	2,426	2,248

Note: The table shows the results of a fixed effects panel regression by quartile of the distance to the industry frontier, defined as the 90Th percentile of labour productivity by industry and year minus labour productivity of the firm. The first quartile contains firms that have productivity above or close to the frontier and the fourth quartile contains firms with productivity furthest below the industry frontier. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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.

This positive impact applies especially to old firms (and not to young firms), firms that belong to a multinational group (and not to independent domestic firms), firms with persistent R&D activities, firms with medium-low and medium-high distance to the industry productivity frontier, and firms in industries with medium-high market concentration and in supplier-dominated industries.

Results of alternative separate regressions for specific industries and specific groups of firms are reported in Annex 8. Table A8.1 shows the results of regressions for industries ranked by the average level of intangible assets and Table A8.2 for industries ranked by ICT Intensity. Table A8.3 shows the results by quartile, with firms ranked by liquidity (acid test ratio), Table A8.4 the results by quartile, with firms ranked by solvency (long-term financial independence) and Table A8.5 the results by quartile, with firms ranked by profitability. These results are not discussed in detail, only the most noticeable findings are pointed out.

In terms of industries ranked by average level of intangible assets (Table A8.1), the most distinct result appears to be that the coefficient of intra-industry spillovers from firms that combine at least two of the three main public support categories is statistically significant for all four quartiles, but it is negative for industries with the lowest average intangible assets (1st quartile) and positive for the three other quartiles. This indicates that firms in low-intangible intensive industries do not appear to be able to absorb the results of R&D by other firms in the industry although they do succeed in generating a large return from self-financed R&D and R&D financed through regional subsidies.

The return to self-financed R&D and R&D financed with regional subsidies is higher the more ICT intensive the industry in which the firm operates (Table A8.2). On the other hand, firms in low ICT intensive industries benefit from spillovers of R&D by firms in the same industry that only use corporate income taxation incentives and from R&D by firms in other industries, that use regional support but no tax benefits. The coefficients of these spillover variables are only statistically significant at 10% and the coefficient of intra-industry spillovers from R&D of firms that only use regional subsidies, is statistically significant negative. Only firms in the most ICT intensive industries seem to benefit from intra-industry spillovers from R&D of firms that combine ate least two of the three main public support categories. However, in the most ICT intensive industries, three coefficients of the spillover variables are statistically significant negative. The coefficient of inter-industry spillovers from R&D by firms that combine at least two of the three main public support categories is very large.

In terms of financial indicators, firms with the lowest liquidity (Table A8.3), the lowest solvency (Table A8.4) and the lowest profitability (Table A8.5) seem to be able to generate a substantial return from self-financed R&D and R&D financed with regional subsidies but not to be able to absorb spillovers from R&D by other firms. For the lowest quartile of these three financial indicators, the only coefficients of the spillover variables that are statistically significant, are negative. Only for higher quartiles some of the coefficients of the spillover variables are statistically significant positive.

Table A8.6 shows the results for a regression in which multi factor productivity is considered as the dependent variable instead of labour productivity. Multi factor productivity considers all, or most, input factors and not only labour. Multi factor productivity is in principle preferred to labour productivity as a measure of the technical efficiency of firms, but the estimation is fraught with several well-known limitations. Estimations using a control function approach to account for potential endogeneity results in unreliable coefficient estimates and are therefore not used. The results reported in Table A8.6 use multi factor productivity from an Ordinary Least Squares estimation, using alternatively turnover and value added as output variable. The coefficient estimates are also not very reliable but less so than for the control function approach estimates.[45] Using multi factor productivity suggests a somewhat unlikely statistically significant negative return to self-financed R&D. The coefficients of R&D financed with regional subsidies and R&D by other firms in the same industry, that use at least two of the three main support categories are all statistically significant positive, both when using turnover and value added as output measure.

As pointed out before, it is not obvious which measure needs to be considered to assess the results of R&D activities. Rather than considering productivity, Table 44 considers the impact on turnover, value added and the number of employees (FTE) and Table 45 the impact on the growth in these three variables.

According to the results in Table 44, the impact of self-financed R&D on turnover is statistically significant negative and the impact on the number of employees (FTE) statistically significant positive. As with labour productivity, the impact of R&D financed through regional is statistically significant positive and considerable, both for turnover and value added, as well as for the number of employees although this coefficient is smaller. In contrast with the estimations with labour productivity as output measure, some coefficients of the partial exemption schemes are statistically significant positive. For example, the coefficient of the partial exemption for R&D employees with a master's degree is statistically significant positive, both for turnover and value added. The coefficient of the patent income deduction and the innovation income deduction is also statistically significant positive for turnover and the number of employees. When considering turnover as output, the positive coefficient of intra-industry spillovers from R&D of firms that combine at least two of the three main public support categories is statistically significant but so is the negative coefficient of inter-industry spillovers from R&D of firms that use regional subsidies but no tax incentives. When considering value added, the latter coefficient is statistically significant positive. The R-squared of the regression using value added as output measure is rather low (0.05) indicating that the independent variables do not explain much of the variance in value added. The coefficient of inter-industry spillovers of R&D by non-supported firms is statistically significant negative in the estimation that considers the number of employees as output variable.

In contrast with the level of turnover, self-financed R&D has a statistically significant positive impact on turnover growth (Table 45), but as for the public support variables, only the coefficient of the patent income deduction has a statistically significant positive coefficient. The impact of self-financed R&D is also statistically significant positive for growth in the number of employees. The coefficient of R&D financed through the partial exemption for R&D personnel with a bachelor's degree is statically positive and substantial in the estimation using growth in value added as dependent variable whereas the coefficient of R&D financed with EU funding is statistically significant negative. For the turnover growth estimation, only one coefficient of the spillover variables is statistically significant positive and only one statistically significant negative, and even then, both are only significant at 10%.

45 A possible explanation may be that an estimation using multi factor productivity is more biased due to double counting of R&D factor input (see footnote 41 on page 106) than labour productivity, as the latter does not consider capital and therefore avoids the double counting of capital used for R&D.

Table 44 Results of a panel estimation of the impact of public support on turnover, value added and number of employees

Dependent variable:	Turnover	Value added	Number of Employees (FTE)
R&D expenditures financed by firm	-0.02 (-2.95) ***	-0.09 (-1.27)	0.03 (4.89) ***
R&D expenditures financed by public support:			
Regional subsidies	0.51 (9.10) ***	1.11 (2.14) **	0.26 (5.52) ***
Research cooperation	0.01 (1.49)	0.03 (0.51)	-0.00 (-0.85)
Young Innovative Company	-0.00 (-0.21)	0.06 (0.40)	-0.01 (-1.25)
PhDs and civil engineers	0.01 (1.80) *	0.05 (1.12)	0.00 (0.93)
Master	0.01 (2.56) ***	0.08 (1.64) *	-0.00 (-0.34)
Bachelor	-0.00 (-0.20)	-0.01 (-0.14)	0.00 (0.84)
Tax credit R&D	-0.00 (-0.14)	0.04 (0.57)	0.00 (0.48)
Tax deduction R&D°	0.01 (1.14)	0.09 (1.12)	0.01 (1.21)
Patent income deduction	0.01 (1.65) *	0.09 (1.33)	0.01 (2.51) **
Innovation income deduction	0.01 (2.44) **	0.01 (0.31)	0.01 (3.20) ***
Innovation bonus	-0.00 (-0.11)	-0.01 (-0.20)	0.00 (0.05)
EU Funding	0.00 (0.21)	-0.02 (-0.61)	0.00 (1.68) *
R&D expenditures of other firms (spillovers):			
Intra-industry no support	-0.00 (-0.72)	-0.03 (-0.87)	0.00 (1.06)
Intra-industry regional subsidies only	0.00 (0.82)	-0.05 (-1.52)	-0.00 (-0.71)
Intra-industry partial exemption only	-0.00 (-1.17)	0.03 (1.57)	0.00 (0.17)
Intra-industry CIT incentives only	0.00 (0.35)	-0.02 (-0.64)	-0.00 (-0.07)
Intra-industry combined support	0.01 (2.60) ***	0.08 (1.59)	-0.00 (-0.26)
Inter-industry no support	0.00 (1.18)	-0.01 (-0.26)	-0.01 (-3.02) ***
Inter-industry regional subsidies only	-0.01 (-1.99) **	0.04 (1.87) *	-0.00 (-1.18)
Inter-industry partial exemption only	0.00 (0.37)	0.01 (0.30)	0.00 (0.37)
Inter-industry CIT incentives only	0.00 (0.27)	0.02 (0.83)	-0.00 (-0.15)
Inter-industry combined support	-0.01 (-1.52)	-0.05 (-1.24)	0.00 (0.53)
R-squared (within)	0.34	0.05	0.21
Number of observations	10,965	7,104	10,705

Note: The table shows the results of a fixed effects panel regression, using alternatively turnover (in logs), value added (Inverse Hyperbolic Sine), and the number of employees (FTE), as output measure. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 45 Results of panel estimation of the impact of public support on growth in turnover, value added and the number of employees (FTE)

Dependent variable:	Turnover	Value added	Number of Employees (FTE)
R&D expenditures financed by firm	0.02 (2.95) ***	-0.02 (-0.21)	0.01 (3.25) ***
R&D expenditures financed by public support:			
Regional subsidies	0.00 (1.43)	0.03 (1.35)	0.00 (1.12)
Research cooperation	0.00 (0.37)	-0.01 (-0.18)	0.00 (1.36)
Young Innovative Company	0.00 (0.60)	0.03 (0.44)	0.01 (3.06) ***
PhDs and civil engineers	-0.00 (-0.01)	-0.06 (-1.37)	-0.00 (-0.81)
Master	0.00 (1.33)	0.01 (0.17)	-0.00 (-0.34)
Bachelor	-0.00 (-0.46)	0.09 (2.47) ***	0.00 (0.83)
Tax credit R&D	-0.01 (-2.24) **	0.06 (0.89)	-0.00 (-1.72) *
Tax deduction R&D°	-0.00 (-0.45)	-0.00 (-0.12)	-0.00 (-0.49)
Patent income deduction	0.01 (3.10) ***	0.03 (0.66)	-0.00 (-1.01)
Innovation income deduction	0.01 (1.67) *	-0.02 (-0.27)	-0.00 (-1.27)
Innovation bonus	0.00 (0.10)	-0.03 (-0.98)	-0.00 (-0.74)
EU Funding	-0.00 (-0.62)	-0.06 (-1.99) *	-0.00 (-0.13)
R&D expenditures of other firms (spillovers):			
Intra-industry no support	-0.00 (-0.32)	0.07 (0.87)	-0.00 (-0.91)
Intra-industry regional subsidies only	0.00 (0.29)	-0.05 (-1.42)	0.01 (1.57)
Intra-industry partial exemption only	-0.00 (-0.49)	0.02 (0.80)	0.00 (0.87)
Intra-industry CIT incentives only	-0.01 (-1.75) *	-0.04 (-0.79)	-0.00 (-0.58)
Intra-industry combined support	-0.00 (-0.12)	-0.01 (0.15)	0.00 (0.16)
Inter-industry no support	0.00 (1.11)	-0.03 (-1.15)	0.00 (0.67)
Inter-industry regional subsidies only	-0.01 (-1.59)	0.05 (1.60)	-0.00 (-1.43)
Inter-industry partial exemption only	0.00 (1.25)	0.03 (0.88)	-0.00 (-0.58)
Inter-industry CIT incentives only	0.00 (1.92) *	0.03 (0.87)	0.00 (0.86)
Inter-industry combined support	0.00 (0.17)	-0.04 (-0.99)	0.01 (2.80) ***
R-squared (within)	0.04	0.02	0.18
Number of observations	10,443	6,786	10,223

Note: The table shows the results of a fixed effects panel regression, using alternatively turnover growth, value-added growth, and growth in the number of employees (FTE), as output measure. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 low R-squared of the regressions in Table 45 indicate that the independent variables do not explain much of the variance in the growth in turnover or value added. In the estimation using growth in the number of employees, the coefficient of inter-industry spillovers from R&D financed through a combination of direct and tax support is statically significant positive.

Table 46 shows the results of regressions in which the profit level and the profit rate are alternatively considered as output measure and Table 47 shows the results of regressions in which the growth in the profit level and the growth in the profit rate are considered. The R-squared of all regressions in Table 46 and 47 is low, again indicating that the independent variables that are included do not explain much of the variance in the dependent variables. None of the coefficients of self-financed R&D are statistically significant positive. The coefficient of R&D financed through direct support is statistically significant positive and unlikely large in the regression considering the profit level.

Table 46 Results of panel estimation of the impact of public support on profit

Dependent variable:	Profit	Profit rate
R&D expenditures financed by firm:	-0.20 (-1.51)	0.01 (0.81)
R&D expenditures financed by public support:		
Regional subsidies	2.55 (3.57) ***	-0.07 (-0.80)
Research cooperation	0.19 (2.22) **	0.01 (1.43)
Young Innovative Company	0.21 (1.59)	0.01 (0.99)
PhDs and civil engineers	0.18 (2.63) ***	0.00 (1.38)
Master	0.10 (1.32)	0.01 (1.85) *
Bachelor	0.11 (1.32)	-0.00 (-0.12)
Tax credit R&D	0.14 (0.83)	-0.00 (-0.03)
Tax deduction R&D°	-0.01 (-0.07)	0.00 (0.51)
Patent income deduction	0.27 (1.77) *	0.01 (1.58)
Innovation income deduction	0.16 (1.08)	0.00 (0.51)
Innovation bonus	-0.09 (-0.89)	-0.01 (-1.90) *
EU Funding	0.13 (1.88) *	0.00 (0.10)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	-0.04 (-0.28)	-0.00 (-0.83)
Intra-industry regional subsidies	0.07 (0.92)	-0.00 (-0.03)
Intra-industry partial exemption	-0.02 (-0.29)	-0.01 (-2.17) **
Intra-industry CIT incentives	0.18 (2.60) ***	-0.00 (-1.27)
Intra-industry combined support	0.02 (0.14)	0.01 (0.90)
Inter-industry no support	-0.18 (-1.46)	0.00 (0.26)
Inter-industry regional subsidies	-0.04 (-0.59)	-0.00 (-0.03)
Inter-industry partial exemption	-0.05 (-0.86)	0.00 (0.77)
Inter-industry CIT incentives	-0.11 (-2.10) **	0.00 (1.25)
Inter-industry combined support	0.45 (1.17)	-0.01 (-0.97)
R-squared	0.04	0.02
Number of observations	10,790	11,060

Note: The table shows the results of a fixed effects panel regression, using alternatively total profits and the profit rate (return on equity) as profit measure. For total profits, the Inverse Hyperbolic Sine (IHS) transformation is considered to account for firms with a loss. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of the profit variable 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 47 Results of panel estimation of the impact of public support on profit growth

Dependent variable:	Profit	Profit rate
R&D expenditures financed by firm:	-0.19 (-1.37)	-0.00 (-0.15)
R&D expenditures financed by public support:		
Regional subsidies	0.05 (1.14)	0.01 (1.89) *
Research cooperation	-0.14 (-1.34)	-0.00 (-0.28)
Young Innovative Company	0.35 (2.16) **	0.00 (0.05)
PhDs and civil engineers	-0.05 (-0.65)	0.00 (1.00)
Master	0.13 (2.15) **	-0.00 (-0.91)
Bachelor	-0.09 (-1.07)	0.00 (0.10)
Tax credit R&D	-0.00 (-0.02)	-0.00 (-0.17)
Tax deduction R&D°	0.26 (2.61) ***	0.01 (1.45)
Patent income deduction	0.47 (3.80) ***	0.01 (2.29) **
Innovation income deduction	0.44 (3.75) ***	0.02 (3.27) ***
Innovation bonus	0.10 (0.86)	0.00 (0.05)
EU Funding	0.06 (0.87)	0.01 (1.48)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	-0.18 (-1.02)	-0.00 (-0.18)
Intra-industry regional subsidies	0.09 (0.89)	0.00 (0.78)
Intra-industry partial exemption	0.04 (0.47)	-0.01 (-1.52)
Intra-industry CIT incentives	0.07 (0.85)	0.00 (0.88)
Intra-industry combined support	0.12 (0.64)	0.00 (0.39)
Inter-industry no support	-0.18 (-1.34)	-0.01 (-1.60)
Inter-industry regional subsidies	-0.06 (-0.77)	0.00 (0.02)
Inter-industry partial exemption	-0.05 (-0.61)	0.00 (0.26)
Inter-industry CIT incentives	-0.08 (-1.18)	-0.00 (-0.85)
Inter-industry combined support	0.45 (1.13)	-0.01 (-1.91) *
R-squared	0.04	0.02
Number of observations	10,259	10,528

Note: The table shows the results of a fixed effects panel regression, using alternatively growth in total profits and the profit rate (return on equity) as output measure. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of the profit variable 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.

In this regression, two coefficients of the partial exemption schemes (research cooperation and R&D employees with a PhD or civil engineering degree) are also statistically significant positive and rather considerable. When considering the profit level there are statistically significant indications of positive intra-industry spillovers from R&D of firms that only use corporate income taxation incentives but also of negative inter-industry spillovers from R&D of firms that only use corporate income taxation incentives. When considering the profit rate few coefficients of the direct impact of R&D are statistically significant and only the negative coefficient of intra-industry spillovers from R&D of firms that only use partial exemption is statistically significant. Considering the growth variables (Table 47), the coefficients of two partial exemption schemes and three corporate income taxation incentives are statistically significant positive and rather substantial in the regression of profit growth. Only one coefficient of the spillover variables is statistically significant (at 10%) in the profit rate growth regression, the negative coefficient of inter-industry spillovers from R&D by firms that combine at least two of the three main public support categories.

Table 48 shows the results of a regression of the impact of own R&D, and R&D by other firms, on liquidity (acid test ratio) and solvency (long-term financial independence). The coefficient of self-financed R&D in the estimation with liquidity as dependent variable is statistically significant positive and substantial. Some of the coefficients of R&D financed through public support are statistically significant negative, with an especially large negative coefficient of R&D financed with direct support. The coefficient of R&D by firms in other industries that do not receive any public support is also statistically significant negative. As pointed out before, Lahr and Mina (2021) argue that the relationship between financial constraints, R&D and innovation is not straightforward and provide some evidence for the UK that new-to-market innovation may cause financial constraints. This could explain some of the surprising negative coefficients for R&D financed with public support although as also mentioned before, according to Farre-Mensa and Ljungqvist (2016), most proxies of financial constraints do not very well capture constraints but rather reflect differences in the growth and financing policies of firms at different stages of their life cycles. In the estimation using solvency as the dependent variable, only the large positive coefficient of R&D financed with regional subsidies is statistically significant, possibly explained by a positive signalling effect. Using data on regional innovation subsidies for SMEs in Belgium (Flemish region), for the period 1995–2004, Meuleman and De Maeseneire (2012) found indications that receiving subsidies increases access to external financing of SMEs, through a process of certification (granting of a subsidy provides an indication of the quality of the project and the company). In their study, the signal effect is stronger for long-term debt than for short- term debt and stronger for debt financing than for equity financing although the authors provide the caveat that their data did not allow them to distinguish between equity provided by insiders or outsiders.

Patents are often considered as an indicator of intermediate output of R&D, but their role in promoting R&D and innovation is highly debated. Okamuro (2007) found little overlap in the determinants of the technological success (patents) and the commercial success (sales growth) of R&D cooperation in Japan. Argente et al. (2020) and Baslandze (2021) provide evidence for the US that large firms use non-productive patenting to protect their market position and limit the entry of, and innovation by, competitors. Whereas Neves et al. (2021) conclude from their meta-analysis that intellectual property rights have an overall positive impact on innovation and growth, the meta-analysis by Churchill, Luong and Ugur (2022) leads the authors to conclude that the effect of intellectual property rights on innovation, technology diffusion, productivity, and economic growth is statistically or practically insignificant. In a survey of the literature, Sampat (2018) argues that evidence that patents hinder follow-on innovation is mixed, that a considerable share of innovation occurs without patenting and that patents are important for firms to appropriate returns from R&D in some fields but are used for other strategic purposes in other fields. Or put differently, the evidence is rather mixed.

Using available information, Table 49 shows the results of a regression of the impact of own R&D and R&D by other firms on the number of Belgian granted patents and patent application by Belgian firms at the European Patent Office (EPO).

Table 48 Results of panel estimation of the impact of public support on liquidity and solvency

Dependent variable:	Liquidity (Acid test ratio)	Solvency (LT financial independence)
R&D expenditures financed by firm:	0.23 (8.51) ***	0.02 (0.31)
R&D expenditures financed by public support:		
Regional subsidies	-3.89 (-11.88) ***	1.17 (5.98) ***
Research cooperation	0.02 (1.81) *	0.01 (0.47)
Young Innovative Company	-0.03 (-1.36)	-0.01 (-0.16)
PhDs and civil engineers	-0.01 (-0.77)	-0.01 (-0.37)
Master	0.01 (1.61)	-0.03 (-1.24)
Bachelor	-0.02 (-1.76) *	0.01 (0.55)
Tax credit R&D	-0.05 (-2.08) **	0.04 (1.07)
Tax deduction R&D°	-0.03 (-1.20)	0.01 (0.31)
Patent income deduction	-0.02 (-0.98)	0.02 (0.71)
Innovation income deduction	0.01 (0.29)	0.06 (1.41)
Innovation bonus	-0.02 (-2.23) **	-0.01 (-0.25)
EU Funding	-0.02 (-2.22) **	0.01 (1.03)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	0.01 (0.56)	0.02 (0.77)
Intra-industry regional subsidies	-0.00 (-0.04)	0.02 (0.86)
Intra-industry partial exemption	0.00 (0.76)	0.00 (0.01)
Intra-industry CIT incentives	-0.01 (-0.61)	0.01 (0.46)
Intra-industry combined support	-0.01 (-0.67)	-0.06 (-1.30)
Inter-industry no support	-0.02 (-3.36) ***	- 0.02 (-1.02)
Inter-industry regional subsidies	0.00 (0.32)	-0.01 (-0.52)
Inter-industry partial exemption	-0.01 (-1.28)	-0.01 (-0.58)
Inter-industry CIT incentives	0.00 (0.55)	0.00 (0.16)
Inter-industry combined support	-0.01 (0.67)	-0.02 (-0.03)
R-squared	0.23	0.08
Number of observations	11,167	6,473

Note: The table shows the results of a fixed effects panel regression, using alternatively liquidity (acid test ratio) and solvency (long-term financial independence) as dependent variable. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of the relevant financial indicator 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 49 Results of a zero-inflated Poisson regression of the impact of public support on the number of patents

Dependent variable:	Belgian patents	European patents (EPO)
R&D expenditures financed by firm:	0.07 (2.64) ***	0.05 (0.94)
R&D expenditures financed by public support:		
Regional subsidies	-0.10 (-3.20) ***	-0.07 (-3.41) ***
Research cooperation	-0.05 (-2.63) ***	-0.00 (-0.08)
Young Innovative Company	0.02 (0.24)	0.00 (0.02)
PhDs and civil engineers	-0.05 (-3.41) ***	-0.01 (-0.86)
Master	-0.01 (-0.86)	-0.01 (-0.88)
Bachelor	-0.02 (-0.98)	-0.01 (-0.79)
Tax credit R&D	-0.05 (-2.97) ***	-0.04 (-4.32) ***
Tax deduction R&D°	-0.02 (-0.34)	-0.03 (-2.22) **
Patent income deduction	-0.00 (-0.02)	-0.05 (-4.09) ***
Innovation income deduction	0.01 (0.34)	-0.01 (-1.51)
Innovation bonus	0.05 (3.40) ***	0.05 (5.59) ***
EU Funding	-0.01 (-0.50)	-0.01 (-0.80)
R&D expenditures of other firms (spillovers):		
Intra-industry no support		-0.03 (-0.57)
Intra-industry regional subsidies		0.01 (0.46)
Intra-industry partial exemption		0.05 (1.41)
Intra-industry CIT incentives		0.02 (3.81) ***
Intra-industry combined support		0.10 (1.90) *
Inter-industry no support		-1.69 (-3.00) ***
Inter-industry regional subsidies		-0.01 (-0.22)
Inter-industry partial exemption		-0.03 (-0.87)
Inter-industry CIT incentives		-0.03 (-4.26)
Inter-industry combined support		1.46 (2.95) ***
Number of observations	18,246 (non-zero: 456)	11,499 (non-zero: 785)

Note: The table shows the results of a zero-inflated Poisson regression, using alternatively the number of patents granted to firms in Belgium and the number of patent application at the European Patent Office by Belgian firms as dependent variable and R&D expenditures of firms by group according to which type of public support that they receive, as explanatory variables. An estimation with the number of Belgian patents that includes spillover variables does not converge. The table therefore reports results of a specification without spillover variables. 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 dependent variable is a count variable that contains many zeros, as most R&D active companies do not have any patents or patent applications in the period under consideration. To account for the extreme skewness and the large number of zero value, zero-inflated Poisson regression is used. In addition to the number of observations, table 49 reports the number of non-zero values. The share of non-zero values is respectively 2.5% for Belgian patents and 6.8% for European patents.

The coefficient of self-financed R&D is positive for both Belgian and European patents, but only statistically significant for Belgian patents. Somewhat surprisingly, the only coefficients of R&D financed through public support that are statistically significant are negative, for example for R&D financed with regional subsidies or R&D financed with the tax credit for R&D investment, except for the coefficient of the innovation bonus which is statistically significant positive, both for Belgian and European patents.

The regression with Belgian patents as dependent variable does not include spillover variables because the regression with spillover variables fails to converge. In the regression with European patent applications, the coefficient of intra-industry R&D of firms that only receive public support through corporate income taxation incentives, and the coefficient of intra-industry and inter-industry R&D of firms that combine at least two of the three main public support categories, is statistically significant positive. The coefficient of R&D by firms in other industries that do not receive public support is statistically significant negative.

Table 50 and Table 51 show results of a zero-inflated Poisson regression with respectively the number of Belgian patents and the number of European patents, in which firms are grouped by firm ownership: domestic firms, firms that belong to a Belgian multinational group and firms that belong to a foreign-controlled multinational group. The results show substantial heterogeneity in the sign and statistical significance of the coefficients. Only for domestic firms is the coefficient of self-financed R&D statistically significant positive for both Belgian and European patents. The results of the spillover variables are rather mixed and differ substantially between the three groups. For domestic firms, the coefficients of the spillover variables that are statistically significant are all positive whereas for firms that belong to a multinational group the statistically significant coefficients have opposite signs.

A caveat that needs to be pointed out in the estimation of output additionality, as reported in this section, is that most indicators of firm performance may be biased due to income and profit shifting by multinational enterprises, which have a dominant position in the Belgian innovation ecosystem. From a meta-analysis of studies on the link between R&D expenditures and the effective corporate income tax rate, Belz, Hagen and Steffens (2017) conclude that 10% of the profit shifting effect results from R&D tax credits. Gaessler, Hall and Harhoff (2021) question whether tax benefits based on patent income (patent) effectively encourage innovation, rather than facilitate corporate income shifting to low tax countries. In a report requested by the subcommittee on Tax Matters of the European Parliament, Van de Velde and Cannas (2021) argue that patent boxes can be regarded as tax benefits that attract highly mobile capital and relocate corporate income, rather than promote innovation. The authors point out that despite the shortcomings of patent boxes, once several EU member states have them in force, other countries may be forced to introduce them to attract foreign investors.

Table 50 Results of a zero-inflated Poisson regression of the impact of public support on the number of Belgian patents

	Domestic	Belgian MNE	Foreign-controlled MNE group
Dependent variable: Number of Belgian patents (granted)			
R&D expenditures financed by firm	0.26 (4.31) ***	0.06 (1.40)	0.15 (1.92) *
R&D expenditures financed by public support:			
Regional subsidies	-1.38 (-5.06) ***	-0.15 (-2.78) ***	-0.03 (-0.69)
Research cooperation	-0.04 (-0.64)	-0.05 (-1.64) *	-0.13 (-2.25) **
Young Innovative Company	-0.07 (-1.29)	0.10 (1.10)	-3.88 (-30.81) ***
PhDs and civil engineers	-0.10 (-2.27) **	-0.07 (-4.52) ***	-0.07 (-2.02) **
Master	-0.07 (-1.58)	-0.05 (-2.29) **	0.02 (0.97)
Bachelor	-0.16 (-2.89) ***	-0.20 (-4.23) ***	-0.13 (-1.80) *
Tax credit R&D	0.07 (0.78)	-0.02 (-0.39)	-0.07 (-4.34) ***
Tax deduction R&D°	-2.69 (-12.24) ***	0.08 (2.02) **	-0.39 (-4.60) ***
Patent income deduction	0.03 (0.52)	0.10 (4.04) ***	-0.04 (-2.73) ***
Innovation income deduction	0.00 (0.09)	-0.00 (-0.12)	0.06 (2.79) ***
Innovation bonus	-0.13 (-2.89) ***	0.11 (5.17) ***	0.01 (0.30)
EU Funding	-0.04 (-0.93)	-0.03 (-0.88)	-0.02 (-0.73)
R&D expenditures of other firms (spillovers):			
Intra-industry no support	0.03 (0.18)	-0.05 (-0.34)	
Intra-industry regional subsidies only	-0.01 (-0.08)	0.02 (0.39)	
Intra-industry partial exemption only	-0.02 (-0.33)	0.05 (2.82) ***	
Intra-industry CIT incentives only	-0.10 (-1.29)	-0.03 (-1.40)	
Intra-industry combined support	0.20 (1.83) *	-0.07 (-0.55)	
Inter-industry no support	4.61 (1.83) *	-2.73 (-0.82)	
Inter-industry regional subsidies only	0.05 (0.79)	-0.05 (-1.19)	
Inter-industry partial exemption only	0.01 (0.20)	0.07 (1.28)	
Inter-industry CIT incentives only	0.03 (0.50)	0.02 (1.31)	
Inter-industry combined support	-1.08 (-0.75)	2.53 (0.85)	
Number of observations	6,508 (non-zero: 114)	2,568 (non-zero: 178)	3,652 (non-zero: 91)

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. Data on firm ownership is provided by Hambÿe et al. (2022). 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 patents (granted) 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 51 Results of a zero-inflated Poisson regression of the impact of public support on the number of European patents

	Domestic	Belgian MNE	Foreign-controlled MNE group
Dependent variable: Number of European patents (applications)			
R&D expenditures financed by firm	0.23 (2.89) ***	0.00 (0.02)	0.04 (1.18)
R&D expenditures financed by public support:			
Regional subsidies	-0.33 (-3.22) ***	-0.16 (-6.22) ***	-0.07 (-3.93) ***
Research cooperation	-0.04 (-1.29)	-0.01 (-0.91)	0.01 (0.85)
Young Innovative Company	0.03 (1.03)	0.07 (2.14) **	-0.14 (-3.11) ***
PhDs and civil engineers	0.08 (3.52) ***	-0.01 (-0.37)	-0.03 (-1.24)
Master	-0.07 (-2.73) ***	0.05 (4.16) ***	-0.04 (-3.79) ***
Bachelor	-0.08 (-2.00) **	-0.04 (-1.76) *	0.02 (0.84)
Tax credit R&D	-0.10 (-3.28) ***	-0.01 (-0.73)	-0.05 (-6.62) ***
Tax deduction R&D°	-0.08 (-2.09) **	-0.05 (-1.35)	-0.04 (-1.97) *
Patent income deduction	-0.01 (-0.45)	-0.00 (-0.40)	-0.06 (-3.59) ***
Innovation income deduction	-0.06 (-1.88) *	0.00 (0.19)	-0.03 (-1.56)
Innovation bonus	-0.03 (-0.74)	0.05 (3.03) ***	0.06 (6.03) ***
EU Funding	0.06 (1.89) *	0.01 (0.61)	0.00 (0.13)
R&D expenditures of other firms (spillovers):			
Intra-industry no support	0.18 (1.65) *	0.03 (0.55)	0.12 (1.90) *
Intra-industry regional subsidies only	0.04 (0.52)	-0.04 (-1.63) *	0.00 (0.03)
Intra-industry partial exemption only	-0.03 (-0.65)	0.03 (0.89)	0.08 (1.46)
Intra-industry CIT incentives only	-0.00 (-0.02)	0.02 (2.03) **	0.02 (2.11) **
Intra-industry combined support	0.13 (1.45)	-0.02 (-0.29)	0.21 (2.91) ***
Inter-industry no support	8.94 (3.14) ***	-0.19 (-0.39)	1.77 (1.09)
Inter-industry regional subsidies only	-0.01 (-0.14)	0.04 (1.59)	0.00 (0.09)
Inter-industry partial exemption only	0.04 (0.79)	0.00 (0.02)	-0.05 (-0.97)
Inter-industry CIT incentives only	0.02 (1.18)	-0.01 (-0.94)	-0.04 (-8.08) ***
Inter-industry combined support	0.26 (0.19)	0.12 (0.29)	1.72 (1.61)
Number of observations	6,508 (non-zero: 180)	2,568 (non-zero: 327)	2,423 (non-zero: 278)

Note: The table shows the results of a zero-inflated Poisson regression, using the number of patent application at the European Patent Office by Belgian firms, by group according to which type of public support that they receive, as explanatory variables. Data on firm ownership is provided by Hambÿe et al. (2022). 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 patent applications 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.

5. Conclusions

The results of the fourth evaluation of public support to business R&D in Belgium, presented in this report, provide robust indications that direct support (regional subsidies), and the partial exemption from payment of the withholding tax on the wages of R&D personnel, encourage companies to invest in R&D activities, in addition to the public support that they receive. This result is in line with previous evaluations. The finding of input additionality also holds for the partial exemption for R&D employees with a bachelor’s degree, which was introduced in 2018 and not included in previous evaluations.

Also in line with previous evaluations, there are no robust indications of input additionality for the tax credit for R&D investment and the patent income deduction. The tax deduction for R&D investment, which given partial information was not fully assessed in the previous evaluations, is found to result in additional R&D expenditures by companies. The most worrying finding of this fourth evaluation concerns the innovation income deduction. This corporate income taxation incentive was introduced in 2016 to replace the patent income deduction, which was phased out in 2021. The innovation income deduction was developed according to the Base Erosion and Profit Shifting (BEPS) guidelines of the OECD, which aim to tackle harmful tax avoidance by multinational enterprises. However, the estimations presented in this report provide robust indications of crowding out for this tax scheme, that is, it appears that the innovation income deduction is financing R&D expenditures that companies would finance themselves in the absence of the tax support. The fact that the corporate income taxation incentives, except for the tax deduction for R&D investment, seem ineffective or even result in crowding out, points at an opportunity to increase the efficiency of R&D tax benefits, especially considering that they claim the lion’s share of the budgetary cost of public support to business R&D in Belgium.

This fourth evaluation considers the effectiveness and efficiency of the innovation bonus, a compensation that is exempted from social security contributions, for workers that generate innovative ideas within a company, and EU funding of research. The estimates provide evidence of input additionality for the innovation bonus and robust indications of crowding out for EU funding.

Results of separate estimations for distinct groups of firms and industries along several dimensions, reveal substantial heterogeneity in the impact of public support, even with opposite signs for different groups of firms and industries, that may cancel each other out in estimations that consider all R&D active firms as a homogenous population. For example, it appears that the crowding-out effect of some corporate income taxation incentives mainly applies to large and older firms, firms that belong to a multinational group and to highly concentrated industries.

In line with the previous evaluations, there are clear indications that the combination of several schemes of direct and indirect support substantially reduces the effectiveness of individual support instruments. However, the combination of different support instruments does not appear to be the problem as such but rather the combination of large amounts of support without any limit as to the total amount of public support that companies receive. This is confirmed by the decrease in effectiveness of public support as total public support increases, both in terms of the rate of support and the total amount of support. The crowding out of corporate income taxation incentives is revealed at the highest levels of the total amount of public support. This suggests that the introduction of a cap on the total amount of public support for business R&D can contribute to an increase in the effectiveness and can be instrumental in containing the considerable rise in the budgetary cost of public support, which is predominantly due to those tax incentives that appear least effective. From an analysis of some 20 OECD countries, including Belgium, Appelt et al. (2020) conclude that R&D tax incentive schemes that cap the amount of supported R&D expenditures, or reduce the support rate once a certain threshold has been reached, are likely to show greater input additionality.

Most tax incentives for business R&D in Belgium are based on the volume of R&D activities (total expenditures or wages) and not on growth (incremental). It appears, from the estimations, that the effectiveness of tax support to raise additional R&D expenditures decreases with the persistence of use of the support. This seems to imply that the deadweight loss of volume-based tax support starts to weigh more heavily with time. The results of the meta-regression analysis of Dimos e al. (2022) suggest that incremental tax credit schemes are more effective than volume-based schemes.

This report examines in more detail than the previous evaluations the role of public support in the potential outcome of R&D activities. The rationale to provide public support to business R&D leans on the existence of a positive impact from the R&D activities of companies on the rest of the economy These spillovers create a gap between the private return to R&D and the social return to R&D. As private companies are only interested in the private return of their R&D activities, they will not invest sufficiently in R&D from a societal perspective, hence the potential role of subsidies and tax incentives to support business R&D. Rather than the direct impact of own R&D, the impact of the R&D activities of companies on the rest of the economy is essential in the assessment of public support. The choice of output indicator and the construction of variables that may reveal spillovers is however not trivial. Considering indicators as productivity, turnover, value added and profit, self-financed R&D seems to generate a positive return. The return to R&D financed with regional subsidies appears to be even higher than self-financed R&D. The return to R&D financed through partial exemption from payment of the withholding tax is found to be negative in some cases, which could indicate that R&D activities financed through these schemes support marginal activities. R&D financed with corporate income taxation incentives, including the innovation income deduction, according to some estimations generates a positive return, though generally lower than the return to self-financed R&D and R&D financed with regional subsidies. The latter result should be interpreted with some caution as these tax incentives are based on output (income) so only profitable firms and firms with income generated from past R&D can use these benefits and the more successful past R&D, the higher the tax benefit will be. There are indications of positive spillovers, for example from R&D of firms that combine support schemes, but also of negative spillovers which may hint at business-stealing effects and imitation by laggards. Moreover, young firms, domestic firms that do not belong to a multinational group, and firms with only occasional R&D activities, do not appear to benefit from R&D by other firms which casts some doubt on the valorisation of R&D spillovers in Belgium. The current evaluation does not consider foreign R&D, which is known to be very important for small open economies as Belgium. The absence of foreign spillover variables may bias the estimates of the private return to R&D and the estimates of domestic spillovers and is therefore kept in mind for future evaluations. Bloom, Van Reenen and Williams (2019) argue that subsidies, in contrast with tax incentives, permit to target R&D activities that generate most spillovers and avoid business-stealing effects. The results presented in this report suggest that the impact of subsidies on the return to own R&D is substantially larger than the impact of tax incentives on own R&D but this does not hold for spillovers, which are generally larger for firms that combine subsidies with tax support than for firms that only benefit from subsidies.

Guillard et al. (2021) point at the heterogeneity in the size of knowledge spillovers across technological areas, to advocate for targeting of public support to R&D, and at the variation in the extent to which spillovers are internalized within countries, to justify supranational policy coordination, especially among smaller countries. The results in this report confirm heterogeneity across industries, in input additionality as well as in the sign and size of R&D spillovers. However, the results also indicate that heterogeneity across firms, within industries, may be more substantial than heterogeneity across industries. This suggests that by targeting specific groups of firms, the effectiveness and efficiency of public support may be increased. Such an approach however requires a well-defined and evidence-based framework, which is clearly not in prospect today. Moreover, the conditionality of public support may be at odds with EU state aid rules, which generally prohibit public support to specific companies or industries, although this is right at the core of the current discussion on industrial policy and mission-oriented programs (Mazzucato 2018; Schot and Steinmueller 2018; Council of the European Union 2020; Criscuolo et al. 2022; European Commission 2022).

According to Archibugi and Filippetti (2018) the decrease in the share of public research in total R&D witnessed in most OECD countries may have had negative long-term effects on innovation and economic welfare. Akcigit, Hanley and Serrano-Velarde (2021) warn that over-subsidizing applied research may worsen dynamic misallocation of research effort, whereas investment in public basic research and its interaction with the private sector are significantly welfare-improving. IMF (2021) argues that basic research is underfunded in advanced economies and that targeting support to basic research will deliver the greatest return with public-private partnerships as a second best. Van Reenen (2021) deplores the fact that research funded by the US federal government decreased, as a proportion of national income, from 1.9% in the mid-1960s to less than 0.7% currently, as much of this funding goes to basic research that generates high spillovers. Soete, Verspagen and Ziesemer (2022) find a positive effect of public research by universities and research organizations on productivity growth, especially in countries with a strong complementarity between public and private R&D. Ciaffi, Deleidi and Di Bucchianico (2022) argue that the decrease in public R&D, relative to private R&D, in the US during the period 1948-2019, helps to explain the structural slowdown in labour productivity growth. Compared to other OECD countries, the mix of direct and indirect support to business R&D in Belgium seems highly skewed towards tax incentives, which tend to encourage applied research or experimental development, more than basic research. Whereas business R&D expenditures have increased substantially - as shown in this report, to some extent maybe because of public support – investment in basic research and especially research by universities and public research institutes has not kept pace. Given the several warnings mentioned above, a reflection may be appropriate on whether the mix of public support in Belgium is not overly biased towards applied research and experimental development, at the expense of investment in (public) basic research and complementarities between companies and other actors of the innovation system.

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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: Revised Pavitt taxonomy for manufacturing and services

From Bogliacino and Pianta (2015)

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

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

Annex 3: Results of fixed effects panel estimation of alternative specifications and by distinct groups of firms

Table A3.1 Results of a fixed effects panel estimation with additional financial indicators as control variables

	(1)	(2)	(3)
Dependent variable (R&D expenditures net of public support)			
Explanatory variables (public support):			
Direct support:			
Regional subsidy	0.09 (9.82) ***	0.09 (9.81) ***	0.09 (9.78) ***
Partial exemption schemes:			
Research cooperation	0.13 (4.99) ***	0.13 (5.00) ***	0.13 (4.99) ***
Young Innovative Company	0.13 (4.88) ***	0.13 (4.89) ***	0.13 (4.90) ***
PhDs and civil engineers	0.02 (1.25)	0.02 (1.26)	0.02 (1.10)
Master	0.13 (8.22) ***	0.13 (8.21) ***	0.13 (8.30) ***
Bachelor	0.05 (2.46) **	0.05 (2.43) **	0.05 (2.45) **
Corporate income taxation incentives:			
Tax credit R&D	-0.03 (-1.39)	-0.03 (-1.40)	-0.03 (-1.33)
Tax deduction R&D°	0.12 (6.64) ***	0.12 (6.54) ***	0.12 (6.52) ***
Patent income deduction	-0.04 (-2.38) **	-0.04 (-2.38) **	-0.04 (-2.67) ***
Innovation income deduction	-0.03 (-1.51)	-0.03 (-1.53)	-0.03 (-1.48)
Other funding:			
Innovation bonus	0.11 (3.95) ***	0.10 (3.95) ***	0.11 (3.97) ***
EU funding	-0.04 (-2.27) **	-0.04 (-2.27) ***	-0.04 (-2.31) **
Control variables:			
Turnover	-0.04 (-0.41)	-0.04 (-0.39)	-0.04 (-0.36)
Number of employees	1.16 (6.83) ***	1.15 (6.81) ***	1.15 (6.80) ***
Age	-1.00 (-3.45) ***	-1.00 (-3.47) ***	-1.02 (-3.53) ***
Capital intensity	0.22 (2.79) ***	0.22 (2.78) ***	0.22 (2.77) ***
Liquidity (Acid test ratio)	-0.00 (-0.13)	-0.00 (-0.13)	-0.01 (-0.15)
Solvency (LT financial independence)	-0.00 (-0.66)	-0.00 (-0.66)	-0.00 (-0.65)
Net profitability 1	0.00 (1.02)		
Net profitability 2		0.00 (1.21)	
Net profitability 3			0.00 (1.91) *
R-squared (within)	0.07	0.07	0.07
Number of observations	19,228	19,219	19,201

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with additional control variables, based on data from the annual account of firms, reflecting liquidity, solvency, and profitability. *, ** 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. °Data on the tax deduction for R&D investment is only available until 2012. Net profitability 1 = (Operating profit/loss)/Equity, Net profitability 2 = (Profit/Loss for the period before taxes)/Equity and Net profitability 3 = (Profit/Loss of the period)/Equity.

Table A3.2 Results of a fixed effects panel estimation with alternative dependent variables

Dependent variable:	$\frac{R\&D\ expenditures}{turnover}$	Number of researchers (FTE)	$\frac{R\&D\ personnel}{Number\ of\ employees}$
Explanatory variables (public support):			
Direct support:			
Regional subsidy	-0.11 (-0.30)	0.01 (2.04) **	0.01 (5.18) ***
Partial exemption schemes:			
Research cooperation	0.57 (0.68)	0.01 (1.26)	0.00 (0.09)
Young Innovative Company	2.14 (0.76)	0.00 (0.11)	0.03 (1.60)
PhDs and civil engineers	14.46 (1.00)	0.01 (2.01) **	0.01 (1.76) *
Master	-9.79 (-1.00)	0.01 (1.77) *	0.01 (3.10) ***
Bachelor	3.41 (0.97)	-	-
Corporate income taxation incentives:			
Tax credit R&D	-3.05 (-1.13)	0.01 (1.24)	-0.00 (-0.24)
Tax deduction R&D°	1.92 (1.21)	0.01 (1.35)	0.01 (1.76) *
Patent income deduction	-0.39 (-0.45)	-0.01 (-1.19)	-0.00 (-0.61)
Innovation income deduction	-4.67 (-0.94)	-	-
Other funding:			
Innovation bonus	-1.25 (-0.66)	0.02 (1.61)	0.01 (1.94) *
EU funding	-1.92 (-0.86)	-0.00 (-0.46)	-0.00 (-0.04)
Control variables:			
Turnover	-	0.04 (1.14)	-0.14 (-3.20) ***
Number of employees	-8.88 (-1.02)	0.57 (6.29) ***	-
Age	-55.65 (-1.02)	-0.12 (-1.06)	-0.20 (-1.96) **
Capital intensity	19.92 (0.99)	0.06 (1.85) *	0.07 (2.52) **
R-squared (within)	0.01	0.21	0.14
Number of observations	29,215	4,622	11,141

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with three alternative dependent variables: R&D intensity (R&D expenditures/turnover), the number of researchers (FTE) and the ratio of R&D personnel to the total number of employees (both in FTE). 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. °Data on the tax deduction for R&D investment is only available until 2012. All estimations include industry*year dummies.

Table A3.3 Results of a fixed effects panel estimation of the impact on the average wage of employees

	(1)	(2)	(3)
Dependent variable (average wage of employees)			
Explanatory variables (public support):			
Direct support:			
Regional subsidy	-0.00 (-0.78)	0.00 (0.55)	0.00 (0.39)
Partial exemption schemes:			
Research cooperation	0.00 (1.52)	0.00 (0.30)	0.00 (0.99)
Young Innovative Company	-0.00 (-0.00)	-0.00 (-0.08)	0.00 (0.91)
PhDs and civil engineers	-0.00 (-0.23)	-0.00 (-0.33)	0.00 (0.27)
Master	0.00 (1.50)	0.00 (1.65) *	0.00 (1.64)
Bachelor	-0.00 (-1.39)	-0.00 (-1.63)	-0.00 (-1.89) *
Corporate income taxation incentives:			
Tax credit R&D	0.00 (0.49)	-0.00 (-0.16)	-0.00 (-0.52)
Tax deduction R&D°	-0.00 (-1.69) *	-0.00 (-2.37) **	-0.00 (-1.92) *
Patent income deduction	-0.00 (-0.67)	-0.00 (-0.98)	-0.00 (-0.66)
Innovation income deduction	-0.00 (-1.28)	-0.00 (-1.58)	-0.00 (-1.06)
Other funding:			
Innovation bonus	-0.00 (-1.17)	-0.00 (-1.53)	-0.00 (0.15)
EU funding	0.00 (0.25)	-0.00 (-0.30)	-0.04 (-1.68) *
Control variables:			
Share PhDs		0.02 (1.16)	0.01 (0.57)
Share researchers with university degree		-0.00 (-0.19)	0.00 (0.05)
Turnover	0.00 (1.14)	0.01 (1.36)	0.01 (0.83)
Age	0.05 (3.81) ***	0.09 (4.71) ***	0.08 (3.75) ***
Capital intensity	0.04 (8.04) ***	0.03 (6.53) ***	0.02 (4.01) ***
R-squared (within)	0.28	0.24	0.28
Number of observations	29,209	17,398	9,947

Note: The table shows the results of fixed effects estimation of specification (1) on p.24 with the average wage of employees (total wage sum/number of employees) as dependent variable, based on data from the annual accounts of firms. The second column includes the share of R&D employees with a PhD or a university degree. As this information is not available for all companies that respond to the R&D survey the number of observations is smaller than in the baseline specification. The data is also only given for odd years. In the second column the share for even years is imputed from the share in odd years if available. The third column shows the results for a panel that is transformed, using only odd years without imputation for even years). 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. °Data on the tax deduction for R&D investment is only available until 2012. The number of employees is not included as it is the denominator of the dependent variable.

Table A3.4 Results of a fixed effects panel estimation by degree of liquidity

	Low 1st quartile Liquidity	Medium-low 2nd quartile Liquidity	Medium-high 3rd quartile Liquidity	High 4th quartile Liquidity
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.09 (4.83) ***	0.08 (4.13) ***	0.09 (4.98) ***	0.03 (1.59)
Partial exemption:				
Research cooperation	0.10 (1.57)	0.10 (2.73) ***	0.09 (2.78) ***	0.17 (3.01) ***
Young Innovative Company	0.11 (1.72) *	0.14 (2.33) **	0.04 (0.82)	0.09 (3.07) ***
PhDs and civil engineers	0.05 (1.58)	0.04 (1.57)	0.03 (1.07)	0.02 (0.93)
Master	0.12 (4.66) ***	0.06 (2.16) **	0.16 (5.45) ***	0.14 (4.96) ***
Bachelor	0.03 (0.85)	0.04 (0.92)	0.04 (0.98)	-0.02 (-0.64)
CIT incentives:				
Tax credit R&D	-0.03 (-0.75)	0.11 (1.71) *	-0.05 (-0.98)	-0.04 (-1.21)
Tax deduction R&D°	0.04 (1.05)	0.15 (3.24) ***	0.09 (1.90) *	0.09 (2.73) ***
Patent income deduction	-0.08 (-2.70) ***	-0.04 (-1.28)	-0.01 (-0.34)	0.01 (0.16)
Innovation income deduction	-0.03 (-0.93)	-0.02 (-0.35)	-0.02 (-0.38)	-0.05 (-1.56)
Other funding:				
Innovation bonus	0.07 (1.56)	0.11 (2.30) **	0.09 (1.75) *	0.06 (1.32)
EU funding	-0.08 (-2.92) ***	-0.01 (-0.17)	-0.04 (-1.01)	-0.01 (-0.72)
Control variables:				
Turnover	0.20 (1.18)	-0.20 (-1.01)	0.31 (1.46)	0.21 (1.33)
Number of employees	1.03 (3.00) ***	0.85 (2.48) **	0.31 (1.14)	1.23 (4.39) ***
Age	-0.66 (-1.17)	-1.95 (-3.04) ***	-0.90 (-1.44)	-1.55 (-3.29) ***
Capital intensity	0.45 (2.99) ***	0.20 (1.43)	0.15 (0.93)	0.16 (1.26)
R-squared (within)	0.26	0.23	0.25	0.26
Number of observations	7,169	7,490	7,354	6,672

Note: The table shows the results of fixed effects (within) estimation by degree of liquidity, measured by the acid test ratio: (amounts receivable within one year + current investment + cash at bank and in hand)/amounts payable within one year. Firms are grouped by quartile with the 1st quartile (Low) grouping the firms with the lowest liquidity and the fourth quartile (High) grouping the firms with the highest liquidity. 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 A3.5 Results of fixed effects panel estimation by degree of solvency

	Low 1st quartile Solvency	Medium-low 2nd quartile Solvency	Medium-high 3rd quartile Solvency	High 4th quartile Solvency
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.08 (3.60) ***	0.06 (2.96) ***	0.05 (2.92) ***	0.09 (4.12) ***
Partial exemption:				
Research cooperation	0.07 (1.14)	0.04 (0.74)	0.11 (2.30) **	0.14 (2.54) **
Young Innovative Company	0.08 (1.11)	0.04 (0.72)	0.16 (2.22) **	0.15 (2.61) ***
PhDs and civil engineers	0.01 (0.12)	0.01 (0.30)	0.01 (0.39)	-0.04 (-1.19)
Master	0.16 (3.80) ***	0.08 (2.05) **	0.12 (3.32) ***	0.09 (2.70) ***
Bachelor	-0.01 (-0.23)	0.12 (2.41) **	-0.06 (-1.35)	0.03 (0.71)
CIT incentives:				
Tax credit R&D	0.02 (0.33)	-0.02 (-0.52)	-0.06 (-1.08)	-0.02 (-0.54)
Tax deduction R&D°	0.08 (1.44)	0.04 (1.13)	-0.03 (-0.69)	0.08 (2.65) ***
Patent income deduction	-0.13 (-2.48) **	-0.03 (-0.75)	-0.02 (-0.79)	-0.04 (-1.22)
Innovation income deduction	-0.10 (-1.56)	-0.03 (-0.59)	-0.00 (-0.09)	-0.02 (-0.36)
Other funding:				
Innovation bonus	0.11 (1.73) *	0.08 (1.22)	0.08 (1.49)	0.08 (1.19)
EU funding	-0.09 (-1.88) *	-0.06 (-1.55)	0.00 (0.10)	-0.04 (-0.91)
Control variables:				
Turnover	-0.14 (-0.65)	0.25 (0.93)	-0.15 (-0.54)	-0.15 (-0.63)
Number of employees	1.17 (3.37) ***	1.32 (3.11) ***	1.13 (2.09) **	1.49 (3.33) ***
Age	-1.93 (-2.79) ***	-2.51 (-3.59) ***	-0.35 (-0.40)	-1.45 (-2.16) **
Capital intensity	0.21 (1.07)	0.21 (1.02)	0.31 (1.53)	0.23 (1.14)
R-squared (within)	0.33	0.30	0.30	0.31
Number of observations	4,484	4,925	4,991	5,060

Note: The table shows the results of fixed effects (within) estimation by degree of solvency, measured by long-term financial independence: equity/amounts payable after more than one year. Firms are grouped by quartile with the 1st quartile (Low) grouping the firms with the lowest solvency and the fourth quartile (High) grouping the firms with the highest solvency. 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 A3.6 Results of fixed effects panel estimation by degree of profitability

	Low 1st quartile Profitability	Medium-low 2nd quartile Profitability	Medium-high 3rd quartile Profitability	High 4th quartile Profitability
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.06 (3.72) ***	0.09 (4.74) ***	0.03 (2.14) **	0.09 (4.81) ***
Partial exemption:				
Research cooperation	0.17 (3.62) ***	0.14 (2.39) **	0.06 (2.42) **	0.10 (2.41) **
Young Innovative Company	0.09 (2.45) **	0.13 (1.98) **	0.13 (3.11) ***	0.10 (1.92) *
PhDs and civil engineers	0.07 (2.34)	0.03 (1.06)	0.02 (0.79)	0.05 (1.44)
Master	0.15 (5.04) ***	0.16 (6.31) ***	0.15 (5.61) ***	0.10 (3.84) ***
Bachelor	0.03 (0.63)	0.03 (0.93)	0.06 (1.67) *	0.08 (1.93) *
CIT incentives:				
Tax credit R&D	-0.04 (-1.27)	-0.02 (-0.52)	-0.01 (-0.23)	0.06 (0.95)
Tax deduction R&D°	0.03 (0.62)	0.08 (2.47) **	0.04 (1.43)	0.07 (2.03) **
Patent income deduction	-0.06 (-1.43)	-0.03 (-0.77)	-0.08 (-3.27) ***	-0.03 (-0.85)
Innovation income deduction	-0.09 (-1.33)	-0.08 (-1.58)	-0.06 (-1.96) **	-0.01 (-0.27)
Other funding:				
Innovation bonus	0.08 (1.59)	0.05 (1.25)	0.07 (1.92) *	-0.02 (-0.56)
EU funding	-0.05 (-1.84) *	-0.02 (-0.42)	-0.03 (-0.79)	-0.08 (-1.94) *
Control variables:				
Turnover	0.03 (0.21)	-0.02 (-0.07)	-0.00 (-0.01)	0.13 (0.74)
Number of employees	1.46 (4.95) ***	1.28 (3.81) ***	1.43 (3.94) ***	0.99 (3.34) ***
Age	-0.66 (-1.41)	-0.40 (-0.54)	-1.43 (-2.52) **	-0.40 (-0.69)
Capital intensity	0.40 (2.86) ***	0.35 (2.10) **	0.11 (0.77)	0.05 (0.35)
R-squared (within)	0.29	0.25	0.23	0.25
Number of observations	6,734	7,657	7,666	7,348

Note: The table shows the results of fixed effects (within) estimation by degree of profitability, measured as profit (loss) for the period before taxes/equity. Firms are grouped by quartile with the 1st quartile (Low) grouping the firms with the lowest profitability and the fourth quartile (High) grouping the firms with the highest profitability. 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 A3.7 Results of fixed effects panel estimation by degree of productivity

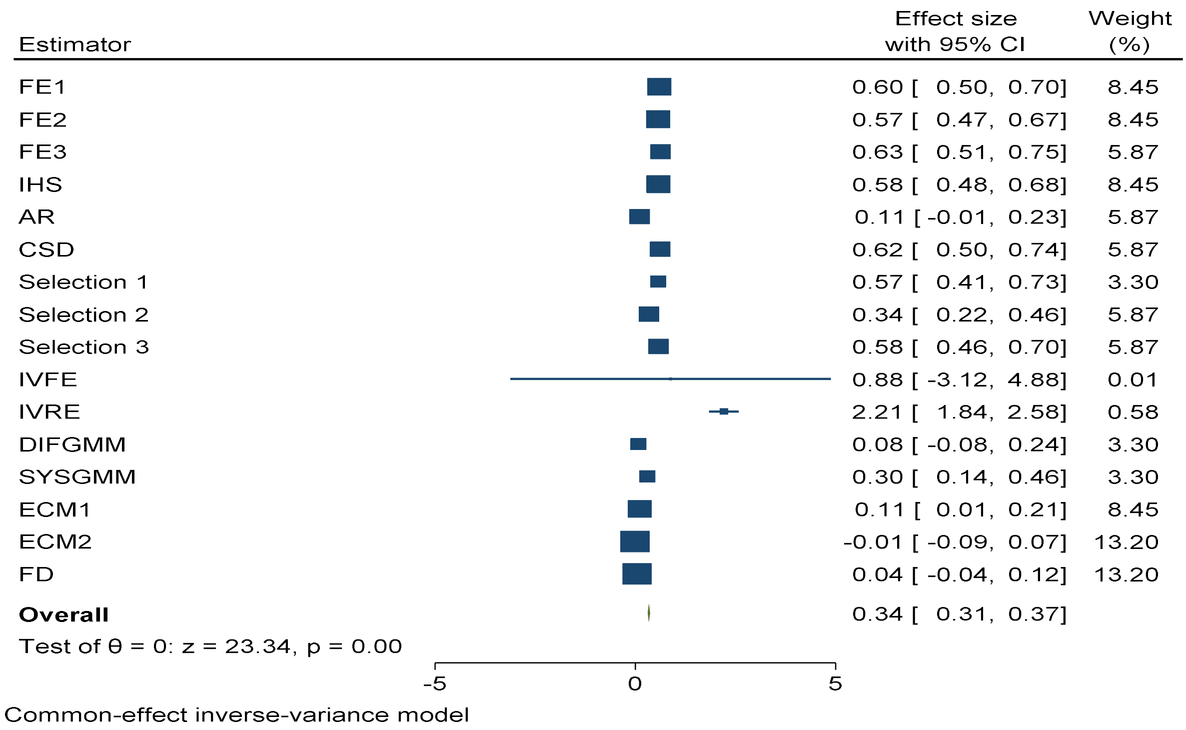
	Low 1st quartile Productivity	Medium-low 2nd quartile Productivity	Medium-high 3rd quartile Productivity	High 4th quartile Productivity
Dependent variable (R&D expenditures net of public support)				
Explanatory variables:				
Direct support:				
Regional subsidy	0.08 (3.88) ***	0.06 (3.73) ***	0.04 (2.81) ***	0.07 (4.35) ***
Partial exemption:				
Research cooperation	0.25 (3.87) ***	0.12 (2.23) **	0.10 (2.36) **	0.12 (3.11) ***
Young Innovative Company	0.19 (2.77) ***	0.16 (3.16) ***	0.07 (1.48)	0.08 (1.64)
PhDs and civil engineers	0.07 (1.56)	0.07 (2.53) **	0.06 (2.30) **	-0.01 (-0.44)
Master	0.16 (4.55) ***	0.14 (5.17) ***	0.09 (3.24) ***	0.12 (4.72) ***
Bachelor	0.09 (1.54)	0.05 (1.20)	-0.01 (-0.19)	0.04 (1.27)
CIT incentives:				
Tax credit R&D	-0.05 (-0.79)	-0.03 (-0.93)	0.06 (1.01)	-0.02 (-0.47)
Tax deduction R&D°	0.04 (0.80)	0.13 (2.93) ***	0.04 (1.71) *	0.08 (2.77) ***
Patent income deduction	-0.04 (-0.66)	-0.01 (-0.20)	-0.04 (-1.45)	-0.05 (-2.56) ***
Innovation income deduction	0.05 (0.66)	-0.13 (-3.20) ***	-0.10 (-3.04) ***	-0.01 (-0.93)
Other funding:				
Innovation bonus	0.11 (1.57)	0.03 (0.73)	0.07 (1.63)	0.05 (1.33)
EU funding	-0.08 (-0.94)	0.02 (0.48)	-0.06 (-2.39) **	-0.04 (-1.64)
Control variables:				
Turnover	0.36 (1.74) *	0.11 (0.38)	-0.38 (-0.98)	-0.18 (-0.61)
Number of employees	1.22 (3.26) ***	1.56 (3.90) ***	0.87 (1.90) *	1.46 (4.08) ***
Age	-1.90 (-3.53) ***	-0.91 (-1.90) *	-1.06 (-1.81) *	-0.88 (-1.42)
Capital intensity	0.07 (0.51)	0.33 (2.92) ***	0.18 (1.29)	0.11 (0.87)
R-squared (within)	0.26	0.21	0.22	0.24
Number of observations	6,965	7,351	7,433	7,397

Note: The table shows the results of fixed effects (within) estimation by degree of labour productivity, measured as turnover per FTE employee. Firms are grouped by quartile with the 1st quartile (Low) grouping the firms with the lowest Productivity and the fourth quartile (High) grouping the firms with the highest Productivity. 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.

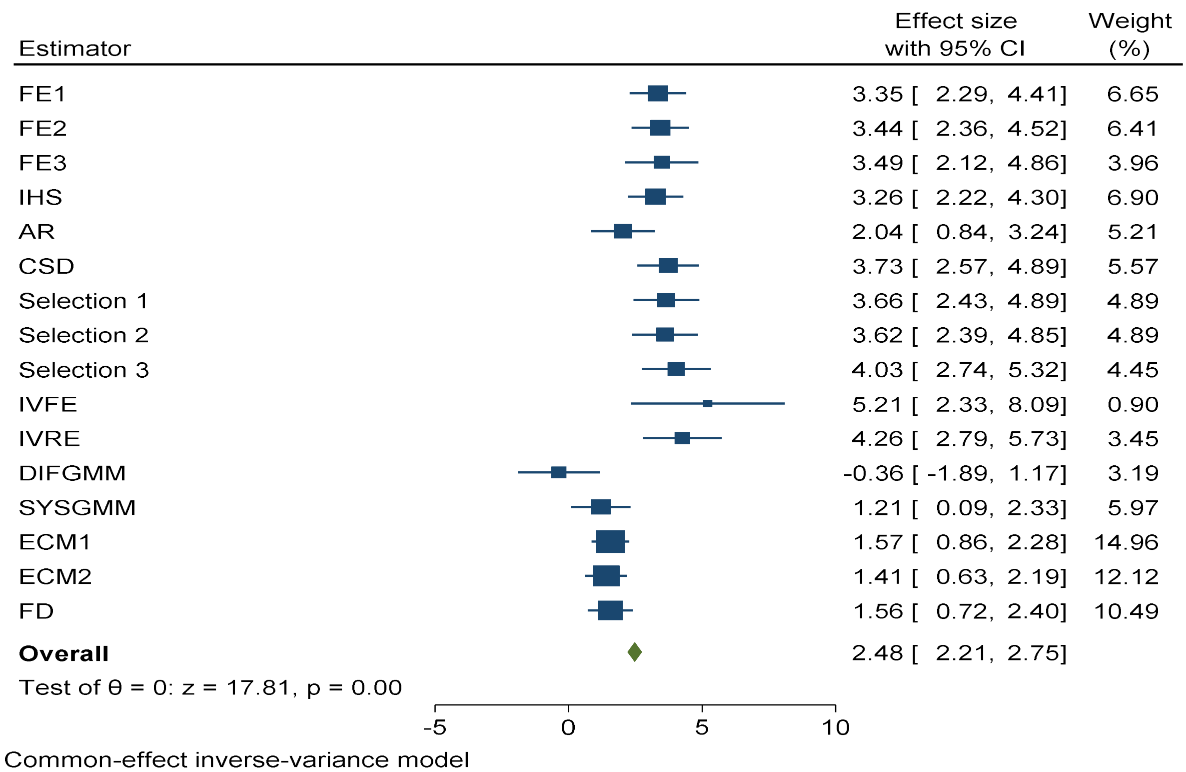
Annex 4: Forest plots of alternative estimates of Bang for the Buck, by public support instrument

Abbreviation	Estimation procedure	Table
FE1	Fixed effects Net R&D - sector and year dummies	6
FE2	Fixed effects Net R&D - sector*year dummies	6
FE3	Fixed effects with additional control variables (net profitability 3)	A3.1 (Annex 3)
IHS	Inverse Hyperbolic Sine	6
AR	Serial correlation	20
CSD	Cross-sectional dependence	20
Selection 1	Sample selection Survey and Response	22
Selection 2	(Self-selection) Support	22
Selection 3	Sample selection Survey, Response and (self-)selection Support	22
IVFE	IV-FE	24
IVRE	IV-RE	24
DIFGMM	First Difference GMM	25
SYSGMM	System GMM	26
ECM1	Single-equation ECM	28
ECM2	Two-step ECM	28
FD	First Difference	29

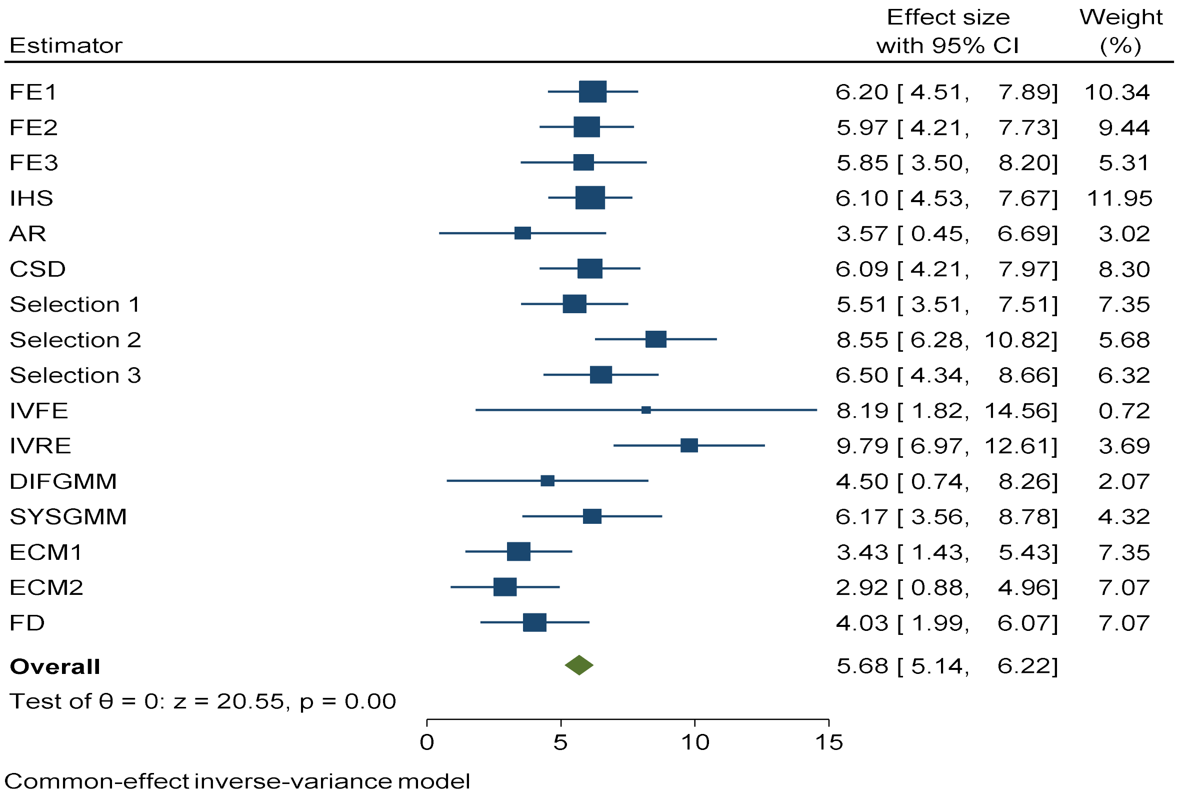
Forest plot of the Bang for the Buck estimates of regional subsidies



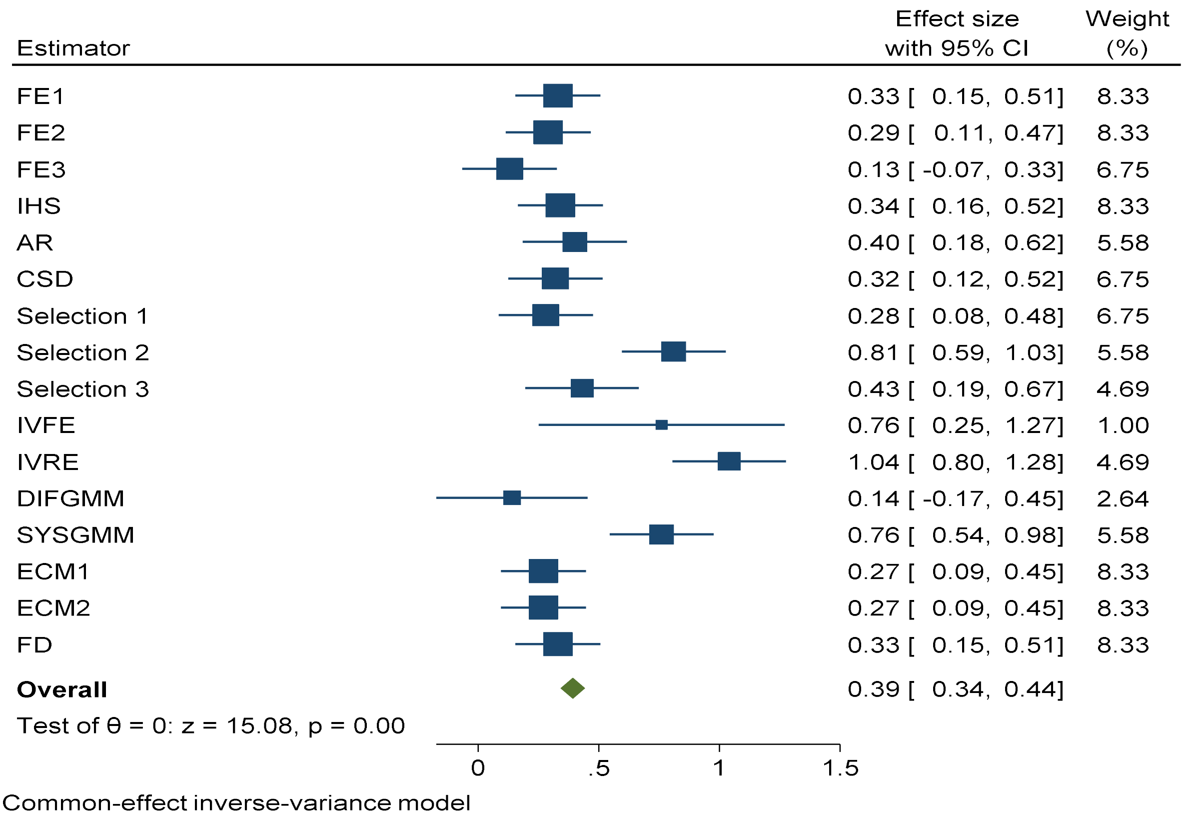
Forest plot of the Bang for the Buck estimates of partial exemption for R&D cooperation



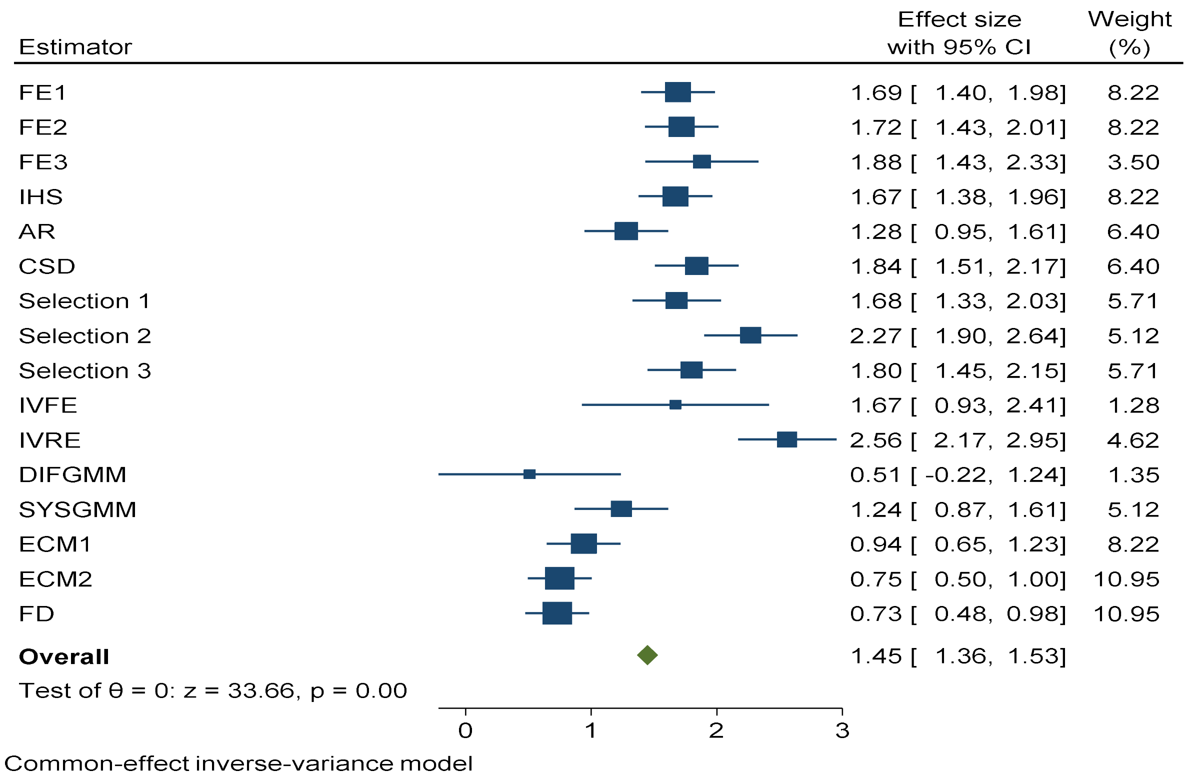
Forest plot of the Bang for the Buck estimates of partial exemption for Young Innovative Companies



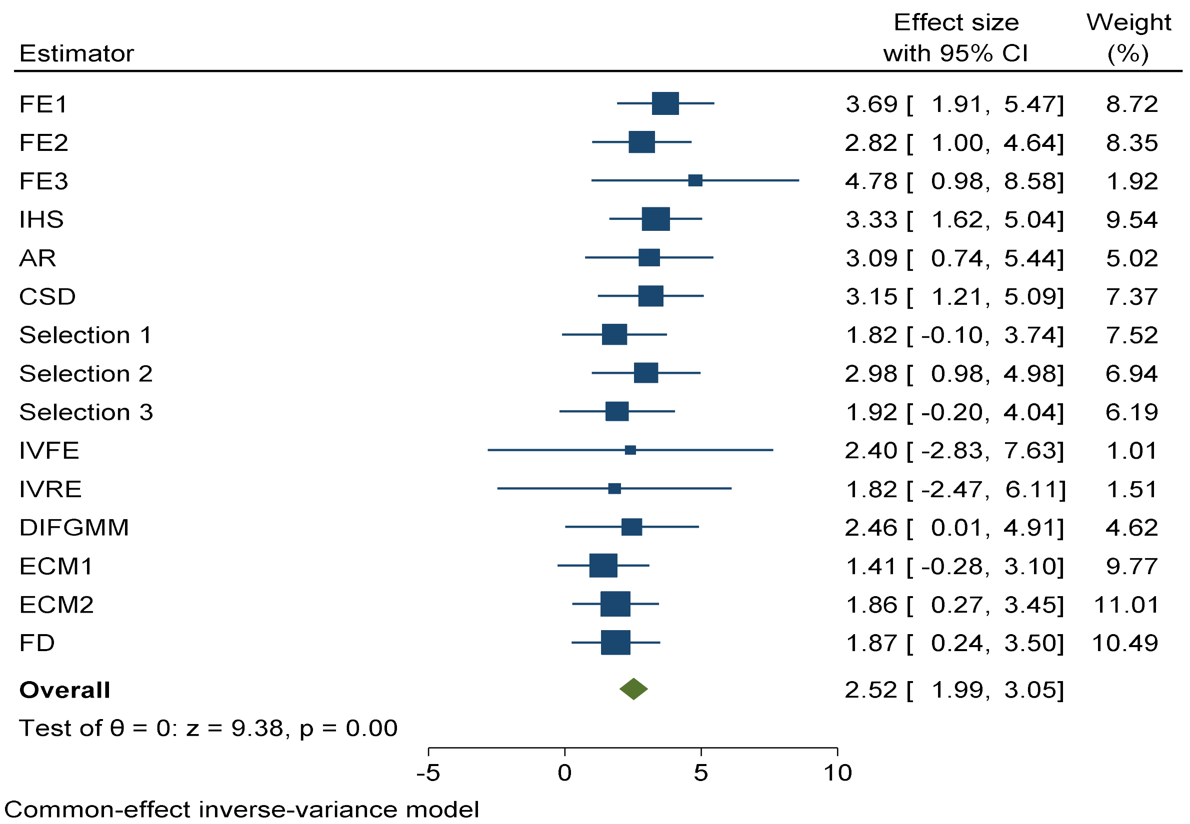
Forest plot of the Bang for the Buck estimates of partial exemption for PhDs and civil engineers



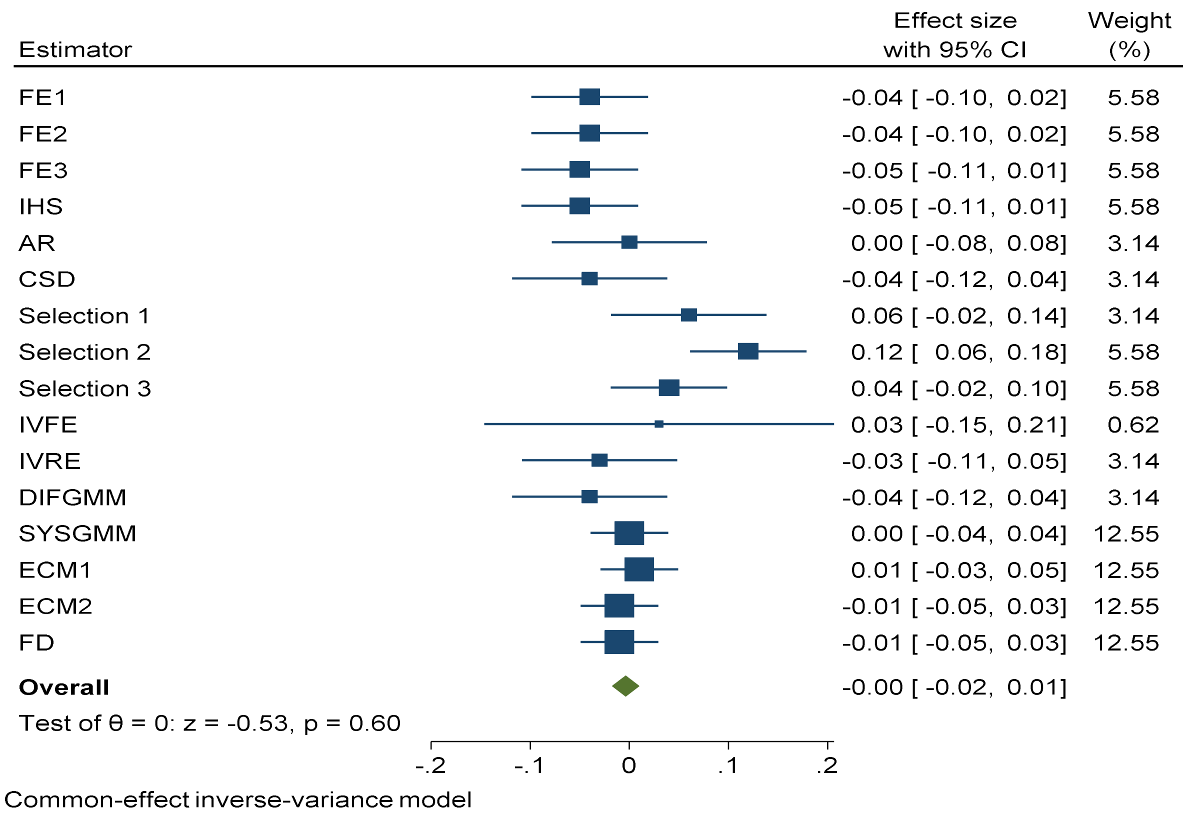
Forest plot of the Bang for the Buck estimates of partial exemption for Masters



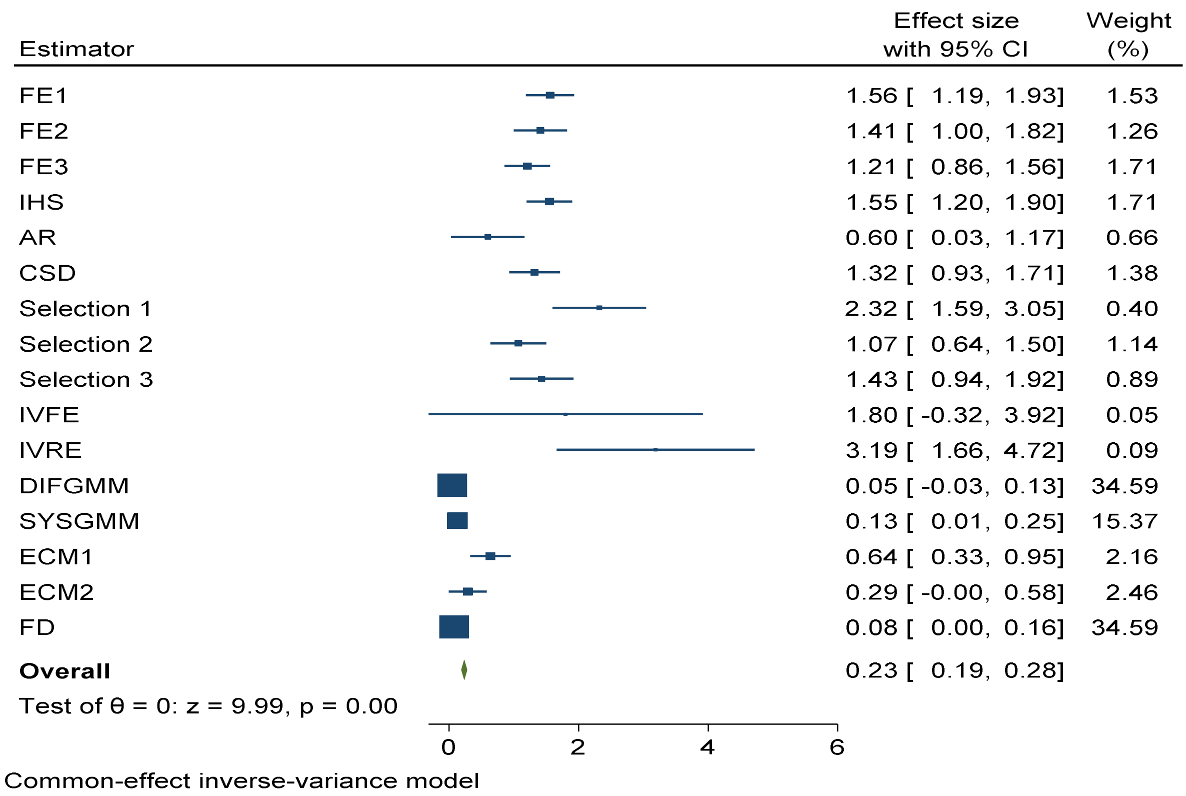
Forest plot of the Bang for the Buck estimates of partial exemption for Bachelors



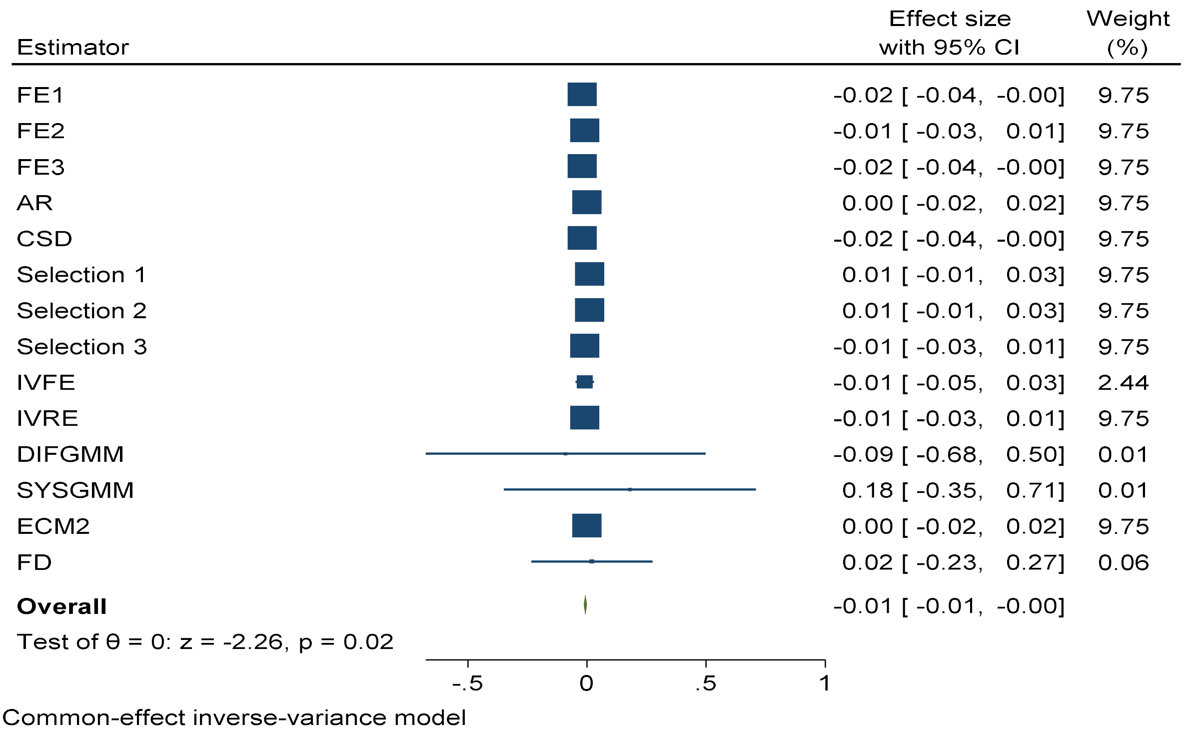
Forest plot of the Bang for the Buck estimates of the tax credit for R&D investment



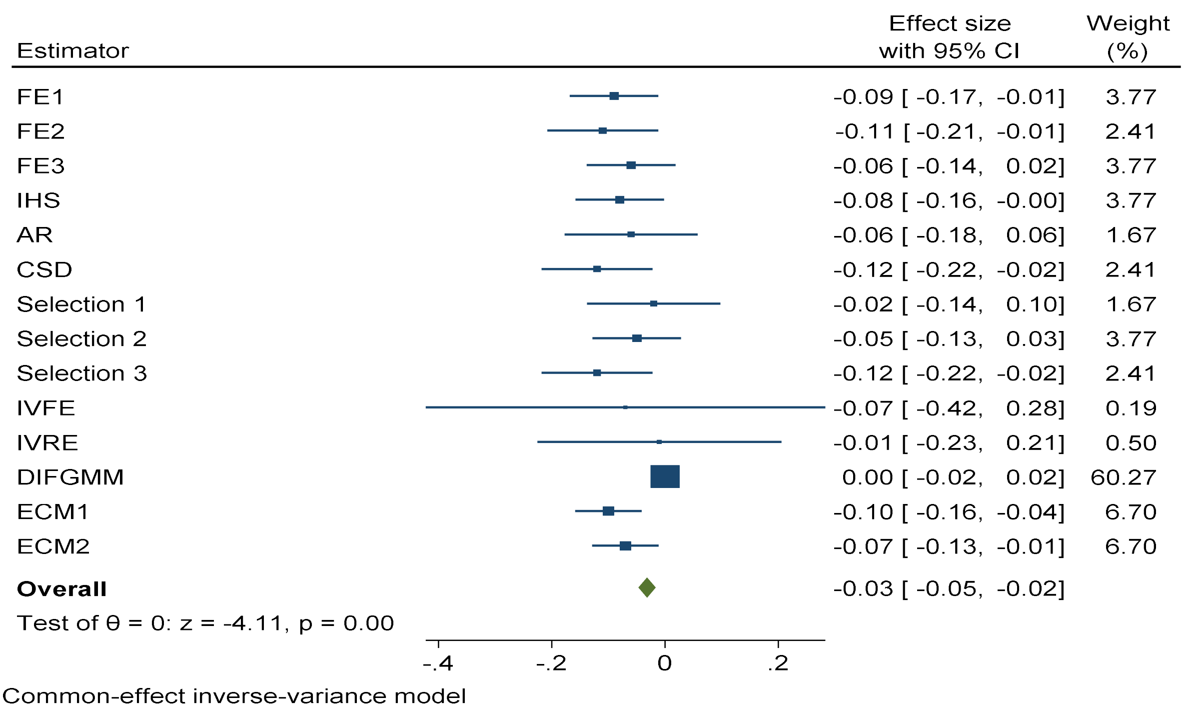
Forest plot of the Bang for the Buck estimates of the tax deduction for R&D investment



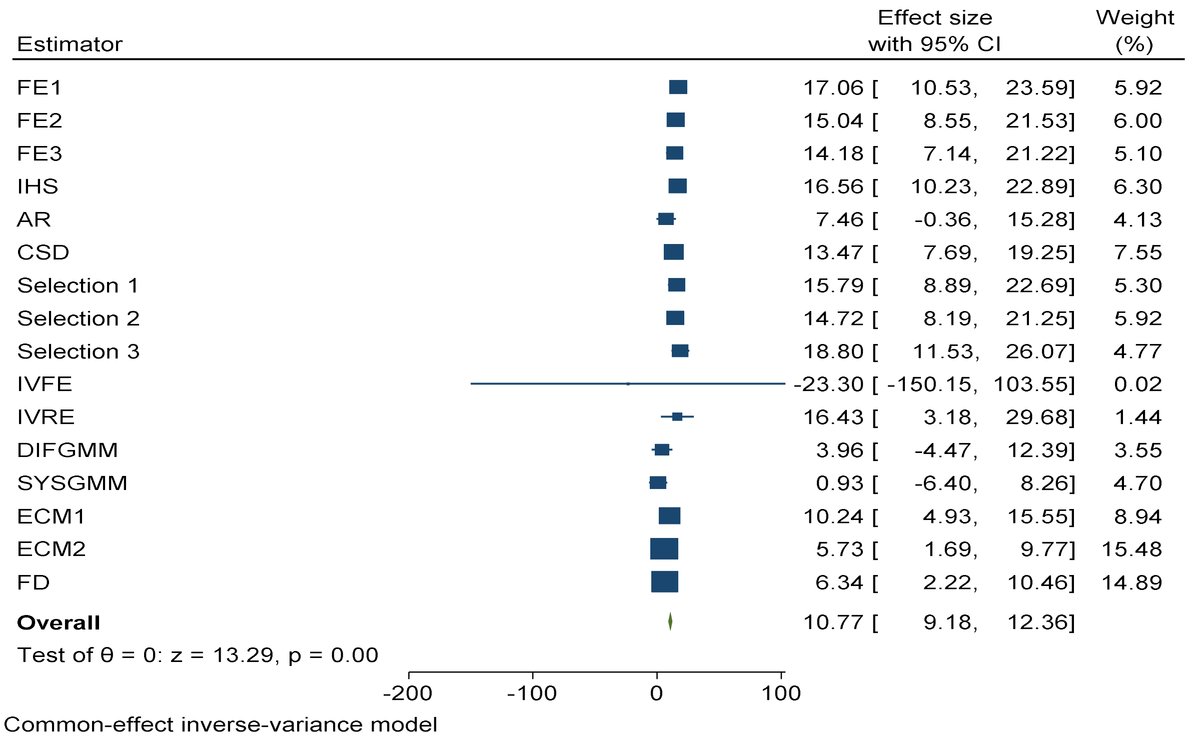
Forest plot of the Bang for the Buck estimates of the patent income deduction



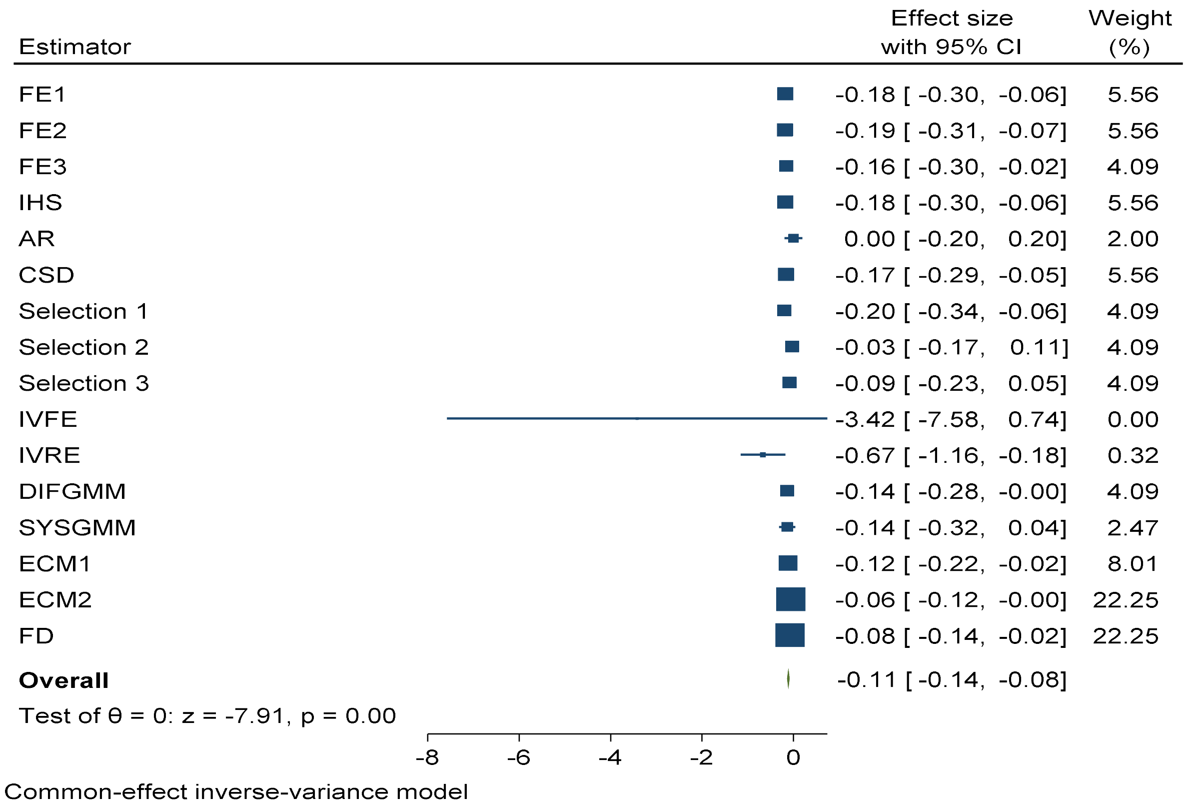
Forest plot of the Bang for the Buck estimates of the innovation income deduction



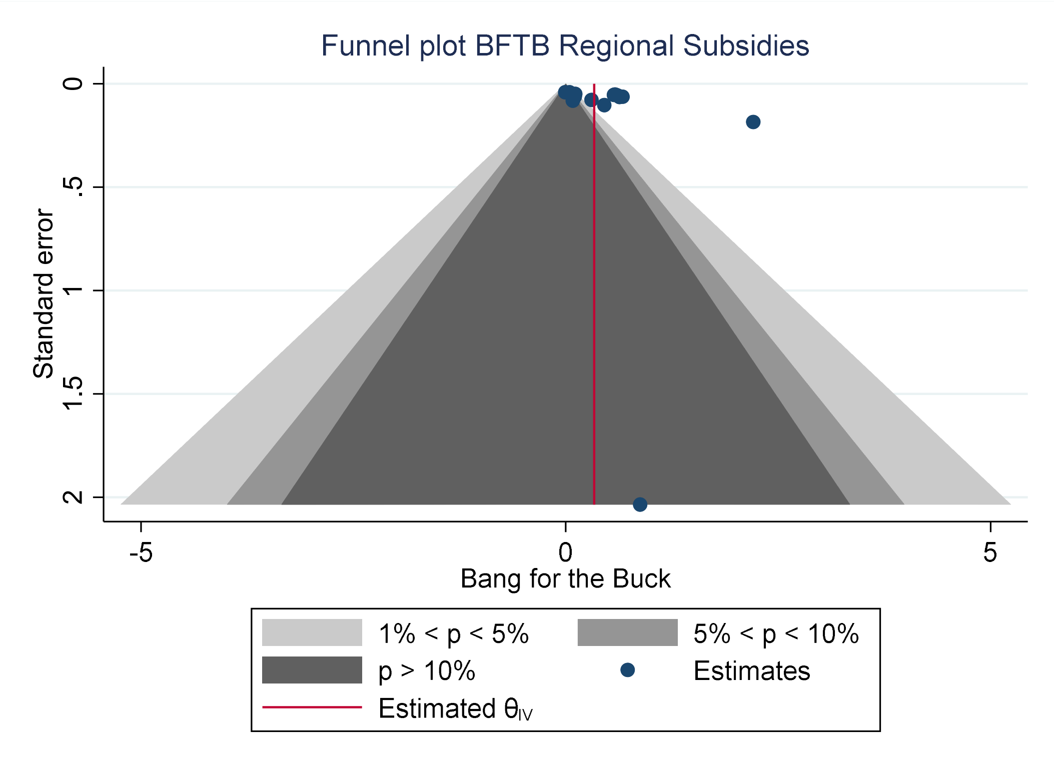
Forest plot of the Bang for the Buck estimates of the innovation bonus

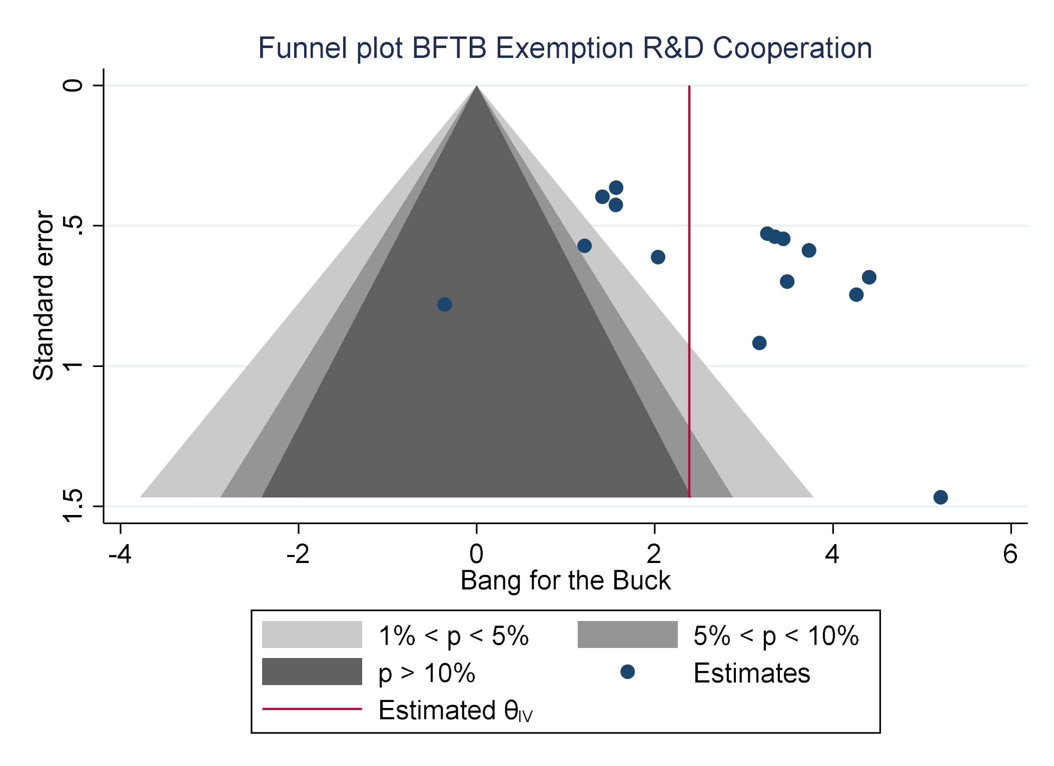


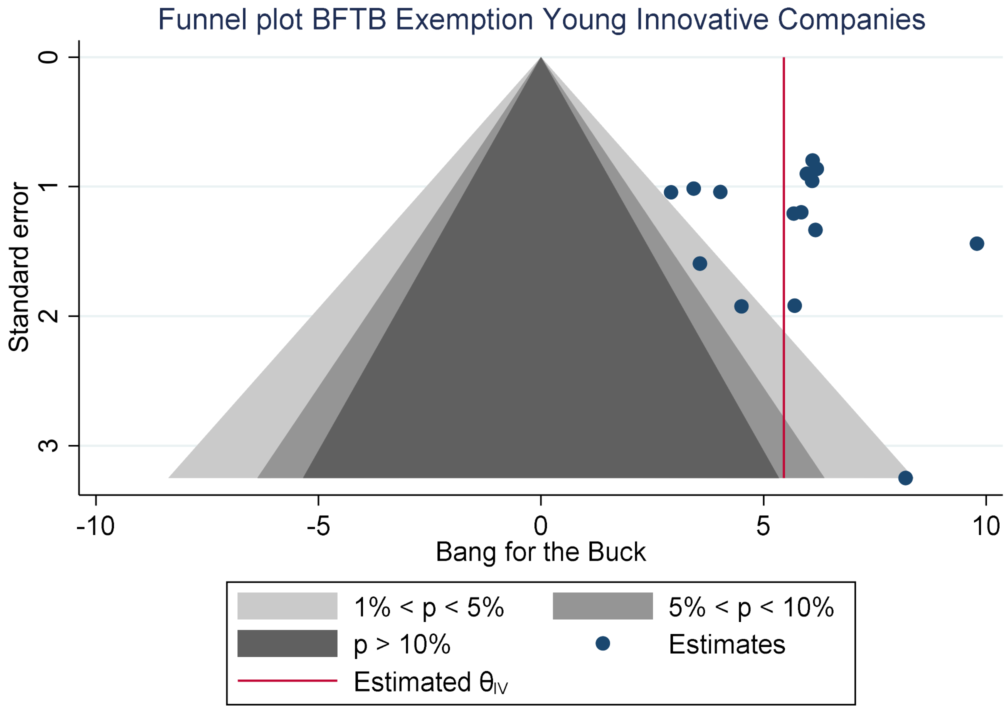
Forest plot of the Bang for the Buck estimates of EU funding

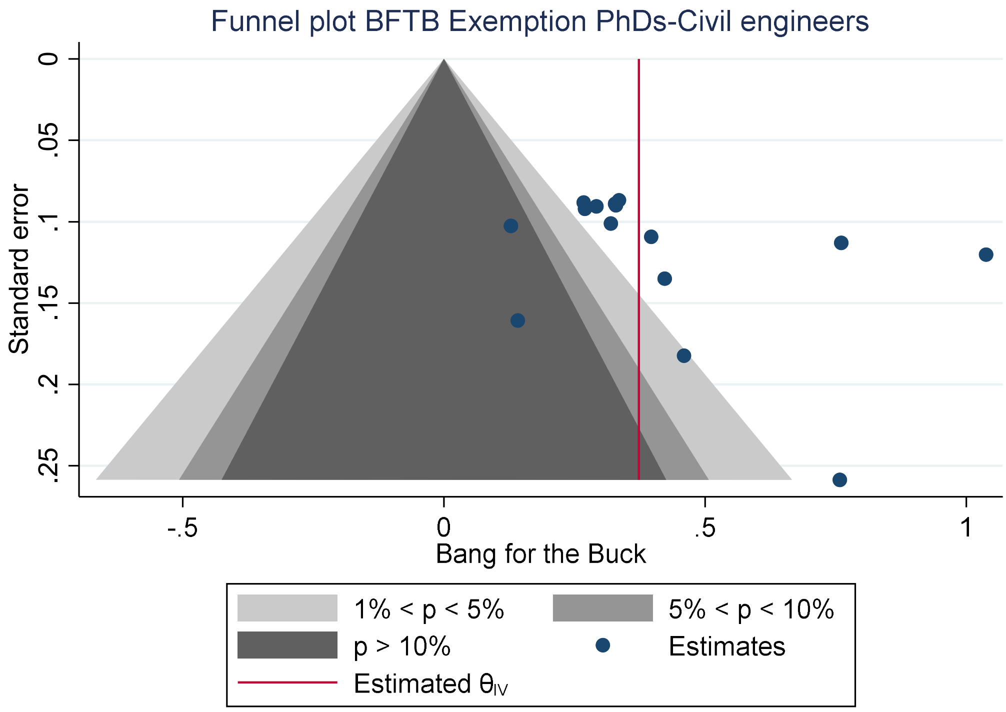


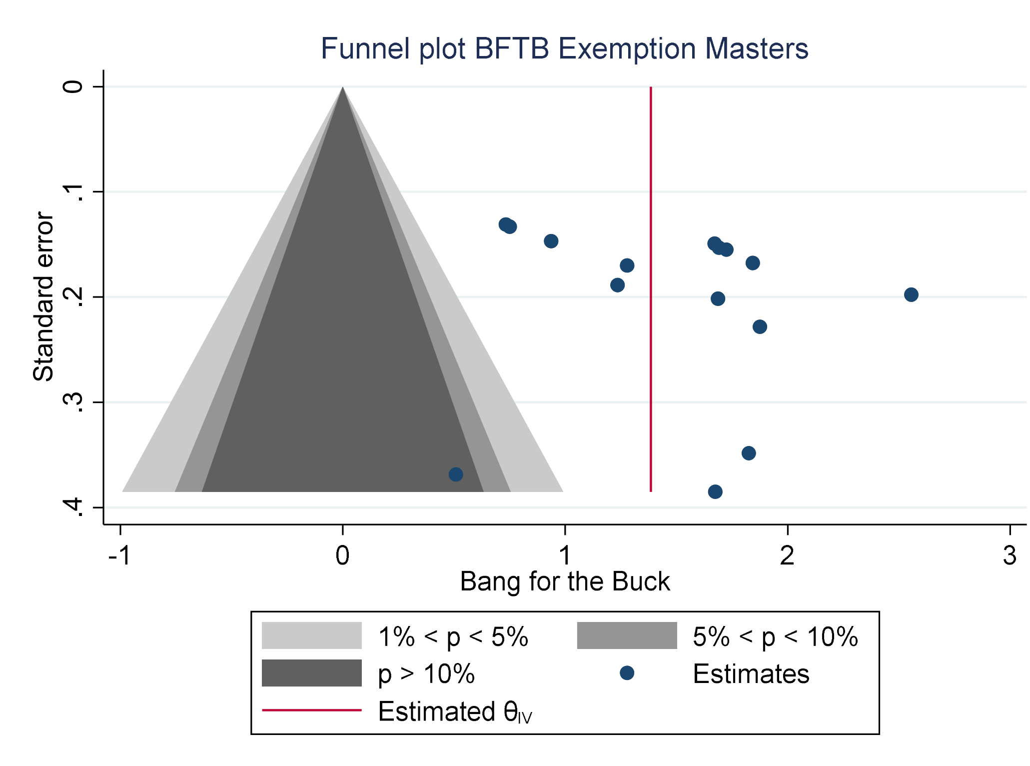
Annex 5: Funnel plots of alternative estimates of Bang for the Buck, by public support instrument

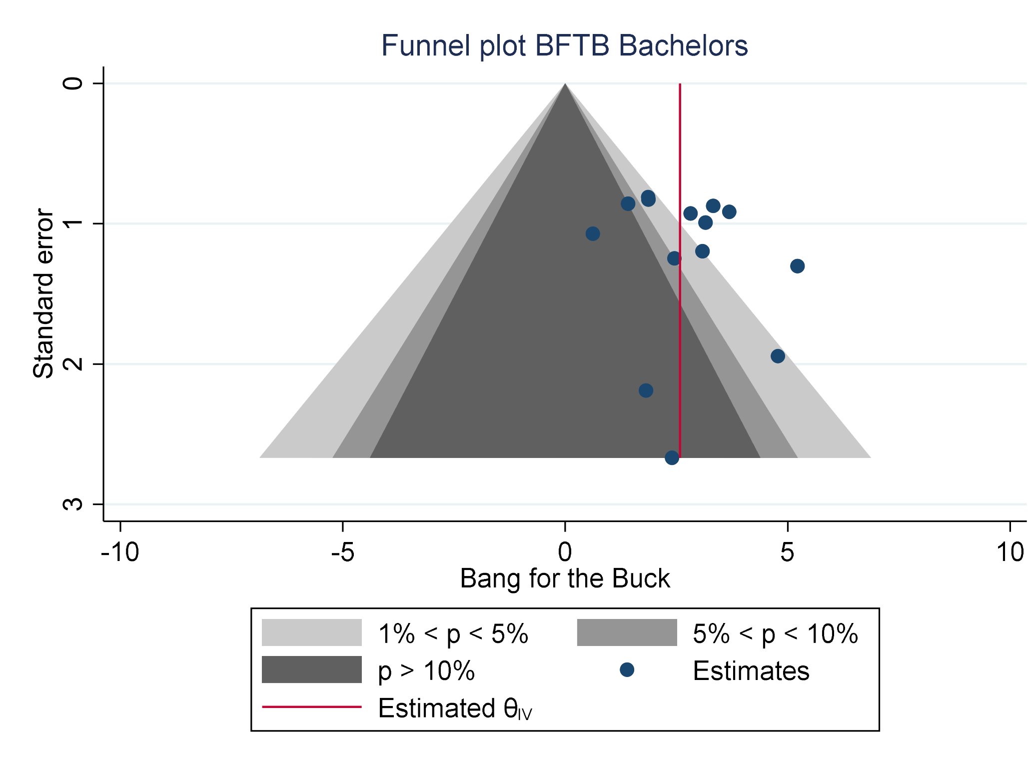


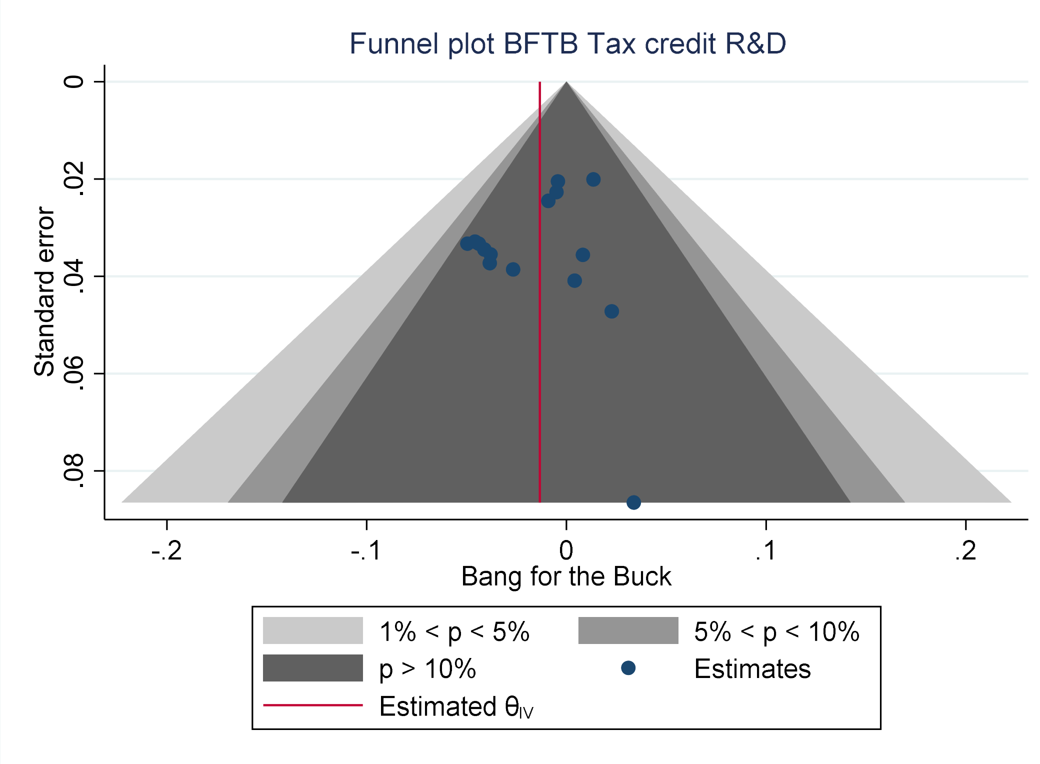


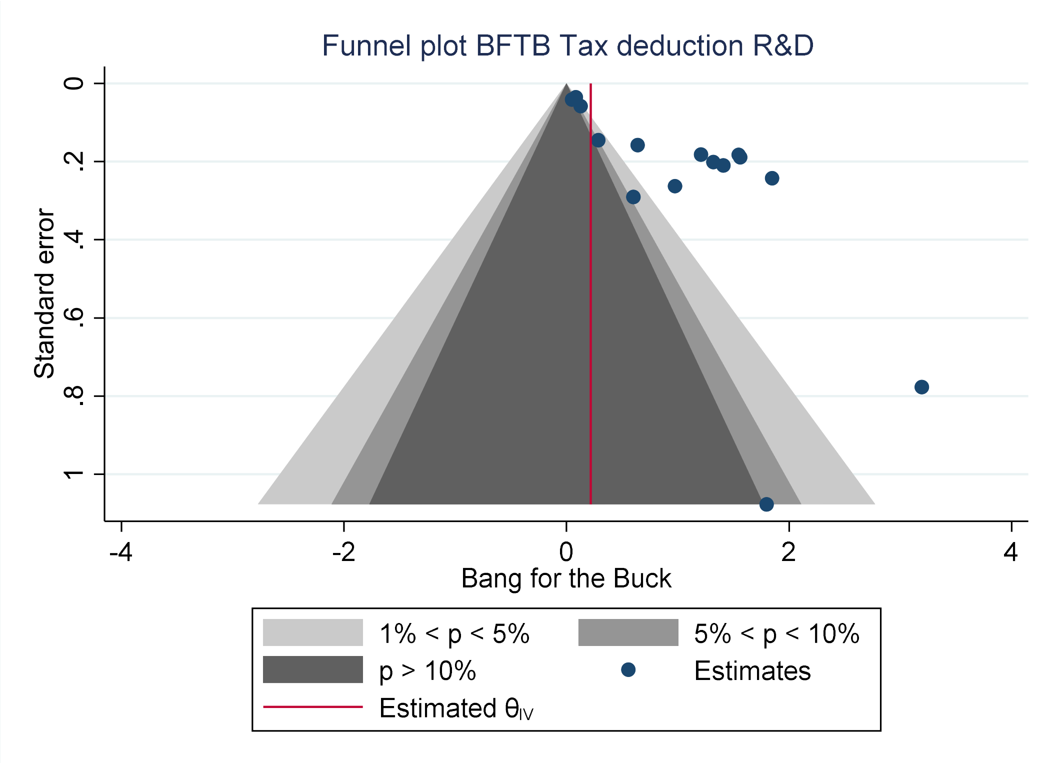

Funnel plot BFTB Exemption Young Innovative Companies
Standard error
0
1
2
3
-10
-5
0
5
10
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV

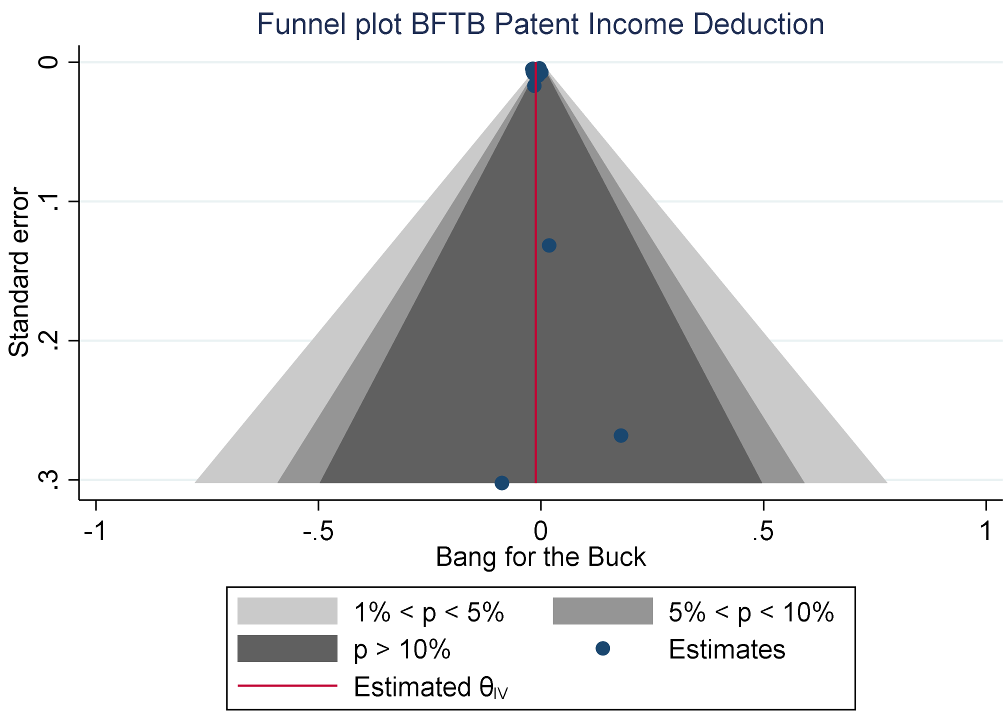

Funnel plot BFTB Exemption PhDs-Civil engineers
Standard error
0
.05
.1
.15
.2
.25
-.5
0
.5
1
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV

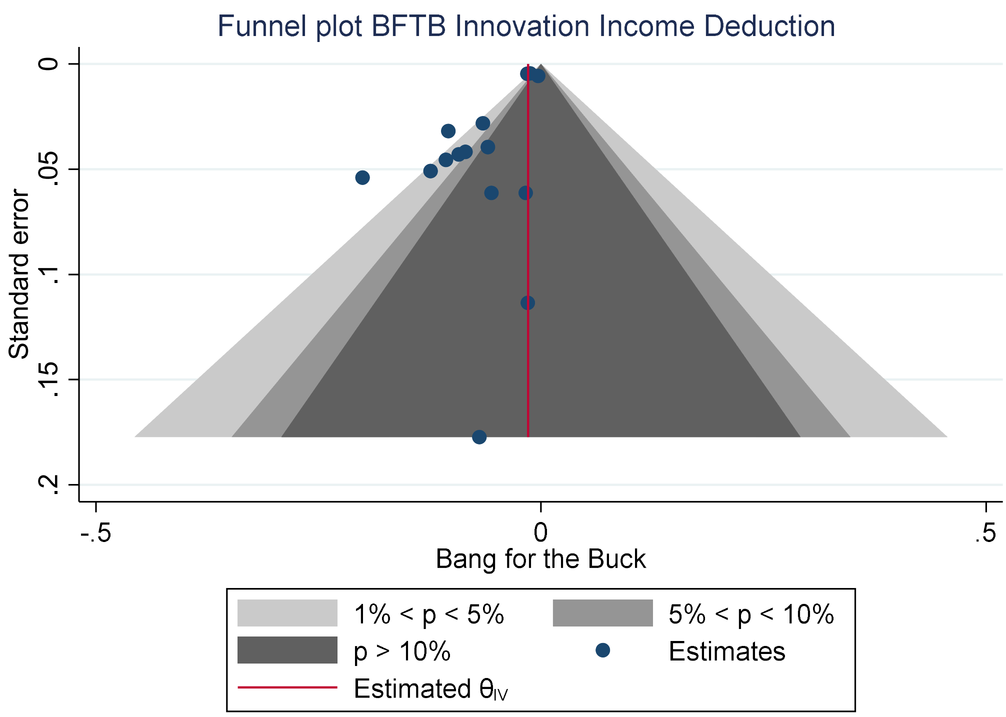

Funnel plot BFTB Exemption Masters
Standard error
0
.1
.2
.3
.4
-1
0
1
2
3
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV

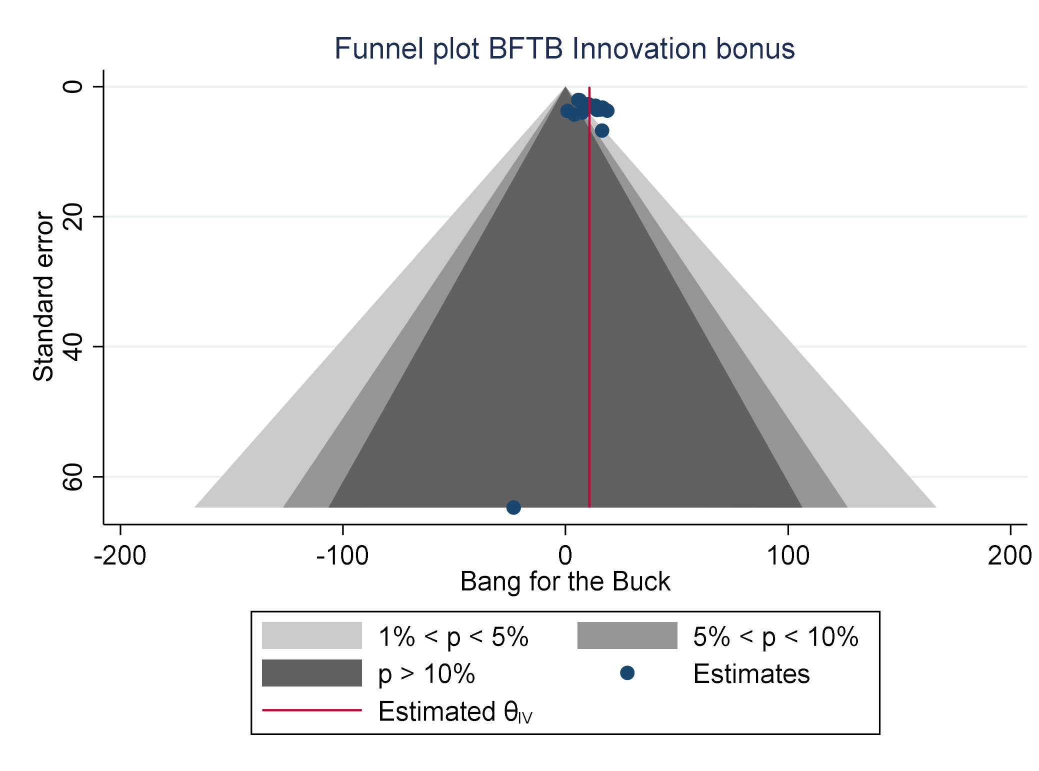

Funnel plot BFTB Bachelors
Standard error
0
1
2
3
-10
-5
0
5
10
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV

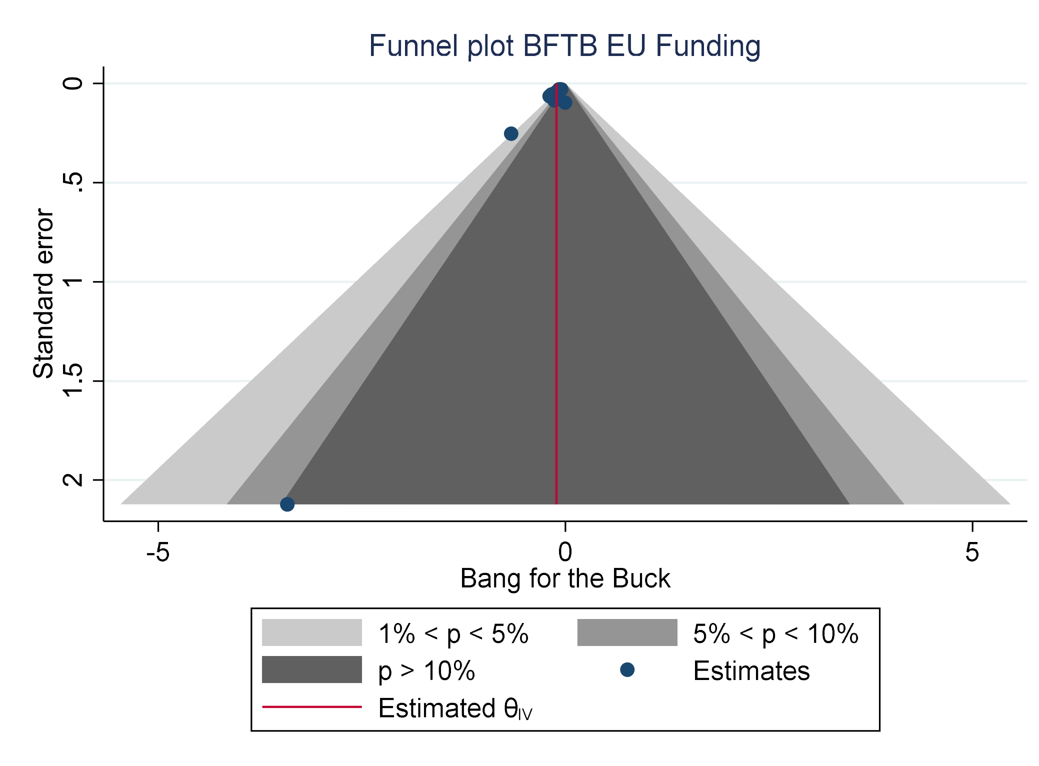

Funnel plot BFTB Tax credit R&D
Standard error
0
.02
.04
.06
.08
-.2
-.1
0
.1
.2
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV


Funnel plot BFTB Tax deduction R&D
Standard error
0
.2
.4
.6
.8
1
-4
-2
0
2
4
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV


Funnel plot BFTB Patent Income Deduction
Standard error
0
.1
.2
.3
-1
-.5
0
.5
1
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV


Funnel plot BFTB Innovation Income Deduction
Standard error
0
.05
.1
.15
.2
-.5
0
.5
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV

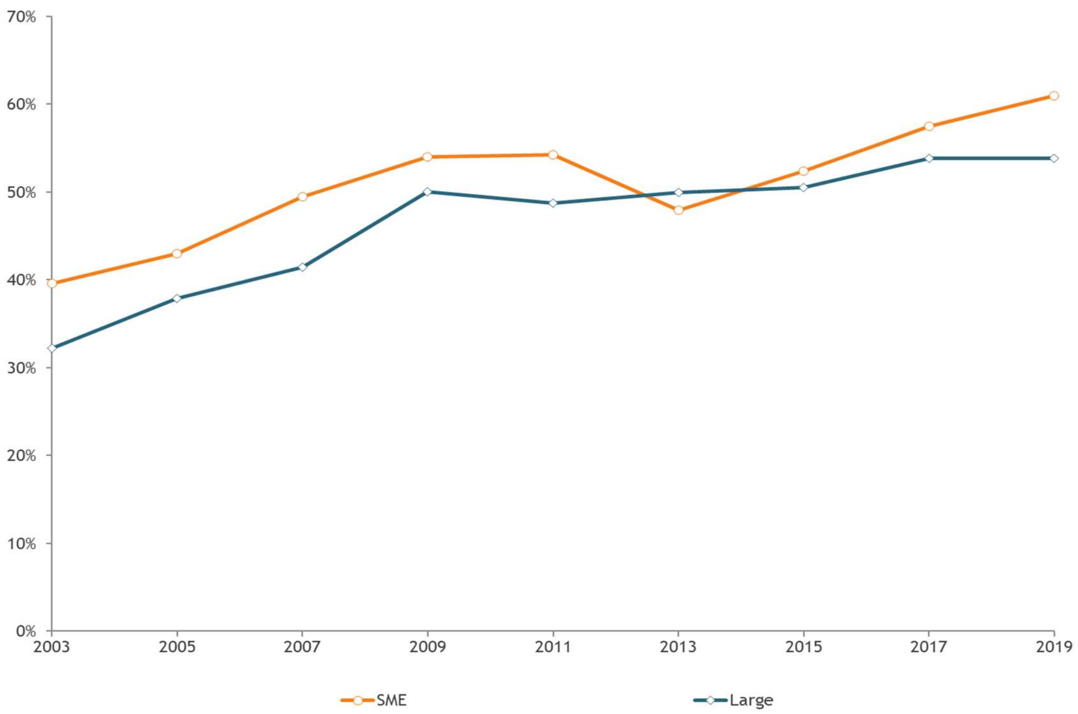

Funnel plot BFTB Innovation bonus
Standard error
0
20
40
60
-200
-100
0
100
200
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV


Funnel plot BFTB EU Funding
Standard error
0
.5
1
1.5
2
-5
0
5
Bang for the Buck
1% < p < 5%
5% < p < 10%
p > 10%
Estimates
Estimated θIV

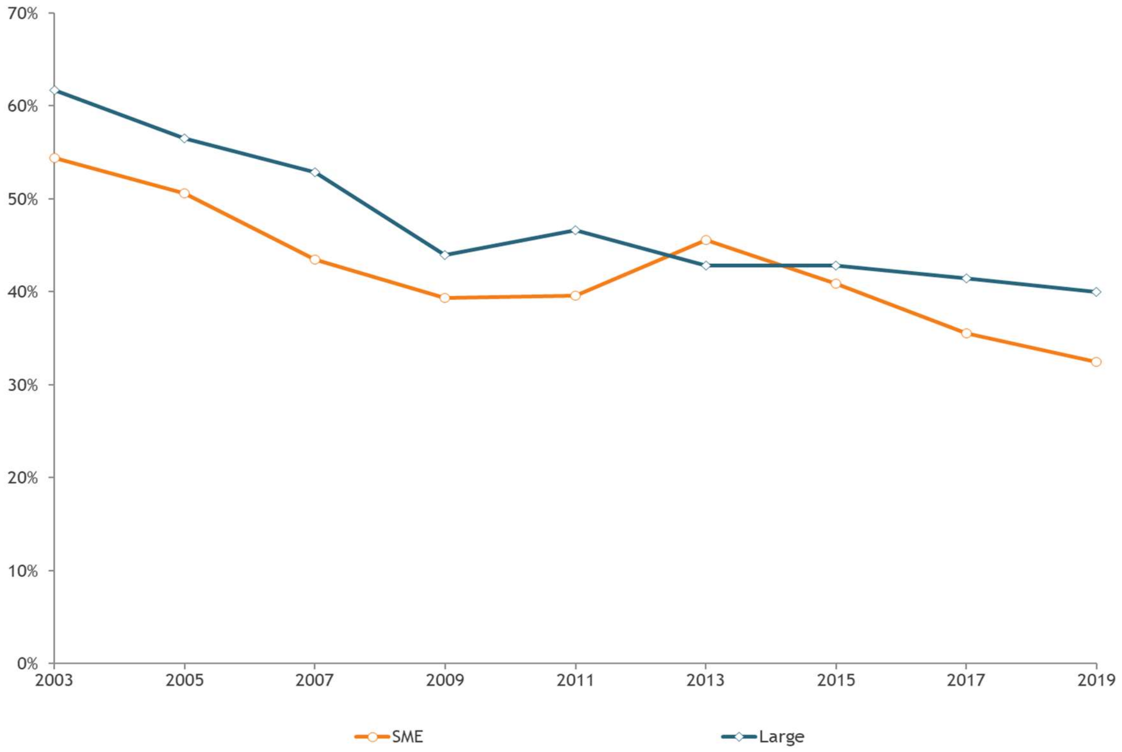
Annex 6: Evolution of the share of type of R&D expenditures – SMEs (less than 250 FTE employees) versus large companies (>= 250 FTE employees)

Basic research

Applied research



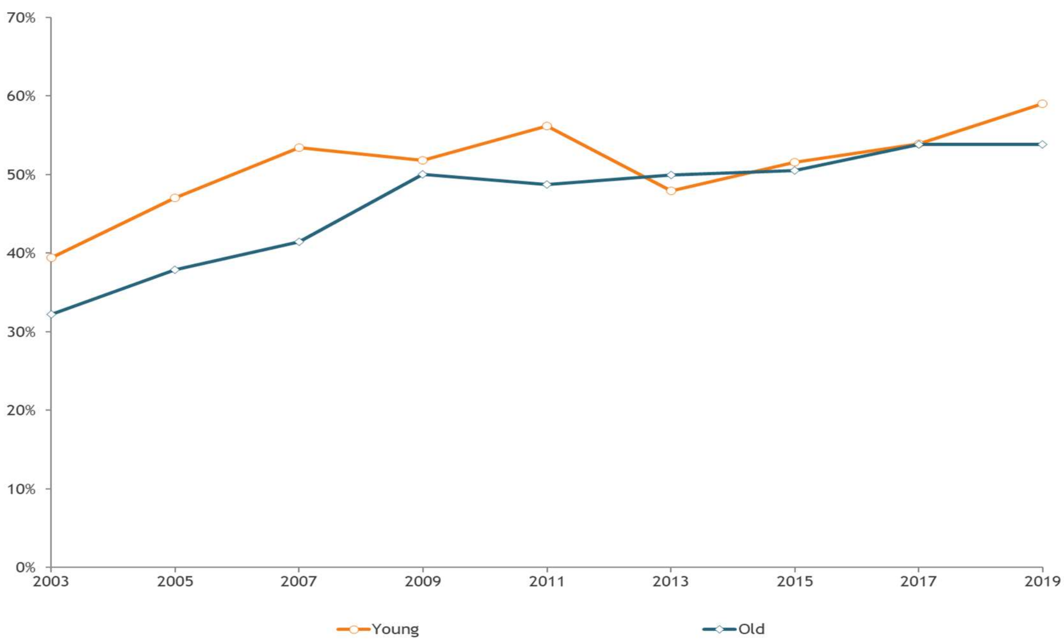
Experimental development



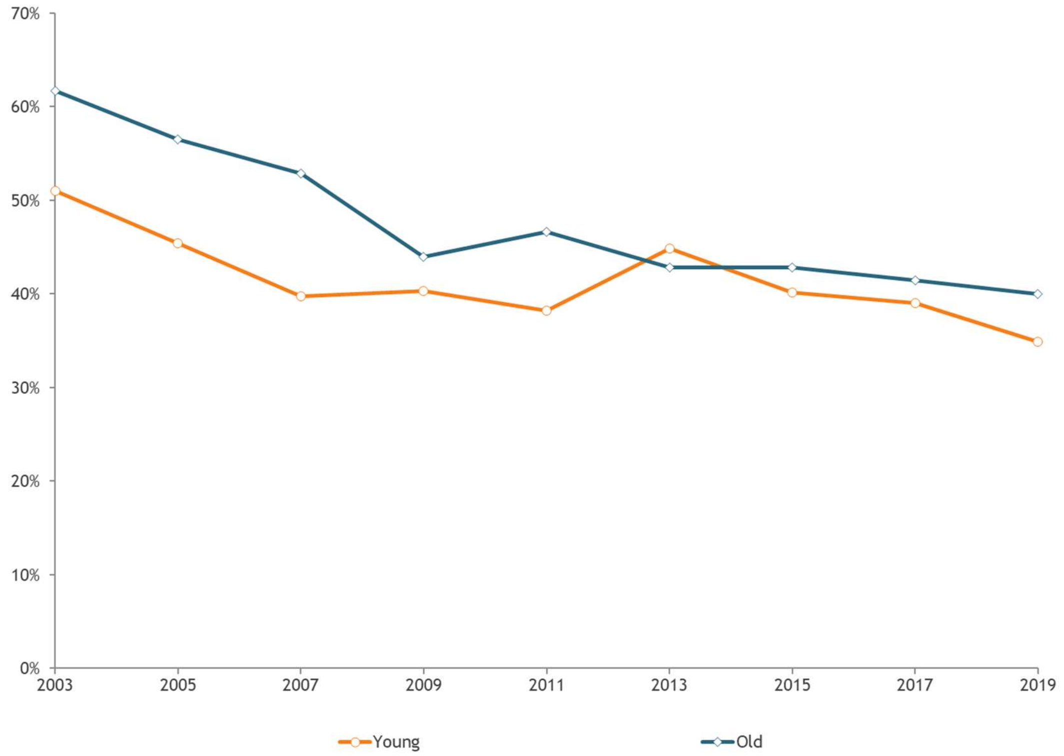
Annex 7: Evolution of the share of type of R&D expenditures - Young (less than 10 years after date of creation) versus old firms (more than 10 years)

Basic research

Applied research



Experimental development



Annex 8: Estimation of output additionality, by groups of firms

Table A8.1 Results of a panel estimation of the impact of public support on labour productivity, by intangible intensity

	Low intangibles intensive	Medium-low intangibles intensive	Medium-high intangibles intensive	High intangibles intensive
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.27 (4.06) ***	0.25 (12.44) ***	0.30 (13.72) ***	0.26 (12.39) ***
R&D expenditures financed by public support:				
Regional subsidies	0.71 (3.88) ***	0.57 (12.00) ***	0.60 (11.57) ***	0.60 (12.57) ***
Research cooperation	0.00 (0.50)	-0.01 (-1.78) *	0.00 (0.87)	-0.00 (-1.00)
Young Innovative Company	-0.01 (-0.68)	-0.00 (-0.02)	-0.01 (-0.71)	0.03 (2.38) **
PhDs and civil engineers	-0.01 (-0.58)	-0.00 (-0.78)	-0.01 (-2.57) ***	0.00 (0.72)
Master	0.01 (1.89) *	-0.01 (-1.84) *	-0.01 (-2.10) **	-0.01 (-1.42)
Bachelor	0.00 (0.08)	0.00 (0.29)	0.01 (1.07)	-0.00 (-0.74)
Tax credit R&D	0.08 (2.09) **	0.03 (2.87) ***	0.05 (5.35) ***	0.05 (7.76) ***
Tax deduction R&D°	0.11 (3.25) ***	0.05 (6.76) ***	0.07 (8.07) ***	0.05 (6.13) ***
Patent income deduction	0.10 (3.23) ***	0.05 (6.49) ***	0.05 (6.14) ***	0.04 (4.60) ***
Innovation income deduction	-	0.03 (4.38) ***	0.01 (0.91)	0.02 (3.37) ***
Innovation bonus	0.01 (0.97)	0.00 (0.82)	0.01 (1.90) *	0.00 (0.32)
EU Funding	0.01 (1.13)	-0.01 (-0.80)	0.00 (0.73)	-0.00 (-1.21)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	0.00 (0.08)	-0.02 (-1.48)	-0.01 (-1.18)	-0.00 (-0.02)
Intra-industry regional subsidies only	-0.01 (-1.50)	-0.00 (-0.29)	-0.00 (-1.45)	-0.00 (-0.20)
Intra-industry partial exemption only	-0.00 (-0.42)	-0.00 (-0.47)	-0.00 (-0.20)	-0.00 (-1.15)
Intra-industry CIT incentives only	-0.00 (-0.16)	0.01 (2.29) **	-0.01 (-1.26)	-0.01 (-1.41)
Intra-industry combined support	-0.01 (-2.21) **	0.02 (1.83) *	0.02 (1.98) **	0.02 (2.28) ***
Inter-industry no support	1.06 (1.27)	-0.39 (-1.42)	0.02 (2.33) **	-0.01 (-2.43) **
Inter-industry regional subsidies only	0.01 (1.38)	-0.00 (-0.15)	-0.00 (-1.45)	0.00 (0.22)
Inter-industry partial exemption only	0.01 (0.66)	-0.00 (-0.28)	-0.00 (-0.51)	-0.00 (-1.15)
Inter-industry CIT incentives only	0.00 (0.73)	-0.01 (-2.40) **	0.00 (0.96)	0.01 (1.68) *
Inter-industry combined support	-0.94 (-1.26)	-0.54 (-1.00)	-0.03 (-3.07) ***	0.08 (1.01)
R-squared (within)	0.54	0.42	0.48	0.52
Number of observations	694	3,507	3,949	2,0471

Note: The table shows the results of a fixed effects panel regression with firms grouped by industry according to the average level of intangible assets. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 A8.2 Results of panel estimation of the impact of public support on labour productivity, by ICT intensity

	Low ICT intensity	Medium-low ICT intensity	Medium-high ICT intensity	High ICT intensity
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.15 (2.55) ***	0.26 (9.30) ***	0.29 (13.38) ***	0.27 (13.13) ***
R&D expenditures financed by public support:				
Regional subsidies	0.48 (4.06) ***	0.54 (8.26) ***	0.62 (10.58) ***	0.60 (14.95) ***
Research cooperation	-0.01 (-0.63)	-0.00 (-0.01)	0.01 (0.99)	-0.00 (-1.03)
Young Innovative Company	-0.02 (-0.87)	0.01 (0.66)	0.02 (2.66) ***	-0.00 (-0.55)
PhDs and civil engineers	-0.00 (-0.28)	0.00 (0.06)	0.00 (0.26)	-0.01 (-2.22) **
Master	0.01 (1.24)	-0.01 (-1.52)	-0.00 (-0.90)	-0.01 (-1.21)
Bachelor	0.01 (1.08)	-0.01 (-1.56)	0.01 (1.32)	0.00 (0.61)
Tax credit R&D	0.03 (0.75)	0.05 (4.74) ***	0.06 (4.82) ***	0.04 (5.10) ***
Tax deduction R&D°	0.08 (2.60) ***	0.06 (5.99) ***	0.06 (5.92) ***	0.05 (7.21) ***
Patent income deduction	0.06 (1.97) **	0.05 (4.91) ***	0.06 (6.79) ***	0.03 (4.75) ***
Innovation income deduction	-	0.01 (1.88) *	0.03 (2.68) ***	0.02 (3.38) ***
Innovation bonus	-0.01 (-0.67)	0.01 (0.93)	-0.00 (-0.44)	0.00 (0.20)
EU Funding	0.01 (1.44)	0.00 (0.73)	-0.01 (-1.64) *	-0.00 (-0.03)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	0.00 (0.24)	-0.00 (-0.23)	0.00 (0.28)	-0.02 (-1.82) *
Intra-industry regional subsidies only	-0.01 (-2.44) **	-0.00 (-0.32)	0.01 (1.77) *	-0.01 (-1.09)
Intra-industry partial exemption only	0.00 (0.87)	0.00 (0.78)	-0.00 (-0.91)	0.01 (1.08)
Intra-industry CIT incentives only	0.03 (1.90) *	-0.00 (-0.32)	-0.01 (-1.26)	0.00 (1.16)
Intra-industry combined support	-0.01 (-0.29)	0.01 (0.89)	0.00 (0.32)	0.02 (1.91) *
Inter-industry no support	0.30 (0.33)	-0.05 (-0.47)	-0.29 (-0.99)	-0.00 (-0.42)
Inter-industry regional subsidies only	0.01 (1.67) *	0.00 (0.18)	-0.00 (-0.87)	0.00 (0.55)
Inter-industry partial exemption only	-0.00 (-1.04)	-0.01 (-1.38)	0.00 (0.01)	-0.01 (-1.68) *
Inter-industry CIT incentives only	-0.02 (-1.41)	-0.00 (-0.02)	0.00 (0.49)	-0.00 (-0.82)
Inter-industry combined support	-0.27 (-0.33)	0.03 (0.29)	-0.23 (-1.25)	-0.79 (-2.55) **
R-squared (within)	0.59	0.45	0.49	0.47
Number of observations	452	3,014	3,221	3,421

Note: The table shows the results of a fixed effects panel regression with firms grouped by industry according to the share of ICT in capital compensation (EU KLEMS data). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. 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 A8.3 Results of panel estimation of the impact of public support on labour productivity, by degree of liquidity

	Low 1st quartile Liquidity	Medium-low 2nd quartile Liquidity	Medium-high 3rd quartile Liquidity	High 4th quartile Liquidity
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.28 (10.14) ***	0.24 (9.64) ***	0.25 (8.64) ***	0.29 (12.71) ***
R&D expenditures financed by public support:				
Regional subsidies	0.63 (9.60) ***	0.68 (9.58) ***	0.68 (7.62) ***	0.54 (12.44) ***
Research cooperation	-0.00 (-0.14)	-0.01 (-2.09) **	-0.01 (-0.94)	-0.01 (-1.38)
Young Innovative Company	0.02 (1.66) *	0.00 (0.44)	-0.01 (-0.91)	-0.00 (-0.11)
PhDs and civil engineers	-0.00 (-0.40)	-0.00 (-0.59)	-0.00 (-0.63)	-0.00 (-0.92)
Master	-0.01 (-1.34)	-0.01 (-2.63) ***	-0.01 (-1.24)	-0.00 (-0.49)
Bachelor	0.00 (0.23)	-0.00 (-0.07)	0.00 (0.04)	0.01 (1.29)
Tax credit R&D	0.05 (5.62) ***	0.05 (3.09) ***	0.07 (4.64) ***	0.05 (5.39) ***
Tax deduction R&D°	0.05 (4.92) ***	0.07 (5.92) ***	0.07 (5.97) ***	0.05 (6.33) ***
Patent income deduction	0.04 (4.01) ***	0.06 (5.13) ***	0.07 (5.46) ***	0.04 (5.65) ***
Innovation income deduction	0.02 (2.32) **	0.03 (2.61) ***	0.05 (3.28) ***	0.01 (1.42)
Innovation bonus	0.01 (1.61) *	-0.00 (-0.17)	0.00 (0.50)	-0.00 (-0.29)
EU Funding	0.00 (0.40)	-0.00 (-0.73)	-0.00 (-0.03)	0.00 (0.04)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	0.00 (0.35)	-0.02 (-1.73) *	-0.01 (-0.41)	-0.04 (-3.03) ***
Intra-industry regional subsidies only	0.00 (0.08)	-0.00 (-0.94)	-0.01 (-2.32) **	0.00 (0.30)
Intra-industry partial exemption only	0.00 (0.37)	0.00 (0.00)	-0.00 (-0.56)	0.00 (0.34)
Intra-industry CIT incentives only	0.00 (0.49)	-0.01 (-1.12)	-0.00 (-0.28)	-0.00 (-0.38)
Intra-industry combined support	0.01 (1.15)	0.02 (2.14) **	0.02 (1.36)	0.04 (2.99) ***
Inter-industry no support	0.01 (0.65)	-0.43 (-3.09) ***	-0.26 (-0.87)	-0.01 (-0.03)
Inter-industry regional subsidies only	-0.00 (-0.35)	0.00 (1.01)	-0.00 (-0.03)	-0.00 (-0.34)
Inter-industry partial exemption only	-0.01 (-2.63) ***	-0.00 (-0.17)	-0.00 (-0.18)	-0.00 (-0.80)
Inter-industry CIT incentives only	-0.00 (-0.80)	0.00 (0.98)	0.00 (0.63)	0.00 (0.90)
Inter-industry combined support	-0.03 (-2.70) ***	0.39 (3.13) ***	0.00 (0.01)	-0.08 (-0.65)
R-squared (within)	0.54	0.50	0.51	0.51
Number of observations	2,599	2,548	2,544	2,506

Note: The table shows the results of a fixed effects panel regression by quartile of liquidity (acid test ratio). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of liquidity 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 A8.4 Results of panel estimation of the impact of public support on labour productivity, by degree of solvency

	Low 1st quartile Solvency	Medium-low 2nd quartile Solvency	Medium-high 3rd quartile Solvency	High 4th quartile Solvency
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.31 (7.89) ***	0.27 (10.06) ***	0.26 (7.35) ***	0.28 (10.20) ***
R&D expenditures financed by public support:				
Regional subsidies	0.71 (8.00) ***	0.70 (8.56) ***	0.70 (7.50) ***	0.63 (9.79) ***
Research cooperation	0.00 (0.19)	0.01 (0.61)	-0.00 (-0.77)	-0.01 (-1.81) *
Young Innovative Company	0.02 (1.28)	-0.02 (-1.68) *	0.01 (0.55)	-0.01 (-0.35)
PhDs and civil engineers	0.01 (1.44)	-0.01 (-2.58) ***	-0.00 (-0.57)	-0.01 (-1.58)
Master	-0.01 (-0.96)	-0.02 (-3.12) ***	-0.00 (-0.84)	-0.01 (-2.45) **
Bachelor	-0.01 (-0.57)	0.01 (1.18)	-0.01 (-1.38)	0.01 (1.75) *
Tax credit R&D	0.07 (4.75) ***	0.05 (3.88) ***	0.07 (5.01) ***	0.04 (3.88) ***
Tax deduction R&D°	0.07 (4.98) ***	0.05 (4.09) ***	0.07 (4.90) ***	0.06 (5.40) ***
Patent income deduction	0.05 (3.57) ***	0.05 (3.98) ***	0.06 (5.50) ***	0.04 (3.26) ***
Innovation income deduction	0.04 (2.36) **	0.01 (1.49)	0.06 (3.74) ***	0.01 (0.95)
Innovation bonus	0.01 (0.84)	-0.00 (-0.56)	0.00 (0.49)	0.01 (1.91) *
EU Funding	0.01 (0.57)	-0.01 (-1.84) *	0.00 (1.13)	0.02 (1.86) *
R&D expenditures of other firms (spillovers):				
Intra-industry no support	-0.01 (-0.16)	-0.00 (-0.30)	0.04 (2.20) **	-0.02 (-1.12)
Intra-industry regional subsidies only	-0.00 (-0.35)	-0.00 (-0.16)	0.00 (0.54)	-0.01 (-0.92)
Intra-industry partial exemption only	-0.01 (-1.12)	-0.00 (-0.10)	-0.00 (-0.83)	0.00 (0.67)
Intra-industry CIT incentives only	0.00 (0.47)	-0.00 (-1.07)	0.00 (0.42)	-0.00 (-0.33)
Intra-industry combined support	0.00 (0.02)	0.01 (0.82)	-0.04 (-2.48) **	-0.02 (-1.18)
Inter-industry no support	-0.76 (-2.00) **	-0.60 (-2.02) **	0.14 (0.33)	0.03 (2.26) **
Inter-industry regional subsidies only	0.01 (0.78)	-0.00 (-0.66)	-0.00 (-0.94)	0.01 (1.64) *
Inter-industry partial exemption only	-0.01 (-1.12)	-0.01 (-1.27)	0.00 (1.49)	0.00 (0.32)
Inter-industry CIT incentives only	-0.00 (-0.52)	0.00 (0.88)	-0.00 (-0.06)	0.00 (0.69)
Inter-industry combined support	-0.15 (-0.60)	-0.03 (-0.14)	-0.12 (-0.81)	-0.22 (-1.30)
R-squared (within)	0.52	0.54	0.57	0.54
Number of observations	1,256	1,768	1,828	1,879

Note: The table shows the results of a fixed effects panel regression by quartile of solvency long-term financial independence). The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of solvency 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 A8.5 Results of panel estimation of the impact of public support on labour productivity, by degree of profitability

	Low 1st quartile Profitability	Medium-low 2nd quartile Profitability	Medium-high 3rd quartile Profitability	High 4th quartile Profitability
Dependent variable Labour productivity				
R&D expenditures financed by firm:	0.33 (10.25) ***	0.27 (9.57) ***	0.23 (9.59) ***	0.28 (11.80) ***
R&D expenditures financed by public support:				
Regional subsidies	0.61 (10.63) ***	0.62 (8.68) ***	0.46 (8.37) ***	0.62 (11.40) ***
Research cooperation	0.00 (0.28)	0.00 (0.29)	0.00 (0.28)	0.00 (0.24)
Young Innovative Company	-0.00 (-0.10)	0.02 (1.24)	0.01 (0.41)	-0.01 (-0.76)
PhDs and civil engineers	-0.01 (-2.17) **	0.00 (0.02)	-0.00 (-0.15)	-0.00 (-0.72)
Master	-0.00 (-0.14)	0.00 (0.02)	-0.01 (-1.35)	-0.01 (-1.87) *
Bachelor	0.01 (0.83)	-0.01 (-1.87) *	0.01 (1.61)	0.01 (1.69) *
Tax credit R&D	0.05 (4.63) ***	0.06 (6.03) ***	0.03 (3.31) ***	-0.01 (-0.65)
Tax deduction R&D°	0.07 (6.09) ***	0.06 (5.98) ***	0.03 (3.61) ***	0.04 (3.63) ***
Patent income deduction	0.03 (3.64) ***	0.05 (5.43) ***	0.03 (4.51) ***	0.06 (5.79) ***
Innovation income deduction	-0.00 (-0.08)	0.03 (3.60) ***	0.02 (2.18) **	0.05 (5.11) ***
Innovation bonus	0.01 (1.33)	0.00 (0.67)	0.00 (0.92)	-0.00 (-0.51)
EU Funding	0.01 (1.44)	-0.00 (-1.21)	-0.00 (-0.29)	0.00 (0.18)
R&D expenditures of other firms (spillovers):				
Intra-industry no support	-0.02 (-0.74)	-0.00 (-0.04)	-0.01 (-0.67)	0.00 (0.42)
Intra-industry regional subsidies only	-0.01 (-1.36)	-0.00 (-0.28)	-0.00 (-0.19)	0.00 (0.15)
Intra-industry partial exemption only	-0.00 (-1.20)	0.00 (1.27)	-0.00 (-0.93)	-0.00 (-0.11)
Intra-industry CIT incentives only	-0.00 (-0.04)	0.00 (1.02)	0.01 (1.07)	-0.01 (-1.62)
Intra-industry combined support	0.02 (1.29)	0.03 (2.35) **	0.02 (1.55)	-0.02 (-1.01)
Inter-industry no support	-0.02 (-2.12) **	-0.60 (-2.02) **	0.02 (2.44) **	0.04 (0.23)
Inter-industry regional subsidies only	0.00 (0.03)	-0.00 (-0.66)	-0.00 (-0.09)	0.00 (0.33)
Inter-industry partial exemption only	-0.00 (-0.23)	-0.01 (-1.27)	-0.00 (-0.93)	0.00 (0.43)
Inter-industry CIT incentives only	-0.00 (-0.76)	0.00 (0.88)	-0.00 (-0.32)	0.01 (1.79) *
Inter-industry combined support	-0.03 (-0.33)	-0.03 (-0.14)	-0.02 (-2.22) **	-0.02 (-0.15)
R-squared (within)	0.56	0.50	0.49	0.54
Number of observations	2,304	2,752	2,803	2,338

Note: The table shows the results of a fixed effects panel regression by quartile of net profitability. The dependent variable, labour productivity, is defined as turnover per full-time equivalent employee. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of 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.

Table A8.6 Results of panel estimation of the impact of public support on multi factor productivity

Dependent variable: Multi factor productivity	Turnover as output	Value added as output
R&D expenditures financed by firm:	-0.02 (-6.37) ***	-0.03 (-7.35) ***
R&D expenditures financed by public support:		
Regional subsidies	0.26 (6.42) ***	0.44 (8.27) ***
Research cooperation	0.00 (0.95)	0.00 (0.02)
Young Innovative Company	-0.01 (-0.54)	-0.01 (-0.93)
PhDs and civil engineers	0.00 (0.90)	0.00 (0.96)
Master	0.00 (0.69)	-0.00 (-0.09)
Bachelor	0.00 (1.45)	0.01 (2.08) **
Tax credit R&D	0.00 (0.17)	-0.02 (-2.82) ***
Tax deduction R&D°	0.00 (0.55)	-0.02 (-2.74) ***
Patent income deduction	0.00 (0.02)	-0.02 (-3.19) ***
Innovation income deduction	-0.00 (-1.24)	-0.02 (-2.85) ***
Innovation bonus	0.00 (0.10)	0.00 (0.94)
EU Funding	-0.00 (-0.33)	-0.00 (-0.83)
R&D expenditures of other firms (spillovers):		
Intra-industry no support	-0.01 (-2.79) ***	-0.01 (-2.81) ***
Intra-industry regional subsidies	-0.00 (-0.83)	-0.00 (-0.13)
Intra-industry partial exemption	-0.00 (-1.37)	-0.00 (-0.20)
Intra-industry CIT incentives	-0.00 (-0.34)	-0.00 (-1.26)
Intra-industry combined support	0.02 (3.57) ***	0.02 (3.09) ***
Inter-industry no support	0.01 (0.81)	-0.00 (-0.10)
Inter-industry regional subsidies	0.00 (1.50)	0.00 (0.42)
Inter-industry partial exemption	-0.00 (-0.40)	-0.00 (-0.16)
Inter-industry CIT incentives	0.00 (0.22)	0.00 (1.05)
Inter-industry combined support	-0.01 (-1.13)	-0.01 (-0.20)
R-squared	0.16	0.12
Number of observations	6,926	6,539

Note: The table shows the results of a fixed effects panel regression, using multi factor productivity as dependent variable. Multi factor productivity is estimated as the residual from a panel regression of output on the production factors. Output is alternatively measured as turnover, with capital, labour and intermediate inputs as production factors and value added, with capital and labour as production factors. Explanatory variables are R&D expenditures of firms, grouped according to which type of public support that they received (regional subsidies, partial exemption from payment of the withholding tax on the wages of R&D personnel and corporate income taxation (CIT) incentives). The spillover variables are the R&D expenditures of other firms within the same industry (intra) and the total R&D expenditures of all firms in all other industries (inter). For the spillover variables, firms are also grouped according to the type of public support that they received. All variables are considered in logs. Own R&D expenditures are included with a one-year lag and spillover variables with a two-year lag. Estimations include year and industry dummies and four inverse Mills variables computed from the estimation of a selection model in which a lag of multi factor productivity is included. The multinomial logit estimation of the selection model for value added TFP did not converge. *, ** 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.

Annex 9: Bayesian afterthought on priors

McGrayne (2011) provides a vivid description of the long and winding history of Bayes' rule, which states that a prior - potentially subjective- belief can be updated using new objective information (data), resulting in an improved posterior belief. Statisticians have long objected to Bayes' rule, mainly because of its use of subjective priors. For a long time, Bayes was banned from academia, where the frequentist approach ruled mainly unquestioned. Rather recently, Bayesian statistics has gained traction.

Most evaluations of public support to business R&D clearly fit within a frequentist framework, with its exclusive use of data and a strong focus on statistical significance and p-values. The evaluation presented in this report - as all three previous evaluations- follows suit. Although a frequentist approach dominates the empirical literature, its basic assumptions and its reliance on p-values is not uncontroversial. Imbens (2021) lists the limitations of this approach and points out the possible advantage of Bayesian concepts.

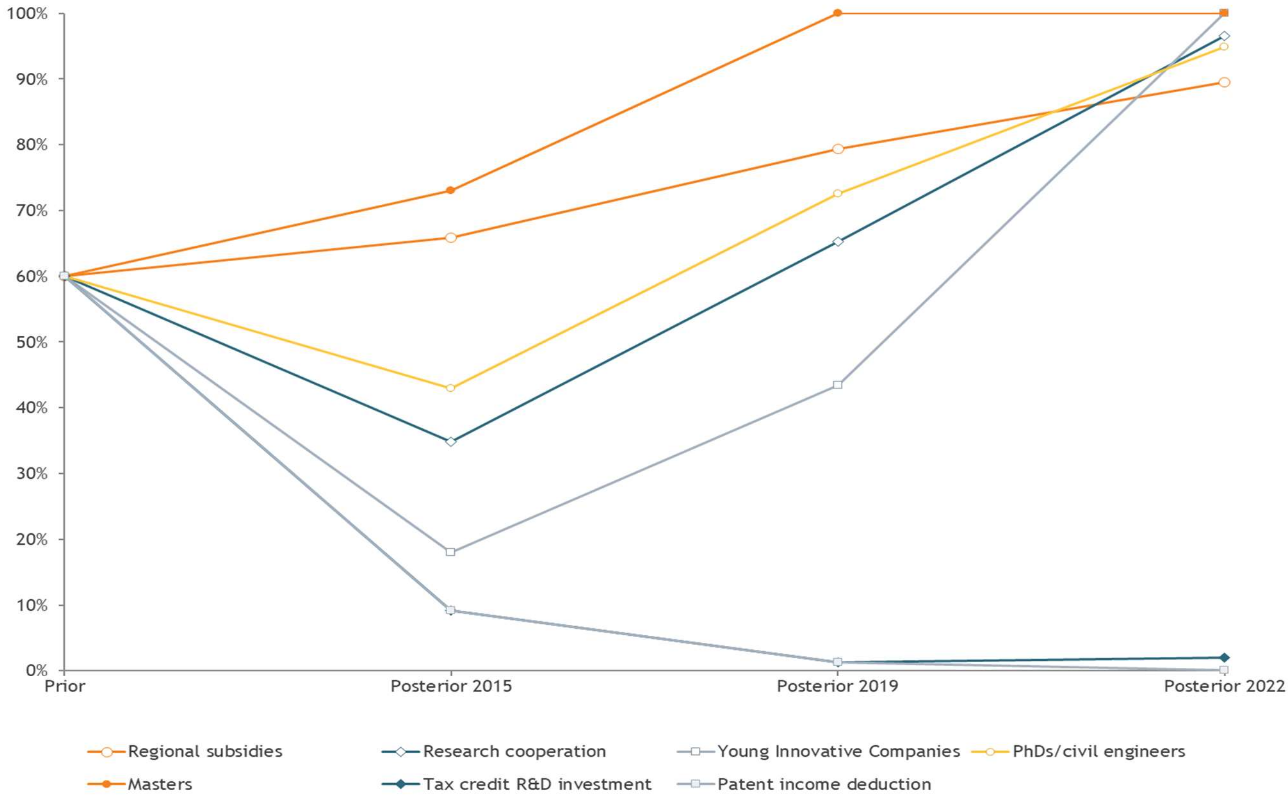
In this annex, rather than considering the statistical significance of coefficient estimates, the probability of input additionality of the public support schemes is computed following a Bayesian approach. The average probability of input additionality from the meta-analyses of Zúñiga-Vicente et al. (2014), Castellacci and Lie (2015) and Dimos and Pugh (2016), which equals 60%, is taken as the prior.[46] The prior probability is then updated with the results of each new evaluation. The computed posterior probability is then used as prior for the next evaluation. The different alternative estimates of the evaluations are considered to compute the data-based probabilities. The posterior probability of input additionality is computed following Bayes' rule:

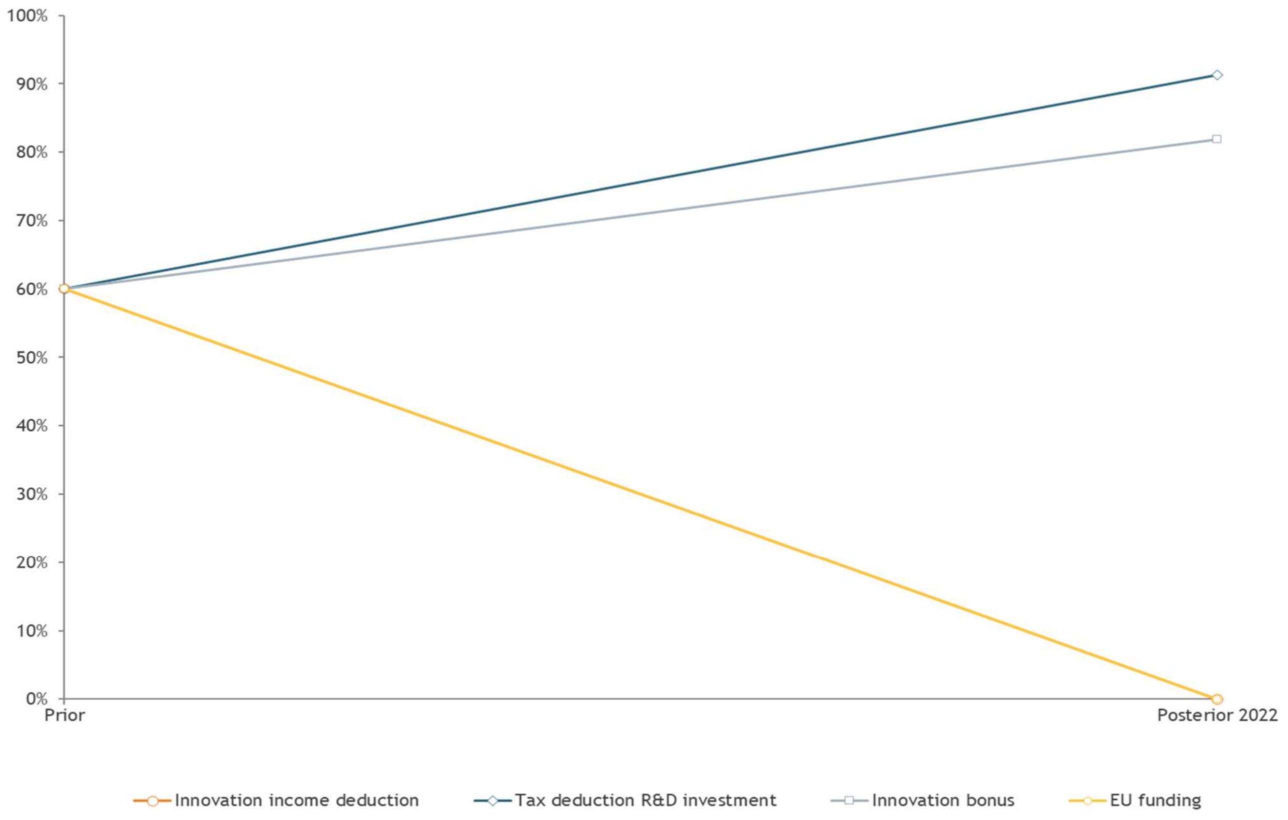
$$P(Additionality/Data) = \frac{P(Additionality)P(Data/Additionality)}{P(Additionality)P(Data/Additionality) + P(No\ additionality)P(Data/No\ additionality)}$$

As the first evaluation did not provide alternative estimates, it is not considered for the computation of the probability of input additionality. The computation of the posterior probability is computed sequentially for the second evaluation (2015), the third evaluation (2019) and the fourth evaluation (2022, as presented in this report). For each individual support scheme, the initial prior probability of additionality is equal to 60%, based on the average of the two meta-analyses. The first graph shows the evolution of the posterior probability of input additionality for the support schemes that were considered in all three evaluations. The second graph shows the evolution of the posterior probability of input additionality for the four schemes that were only considered (fully) in the fourth evaluation.

[46] Arithmetic average of 65% for Castellacci and Lie (2015), based on Table 1 and Table 2 on page 822, and of 55% for Dimos and Pugh (2016), based on Table 2 on page 801. In this exercise, statistical significance of estimates (at most at 5%) is considered as an indication of additionality.

Bayesian probability of input additionality





For regional subsidies and the partial exemption for R&D employees with a master's degree, the posterior probability of input additionality increased with each evaluation. For the three other schemes of partial exemption, the posterior probability after the second evaluation (2015) was lower than the prior probability but increased substantially after the third and the fourth evaluation.

For regional subsidies and the four partial exemptions schemes, the posterior probability of input additionality after the fourth evaluation is at least 89% and 100% for the partial exemption for Young Innovative Companies and R&D employees with a master's degree.

For the tax credit for R&D investment and the patent income deduction, the posterior probability of input additionality dropped dramatically after the second evaluation (2015) and further decreased, reaching respectively 2% and 0% after the fourth evaluation (2022).

For the four support schemes that are only (fully) considered in the fourth evaluation, a substantial posterior probability of input additionality is found for the tax deduction for R&D investment and the innovation bonus whereas for the innovation income deduction and EU funding, posterior probability of input additionality is 0% right from the first evaluation.[47] This obviously results from the rather robust indications of crowding out for these support schemes.

[47] As both overlap perfectly, the yellow line of EU funding fully covers the orange line of the innovation income deduction.