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Public support for R&D and the educational mix of R&D employees

October 2014

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Responsible publisher: Philippe Donnay
Legal Deposit: D/2014/7433/20

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Abstract - In this paper we assess the impact of public support for R&D activities on the educational mix of R&D employees in private companies in Belgium, covering the period 2001-2009. Data on federal tax incentives in support of R&D activities are matched with R&D survey data to investigate changes in the share of R&D employees with a specific degree: PhDs; higher education (second stage and first stage respectively); and other qualifications. Estimations show that public support significantly raises the share of researchers holding a PhD. There are indications that PhDs substitute for R&D employees with a lower degree. We also show that controlling for the changes in the educational mix of R&D personnel lowers the estimates of the impact of public support on the average wages of researchers.

Jel Classification - H32, O32, O38

Keywords - R&D, tax incentives, educational mix, wages researchers

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Executive summary

Acknowledging the fundamental role of Research and Development (R&D) in technological progress and well-known market failures in knowledge creation, a large majority of OECD countries provide direct or indirect support for R&D activities of private companies. Most studies that evaluate public support focus on the extent to which subsidies or tax incentives foster R&D projects that companies would not have carried out without support (so-called input additionality). Some recent studies consider output additionality, in effect; the impact of public support for R&D on product and process innovation or productivity. The possible effects of public support on R&D behaviour, for example; shifting R&D activities towards more risky and potentially more profitable projects, is studied by even fewer scholars.

Between 2005 and 2007 the Belgian federal government introduced four distinct measures that consist in the partial exemption of the withholding tax on the wages of researchers. The measures in support of R&D collaboration or of Young Innovative Companies are rather general but for the two other measures, only researchers with a specific educational degree are eligible (for example, PhDs and masters in exact or applied sciences or civil engineers). These measures affect the relative wage cost of specific groups of R&D personnel and thereby relative demand. If the supply of some inputs is inelastic, the rising demand for these inputs due to targeted incentives may raise factor prices (wages). In this paper we assess the effects of recent tax benefits oriented towards highly qualified researchers both on the composition of R&D personnel and the average wages of researchers.

The results presented in this paper show that some measures of public support indeed affect the composition of R&D personnel in companies. There are some indications of substitution of PhD's and civil engineers for R&D employees with a lower degree. Although firms are free to decide how to use the money freed by the partial exemption from withholding tax on the wages of researchers, the partial exemption for researchers with a PhD or civil engineering degree is found to have a substantial positive impact on the share of researchers with that specific degree. The partial exemption for researchers with a master degree is not found to have had a statistically significant impact on the number of R&D employees or the share of researchers with a master degree. In line with previous studies, we find evidence that public support raises the average wage of researchers. Our results however clearly show the need to disentangle the impact on wages due to changes in the educational mix of R&D personnel from the impact public support may have by raising demand for researchers when supply is inelastic. If data over a longer period become available, possible changes in the supply of researchers could be taken into account in the assessment of the impact of public support for R&D on the educational mix of R&D personnel.

A more in-depth estimation of the impact of changes in the educational mix of R&D personnel on the orientation of R&D activities (e.g., the share of R&D dedicated to basic research, applied research or experimental development) seems warranted. Further analysis is also necessary to shed light on whether or not changes in the educational mix translate into changes in innovative performance. This would help in the debate on the relation between policy support and the wages of R&D personnel, in effect, the extent to which rising wages reflect the rising education level of researchers and whether the latter has a positive impact on the long-term innovative capacity of firms.

Synthèse

Vu le rôle fondamental joué par la Recherche & Développement (R&D) dans les progrès technologiques et les imperfections bien connus du marché pour la création de connaissances, la grande majorité des pays de l'OCDE soutiennent directement ou indirectement les activités R&D des entreprises. La plupart des études évaluant les aides publiques se concentrent sur la mesure dans laquelle les subventions ou incitations fiscales soutiennent les projets de R&D que les entreprises n'auraient pas lancés sans cet apport (additionnalité dite par input). Certaines études récentes tiennent, quant à elles, compte de l'additionnalité par output, c'est-à-dire de l'impact des aides publiques en faveur de la R&D sur l'innovation des produits et processus et sur la productivité. Enfin, quelques études se penchent sur les effets possibles des aides publiques sur la nature des activités R&D déployées, par exemple si les aides entraînent un glissement des activités R&D vers des projets plus risqués, mais donc potentiellement plus rentables.

Entre 2005 et 2007, le gouvernement fédéral belge a introduit quatre mesures distinctes consistant en une dispense partielle de versement du précompte professionnel sur les salaires des chercheurs dans les entreprises. Les mesures soutenant la collaboration en matière de R&D et les jeunes sociétés innovantes ont plutôt une portée générale, mais les deux autres mesures ne concernent que les chercheurs détenteurs d'un diplôme bien spécifique (par exemple, les titulaires d'un doctorat ou d'une maîtrise en sciences exactes ou appliquées ou les ingénieurs civils). Ces mesures influencent le coût salarial relatif de groupes spécifiques du personnel R&D et donc la demande relative pour cette main-d'œuvre. Si l'offre de certains inputs est inélastique, la hausse de la demande de tels inputs suite à des stimulants ciblés est susceptible d'accroître les prix des facteurs (salaires). Dans le présent rapport, nous examinons l'impact des récents avantages fiscaux axés sur les chercheurs hautement qualifiés tant sur la composition du personnel R&D que sur le salaire moyen des chercheurs.

Les résultats présentés dans ce rapport montrent que certaines mesures d'aide publique influencent effectivement la composition du personnel R&D dans les entreprises. Certains éléments indiquent que les titulaires d'un doctorat et les ingénieurs civils remplacent les employés R&D détenteurs d'un diplôme moins élevé. Même si les entreprises sont libres de décider de l'usage qu'elles font des sommes d'argent libérées par la dispense partielle de versement du précompte professionnel sur les salaires des chercheurs, la dispense partielle pour les chercheurs titulaires d'un doctorat ou d'un diplôme d'ingénieur civil s'avère avoir un impact positif considérable sur la part des chercheurs ayant ce type de diplôme. En revanche, la dispense partielle pour les chercheurs titulaires d'une maîtrise n'a pas eu un impact statistiquement significatif sur le nombre d'employés R&D ou sur la part des chercheurs titulaires d'une maîtrise. Tout comme dans des études précédentes, divers éléments indiquent que les aides publiques accroissent le salaire moyen des chercheurs. Toutefois, nos résultats montrent clairement le besoin de bien distinguer l'impact sur les salaires suite aux variations dans la composition du personnel R&D selon le niveau de formation de l'impact que les aides publiques sont susceptibles de produire en accroissant la demande de chercheurs lorsque l'offre est inélastique. Si on disposait de données sur une plus longue période, les variations éventuelles dans l'offre de chercheurs pourraient être prises en considération dans l'évaluation de l'impact des aides publiques en faveur de la R&D sur la composition du personnel R&D en fonction du niveau de formation.

Une analyse plus précise de l'impact des variations dans la composition du personnel R&D en fonction du niveau de formation sur la nature des activités R&D (par ex., la part de R&D consacrée à la recherche fondamentale, à la recherche appliquée ou à la recherche expérimentale) semble indiquée. Une analyse plus fouillée permettrait également de déterminer si ces variations se traduisent par des changements en termes d'innovation. Cela contribuerait à faire avancer le débat sur la relation entre les aides publiques et les salaires du personnel R&D, c'est-à-dire la mesure dans laquelle une augmentation des salaires reflète le niveau de formation plus élevé des chercheurs et si cette hausse du niveau de formation a un impact positif sur la capacité d'innovation des entreprises à long terme.

Synthese

Vanwege het fundamenteel belang van onderzoek en ontwikkeling (O&O) voor technologische vooruitgang en het gekend marktfalen in kenniscreatie, verleent een grote meerderheid van OESO-landen directe of indirecte steun voor O&O-activiteiten van ondernemingen. Bij de evaluatie van overheidssteun ligt de focus meestal op de mate waarin subsidies of fiscale voordelen O&O-projecten aanmoedigen die bedrijven zonder ondersteuning niet zouden verrichten (zogenaamde inputadditionaliteit). In sommige recente studies wordt ook gekeken naar outputadditionaliteit, namelijk de impact van overheidssteun op product- en procesinnovatie of productiviteit. Er zijn ook een beperkt aantal studies waarin wordt gekeken naar de mogelijke gevolgen van overheidssteun voor de aard van O&O-activiteiten (gedragsadditionaliteit), bijvoorbeeld of er door steun een verschuiving is naar meer risicovolle maar potentieel meer winstgevende O&O-projecten.

Tussen 2005 en 2007 introduceerde de Belgische federale regering vier verschillende steunmaatregelen waarbij bedrijven een gedeeltelijke vrijstelling van de bedrijfsvoorheffing op de lonen van hun onderzoekers kunnen verkrijgen. De maatregelen ter ondersteuning van onderzoekssamenwerking of van jonge innovatieve bedrijven hebben betrekking op nagenoeg het voltallig O&O-personeel, maar voor de twee andere maatregelen komen alleen onderzoekers met een specifiek diploma in aanmerking (bijvoorbeeld, doctoraten en masters in exacte of toegepaste wetenschappen of burgerlijk ingenieurs). Deze maatregelen beïnvloeden de relatieve loonkost van specifieke groepen van O&O-personeel en daardoor de relatieve arbeidsvraag. Als het aanbod van bepaalde productiefactoren inelastisch is, dan kan een stijgende vraag ernaar als gevolg van gerichte voordelen, resulteren in hogere factorprijzen (lonen). In deze working paper wordt de impact van de recente fiscale voordelen onderzocht, zowel op de samenstelling van O&O-personeel als op het gemiddeld loon van onderzoekers.

Uit de voorgestelde schattingsresultaten blijkt dat sommige maatregelen van overheidssteun inderdaad de samenstelling van O&O-personeel in bedrijven beïnvloeden. Er zijn aanwijzingen dat doctors en burgerlijk ingenieurs O&O-werknemers met een lager diploma vervangen. Hoewel ondernemingen zelf kunnen beslissen over de besteding van het geld dat vrijkomt door de gedeeltelijke vrijstelling van de bedrijfsvoorheffing, blijkt de gedeeltelijke vrijstelling voor onderzoekers met een doctoraat of een diploma van burgerlijk ingenieur een aanzienlijke positieve impact te hebben op het aandeel van onderzoekers met dat specifiek diploma. De gedeeltelijke vrijstelling voor onderzoekers met een master heeft geen significante invloed gehad op het aantal O&O-werknemers of het aandeel van onderzoekers met een master. In overeenstemming met eerdere studies vinden we aanwijzingen dat overheidssteun het gemiddeld loon van onderzoekers verhoogt. Onze resultaten tonen echter duidelijk de noodzaak aan om de impact op lonen als gevolg van veranderingen in de samenstelling van O&O-personeel volgens opleidingsniveau te onderscheiden van de impact die steunmaatregelen kunnen hebben door het verhogen van de vraag naar onderzoekers, bij inelastisch aanbod. Indien gegevens over een langere periode beschikbaar worden, dan zouden eventuele wijzigingen in het aanbod van onderzoekers in rekening kunnen worden gebracht bij de beoordeling van het effect van overheidssteun voor O&O op de samenstelling van O&O-personeel volgens opleidingsniveau.

Een meer diepgaande analyse van de impact van veranderingen in de samenstelling van O&O-personeel volgens opleidingsniveau op de aard van O&O-activiteiten (bijvoorbeeld het aandeel van O&O gewijd aan fundamenteel onderzoek, toegepast onderzoek of experimentele ontwikkeling) lijkt aangewezen. Verdere analyse zou ook licht kunnen werpen op de vraag of die veranderingen zich ook in meer innovatie vertalen. Dit zou kunnen helpen in het debat over de relatie tussen overheidssteun en de lonen van O&O-personeel, namelijk, de mate waarin stijgende lonen het stijgend opleidingsniveau van onderzoekers weerspiegelen en of de toegenomen scholingsgraad een positief effect heeft op het lange termijn innovatievermogen van bedrijven.

1. Introduction

Acknowledging the fundamental role of R&D activities in technological progress and well-known market failures in knowledge creation, most OECD countries provide direct or indirect support for R&D activities of private companies. The assessment of public support tends to focus on input additionality, in effect, the extent to which subsidies or tax incentives foster R&D projects that companies would not have carried out without support. Empirical studies generally indicate that subsidies and tax incentives result in additional R&D by private companies (see for example, reviews by David et al. 2000; Hall and van Reenen 2000). However, in two recent surveys, Köhler et al. (2012) and Zúñiga-Vicente et al. (2014) conclude that in spite of a large body of empirical work, our knowledge as to how effective tax incentives for R&D are, remains rather limited.

To the best of our knowledge, there is hardly any study that considers the impact of tax incentives on the educational mix of R&D personnel – undoubtedly explained by data availability – although it seems evident that government policies that favour certain types of inputs, can affect both the total amount of inputs that firms will use as well as the composition of these inputs. Thereby, public support is likely to influence the decisions of firms as to how much of the different types of inputs (capital or workers with different education degrees) they will use to produce knowledge and new products/processes. If the supply of some specific inputs is inelastic, the rising demand for these inputs due to targeted incentives may raise factor prices (wages). In this paper we study the influence of public support oriented towards highly qualified researchers both on the composition of R&D personnel and the wages of researchers.

These effects may have important implications, both from a methodological and a policy perspective. Studies in which the impact of public support on the total number of R&D employees is estimated (see for example the firm-level studies by Wallsten 2000; Suetens 2002; Aerts 2008 or the estimations for a panel of OECD countries by Wolff and Reinthaler 2008; Thomson and Jensen 2011), may net out opposing effects. If one category of R&D employees is substituted for another, these studies could fail to find any statistically significant impact on R&D employees or conceal substantial shifts in its composition. If the impact of public support on the average wage of R&D employees is estimated (for example, Goolsbee 1998; Marey and Borghans 2000; Jaumotte and Pain 2005; Hægeland and Møen 2007; Lokshin and Mohnen 2013), without accounting for possible changes in the composition, estimates may suggest that part of the rise in R&D expenditures reflects upward wage pressure due to the inelastic supply of researchers, even if rising average wages could be explained by the (relative) substitution of highly qualified researchers for R&D employees with a lower education degree.

Our analysis is based on the relatively recent introduction of a partial exemption of the withholding tax on the wages of highly qualified R&D personnel in Belgian companies. The money that companies save through the partial exemption can be freely used. This measure is the cornerstone of the Belgian policy to support R&D activities of private companies through tax incentives in view of the EU 2020 target that R&D expenditures should amount to 3% of GDP by 2020. Given the increased importance of tax benefits for R&D in policy making in OECD countries and the continuous fine-tuning of these policies (OECD 2013), the Belgian tax benefits which target specific types of knowledge workers provide a pertinent case. An important motivation for the recent Belgian tax benefits was to stimulate the employment of high-level R&D profiles which, as pointed out by Chiesa (1996); Chiesa and Frattini (2007) and Barge-Gil and López (2011, 2012), orient towards more longer term basic and applied research compared to shorter term experimental development.

The estimations, performed on data linking information on tax incentives granted by the federal government in Belgium to responses of companies to the biennial OECD business R&D survey, account for the self-selection of companies, unobserved firm heterogeneity and the endogeneity of public support. The results of the estimations are complemented with detailed information on the appraisal by companies of the federal tax incentives, as gathered through an electronic survey. In line with the increased interest in the policy mix of tax incentives and subsidies in support of R&D (e.g., Nauwelaers et al. 2009; Magro and Wilson 2013; OECD 2013), we control for the impact of R&D subsidies in our assessment of the effects of tax incentives. Section 2 provides an overview of the relevant literature and states the main research questions. Section 3 describes the data that are used. In section 4 the estimation procedure is discussed and the estimation results are reported. Conclusions are provided in section 5.

2. Literature and conceptual framework

2.1. Public support for R&D activities of private companies

Most empirical studies assess the impact of public support for R&D in terms of input additionality, in effect, the extent to which direct or indirect support raises the level of R&D expenditures of companies. Starting from Hitch (1958), Nelson (1959) and Arrow (1962), the neoclassical market failure argument in favour of public support stresses the uncertainty and high risks involved in R&D activities. Tax incentives are used in an increasing number of countries to raise the level of R&D activities of private companies to a perceived socially desired optimum (OECD 2013). Tax incentives have some distinct characteristics compared to the other main policy instrument to support business R&D, i.e. subsidies (OECD 2013). In general, subsidies provide up-front financing of R&D projects independent of a firm's fiscal situation (e.g., profits). Subsidies are more interesting for firms facing appropriability difficulties as additional revenue resulting from innovation could be compromised by imitation. For subsidies, technical challenge is an important decision criterion (e.g. Takalo et al. 2013 for Finland), which also creates steering opportunities towards more beneficial projects from a societal point of view (David et al. 2000).Tax incentives, on average, have a lower administrative burden and are more neutral in terms of winner-picking (avoiding inefficiencies due to uninformed steering - Hall and Van Reenen, 2000) and therefore could be preferred for firms with more substantial appropriability capacity. Tax incentives are more likely to benefit stable R&D performers, whereas subsidies tend to increase the number of R&D performers (Busom et al. 2012; Arqué-Castells and Mohnen 2012).

The specific tax benefits in Belgium are derived from the employment of highly qualified researchers (defined by educational level) but the resources that become available can be freely spent by the firm. Given the low administrative burden and control it is possible that the money from the tax benefits is not spent on R&D (see Lokshin & Mohnen 2013 on deadweight loss) or results in relabeling of expenses as research activities (e.g., Ientile and Mairesse 2009; Antonelli and Crespi 2013). In view of the focus of this paper on the composition of R&D personnel it should be pointed out that firms have no obligation to use the money that is saved through the tax benefit to employ more R&D employees of eligible educational groups.

2.2. Educational mix of R&D personnel

Human resources for R&D activities are repositories of particular skills and knowledge (Nonaka and Takeuchi 1995) which result from two processes (OECD 1995). First, skills and knowledge are the result of learning by doing as employees perform repetitious tasks that raise efficiency (Nemet 2012). However, this type of knowledge is characterized by diminishing returns (Arrow 1962). A second, more permanent, source of skills and knowledge stems from formal education in terms of diplomas (OECD, 1995). The education of PhDs, as the highest education level, is characterized by two purposes. On the one hand, the formation involves skill and capability development to perform independent research activities; and, on the other hand, the final result is a finished product listing the research results (Spithoven and Teirlinck 2010). R&D employees holding certain degrees are often equated with highly qualified personnel and are deemed to be important for R&D activities and innovation (Roach and Sauermann 2010; Lam 2005).

The skills and knowledge gained through formal education are, first and foremost, tacit in nature (Argote and Ingram 2000). Hence, formal education is both part and parcel of building absorptive capacity (Huang and Rice 2009; Azagra-Caro et al. 2006; Roach and Sauermann 2010).

More recently, task-related diversity, expressed both in knowledge area background and educational background, has been put forward as another argument for not considering R&D personnel as a homogeneous group of employees (Faems and Subramanian 2013). This view builds on earlier work by Thomas (2004) that the increasingly complex nature of technology forces firms to diversify manpower in terms of educational and knowledge background, in line with the literature on organizational diversity (Hülsheger et al. 2009).

2.3. Effects on wages of R&D employees

Ientile and Mairesse (2009) argue that rising wages may be due to increasing productivity and that governments provide support precisely to partly offset the wage increases of researchers. However, if the supply of R&D employees is inelastic, an increase in demand may result in upward pressure on wages (OECD 2013). Part of the additionality of public support may therefore simply reflect an increase in wages rather than an increase in R&D activities. Estimations for a panel of 20 OECD countries, by Jaumotte and Pain (2005), point out the difficulty in raising R&D intensity given the inelastic supply of researchers, especially in the short term. Estimates of Goolsbee (1998) for the US, suggest that an increase in R&D expenditures by 10% results in an immediate rise in the wages of researchers by 1% and by another 2% in the ensuing four years. He concludes that by ignoring this effect, the additionality of public support for R&D may be overestimated by 30 up to 50%. Rising wages will also affect those companies that do not receive a subsidy or tax benefit. For the Netherlands, Marey and Borghans (2000) find that an increase in R&D expenditures by 1% results in a long-term increase of 0.5% in the supply of researchers and a rise in wages of 0.4%. In the short run the wage increase is even more substantial. According to the estimates for Norway by Hægeland and Møen (2007), a tax benefit of 100,000 Norwegian Krone is absorbed to the extent of 33,000 Krone (up to 55,000 for SMEs) in rising wages for researchers. Using firm-level data over the period 1997-2004, Lokshin and Mohnen (2013) estimate that the impact on wages reduces the effectiveness of Dutch tax incentives for R&D by 25 percent. However, they rightly point out that regressions that fail to control for individual characteristics of R&D employees may suffer from an omitted variable bias. Accounting for the latter is an important contribution of this paper. In line with the policy measures under consideration (see section 3) we do so by taking account of the educational level of the R&D personnel.

2.4. Research design

As presented in graph 1 the research design focuses on the influence of public policy in terms of R&D tax credits and R&D subsidies on the educational mix of R&D employees and the effects this brings in its wake in terms of the wages of researchers. By lowering the cost of employing R&D employees, a partial exemption from the withholding tax on the wages of researchers (i.e., the specific form of tax incentive in Belgium, see section 3 for details) may stimulate the demand for R&D employees. However, firms are free to decide how to spend the money freed by the exemption and are not obliged to employ specific categories. They can, for example, decide to stimulate the employment of all types of employees (including production workers or administrative employees); employ more R&D employees; upgrade the educational qualifications of the R&D employees (for example, opt for more PhDs) or use the money to pay for increased salaries of qualified researchers that are in high demand but low supply (OECD 2013).

Graph 1 Research design

Public support for R&D — R&D tax incentives

Educational mix of R&D employees	PhD	University or higher education (second stage)	Higher education (first stage)	Other qualifications

Related effects — Wages of researchers

In our assessment of the impact of public support, we assume that tax incentives aimed at lowering the cost of highly educated researchers will have a positive impact on this category of R&D employees employed by companies, as they decrease the relative cost of this specific group with respect to researchers that are not eligible for the tax incentive. The positive impact can be reflected in the fact that if companies decide to increase their R&D activities they will tend to recruit relatively more researchers with an educational degree eligible for the tax benefit. The effect may however also be reflected in relative substitution in companies that do not raise their R&D expenditures, in effect, eligible researchers that substitute for researchers for which companies cannot receive support. We will assess the impact of the tax incentives on the absolute number of specific groups as well as on the share of different groups in total R&D personnel.

With regard to wages, we investigate whether the additionality of public support may be partially offset by rising wages of researchers that result from increased demand with inelastic supply of researchers but control for the share of different educational groups to account for changes in the average wage of researchers that are due to changes in the composition of R&D personnel.

3. Data

To estimate the impact of R&D tax incentives on the educational mix of R&D personnel, a new database created by the Belgian Federal Public Service Finance is triangulated with results from a qualitative opinion poll directed towards the effects of federal tax incentives for R&D. The database from the Federal Public Service Finance combines data from the biennial OECD business R&D survey, compiled by the Belgian Science Policy Office, with data on the direct support by the three Belgian regions (Brussels-Capital region; Flanders and the Walloon Region) and data on the partial exemption from advance payment on the wages of R&D employees. The database covers the period 2001-2009. A major advantage of the database is the availability of the amount of subsidies and tax incentives received by a company instead of a dummy variable denoting whether or not a company receives public support. Dumont (2013) provides a more detailed description of the use of subsidies and the partial exemption from advance payment for R&D employees in Belgium. In addition to the substantial R&D subsidies provided by the regions, in 2005 the Belgian federal government introduced a number of volume-based tax incentives. The most popular measure is the partial exemption from advance payment of the withholding tax on the wages of R&D employees. There are currently four possibilities for companies to obtain such a partial exemption: (i) for R&D employees 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); (ii) for R&D employees (including support staff) in Young Innovative Companies (YIC) (as of 1 July 2006); (iii) for R&D employees with a PhD degree in exact or applied sciences, doctor degree in (veterinary) medicine or a civil engineering degree (as of 1 January 2006, hereafter List 1); (iv) for R&D employees with a master's degree, with the exception of master in social and human sciences (as of 1 January 2007, hereafter List 2). For the first two measures the exemption originally amounted to 50% and for the last two to 25%. For all four measures, the exemption was raised to 65% in July 2008 and to 75% in January 2009. As from July 2013 the exemption amounts to 80%. The changes in the extent of exemption are used to construct instruments for the tax incentives received by companies, as explained in section 4. Unlike tax incentives for R&D in many other countries, the tax incentives introduced by the Belgian federal government aim at the wage cost of R&D employees and therefore also apply to companies that do not make any profit and moreover are made available upfront. In 2009, two thirds of financial public support came from federal tax incentives and one third from regional subsidies (Spithoven 2013). Table 1 shows the number of companies that benefit from direct support provided by one of the three regions or from one of the four measures of partial exemption from advance payment on the wages of R&D employees. The largest number of R&D companies with public support, receive a subsidy from one of the three regional authorities. The partial exemption from advance payment for R&D employees with a degree in List 1 or List 2 is becoming increasingly popular, probably explained by the percentage of exemption that has been raised and the rising acquaintance with the tax incentives. The partial exemption from advance payment for Young Innovative Companies and for companies that cooperate in research with a university, higher education institution or a scientific institution also witnessed a strong increase but given the specific nature of these measures the number of beneficiary companies remains relatively small.

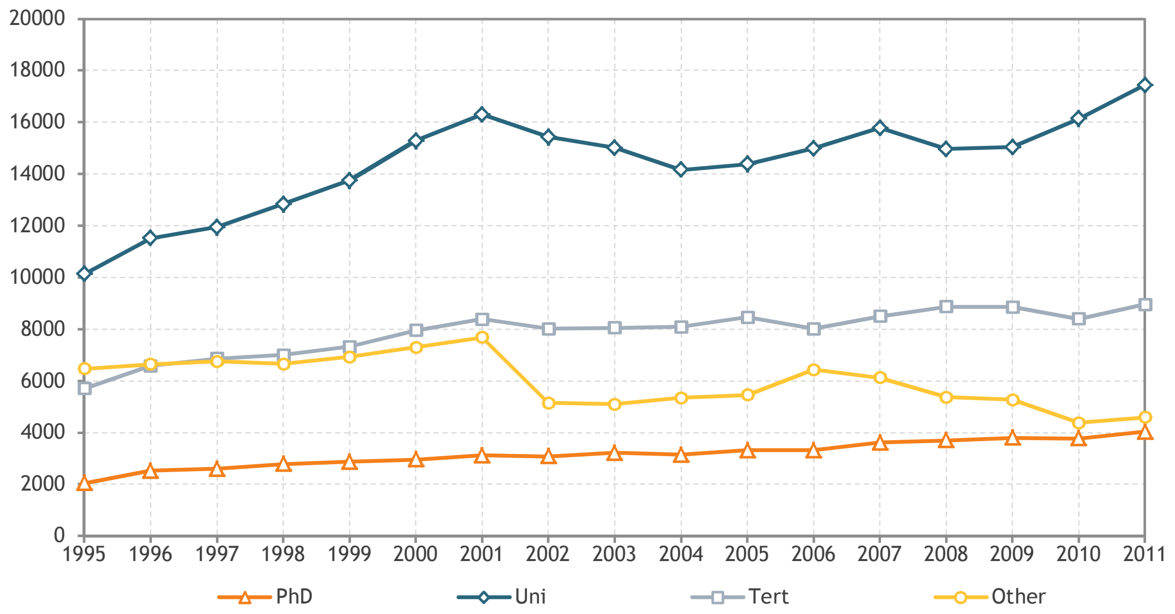
Table 1 Number of R&D active companies that received a regional subsidy or partial exemption from advance payment
2001-2009

	Partial exemption from advance payment for R&D employees:				
	Research cooperation	Young Innovative Company	List 1	List 2	Regional subsidy
2001					484
2002					583
2003					674
2004					777
2005	51				809
2006	152	76	287		884
2007	174	138	376	177	790
2008	155	119	393	274	648
2009	147	134	501	451	558

Note The table shows the number of companies that received a subsidy (Brussels-Capital region; Flanders or the Walloon region) or a partial exemption from advance payment on the wages of R&D employees (four measures as listed in the text) insofar as the company is enlisted in the repertory of R&D active companies, which the Belgian Science Policy Office uses for the biennial R&D survey.

Based on the data provided in the OECD business R&D survey, graph 2 presents, for each education degree, the number of full time equivalent R&D employees in companies in Belgium over the period 1995-2011. Between 1995 and 2001 the absolute number of all four groups increased considerably. The growth in employment, in relative terms, was highest for PhDs, followed by the group of R&D employees with a university degree or a higher education degree (2nd stage). After 2001, the evolution between the four education groups diverged. Whereas employment for R&D employees with a PhD and employees with a higher education degree (1st stage) continued to increase, employment for researchers with a university or higher education degree (2nd stage) and especially R&D employees with a non-tertiary degree dropped.

Graph 2 R&D employees in companies in Belgium, by education degree
1995-2011



Coinciding with the introduction of the federal tax incentives between 2005 and 2007, the number of R&D employees with a university or higher education degree (2nd stage) recovered in 2006 and 2007 only to fall again in 2008. After a drop in 2006, R&D employees with a higher education degree (1st stage) increased from 2007 onwards whereas R&D employees with a non-tertiary degree continued to fall from 2007 onwards after a short recovery in 2006. Researchers with a PhD witnessed a continuous increase in employment after 2005, with a strong increase by almost 9% in 2007. In order to verify the results of estimations based on the database provided by the Federal Public Service Finance, the Belgian Science Policy Office conducted an electronic opinion poll directed to the additionality effects of the federal tax incentives for R&D, in June 2011.

The poll asked for counterfactuals (e.g., what firms would have done in the absence of the tax incentives) related to employment effects (including skills and wages) and was sent to all firms present in the OECD business enterprise R&D repertory for Belgium. The survey yielded 488 responses, of which, after allowance was made for incomplete answers and after some reliability checks, a total of 336 responses remain. Compared to the official list of R&D active companies in the OECD business R&D survey for Belgium firms responding to the opinion poll had a significantly higher share of R&D employees with a master's degree (both in terms of physical units and in terms of full time equivalents), i.e. firms with a larger share of masters were more prone to respond to the opinion poll. The same applies to large firms which stand to benefit considerably from the partial exemption from advance payment for R&D employees. Companies from knowledge intensive services also appear to be overrepresented and companies from less knowledge intensive services underrepresented, which again can be explained by the fact that the issues involved are more relevant to the knowledge intensive service sectors. A similar reasoning explains why firms with a high internal R&D intensity are more inclined to answer the poll. Although the group of firms responding to the poll appears to be unrepresentative in terms of some firm characteristics, this seems to be mainly due to whether firms receive partial exemption from advance payment or not. As most questions in the poll apply to the beneficiaries of federal support, the bias is of less importance to the questions at hand. Nevertheless some caution in the interpretation of the results is warranted.

4. Estimation

The econometric procedure used to estimate the impact of the partial exemption from advance payment is discussed in section 4.1. The estimation results are reported in section 4.2, complemented with findings from the opinion poll whenever these are related to R&D employees.

4.1. Estimation procedure

When assessing the impact of public support for R&D a number of econometric issues needs to be tackled: the well-known self-selection of companies in terms of public support for R&D, unobserved firm heterogeneity and the endogeneity of the amount of public support received by companies. Ordinary Least Squares estimation of the impact of public support on the R&D activities of firms may provide biased results, if the fact that the probability to receive a subsidy or tax benefit differs between companies is not taken into account (see for example Wallsten 2000). To acknowledge for potential self-selection of companies a two-step estimation procedure is used, following Busom (2000) and Hussinger (2008). The first step consists in the estimation of a selection equation. However, unlike in most previous studies multiple possibilities of public support need to be considered. As there are no strong prior reasons to assume that direct (subsidies) and indirect (tax incentives) public support are subject to the same selection process a multinomial Logit specification with four possible outcomes (in line with Busom et al., 2012) is estimated, accounting for unobserved firm heterogeneity, as proposed by Haan and Uhlendorff (2006: p. 231):

$$L = \prod_{i=1}^{N} \int_{-\infty}^{\infty} \prod_{t=1}^{T} \prod_{j=1}^{J} \left\{ \frac{exp(X_{it}\beta_j + \alpha_j)}{\sum_{k=1}^{J} exp(X_{it}\beta_k + \alpha_k)} \right\}^{d_{ijt}} f(\alpha)d\alpha$$

L: Sample Likelihood

i: 1 ..N (firms)

j: Four possible outcomes in terms of public support, 1 (firm receives no public support for its R&D); 2 (firm only receives a subsidy); 3 (firm only receives a partial exemption from advance payment); 4 (firm receives both a subsidy and partial exemption)

X_{it}: Explanatory variables

α_j: Unobserved firm heterogeneity

d_{ijt}: Equals 1 if firm *i* falls in category *j* in year *t* and 0 if not

Hussinger (2008) finds indications that the German Federal Government sticks to a picking-the-winners strategy in its funding of R&D projects as suggested by the positive coefficients for past subsidies, firm size, patenting and credit rating. In the selection equation the following explanatory variables are considered: lagged level of R&D, lagged level of subsidy intensity[1], number of employees, industry; year and region dummies. We apply the GLLAMM procedure in Stata (see Rabe-Hesketh et al. 2002; Haan and Uhlendorff 2006), which permits to account for unobserved firm

1 The lagged level of R&D expenditures and the subsidy rate are used as exclusion variables for identification.

heterogeneity through random effects α_j. Following Dubin and McFadden (1984), an inverse Mills ratio is computed for each category of public support with respect to the reference group (companies which do not receive a subsidy or partial exemption in the considered year). The three inverse Mills ratios are included in the second step, the estimation of the impact of public support. If the coefficient of an inverse Mills ratio is found to differ significantly from zero, Ordinary Least Squares results are likely to be biased by failing to take into account self-selection by companies.

For the second, assessing the impact of public support on specific skill groups, we use employment shares as the dependent variable and use Seemingly Unrelated Regression (SUR) to account for possible correlation between the error terms of the different share equations (e.g., Zellner 1962). These specifications are similar to the employment share equations that have been used by, for example, Berman et al. (1994); Machin and Van Reenen (1998) and Strauss-Kahn (2004) to assess the impact of internationalization and technical change on the position of low-skilled workers. The specification follows from replacing cost shares in equations derived from the cost minimization of a translog cost function, by employment shares, under the assumption that when wages are not fully flexible, labour market shocks will affect relative employment of production factors rather than relative wages. The assumption that wages are not fully flexible is realistic for the labour market in Belgium (OECD, 2013). The amounts of public support included in the specification can be seen as variables that shift the (relative) demand of production factors by affecting their real cost.

The second step estimation considers the actual impact of public support on the educational mix of R&D personnel:

$$\begin{aligned} ln\left(RD_{it}\right) = {} & \alpha_0 + \beta^{reg}\, ln\left(X_{it}^{reg}\right) + \beta^{coop}\, ln\left(X_{it}^{coop}\right) + \beta^{YIC}\, ln\left(X_{it}^{YIC}\right) + \beta^{List\ 1}\, ln\left(X_{it}^{List\ 1}\right) \\ & + \beta^{List\ 2}\, ln\left(X_{it}^{List\ 2}\right) + \beta^{VA}\, ln\left(VA_{it}\right) + \beta^{E}\, ln\left(Employees_{it}\right) \\ & + \sum_{s=2}^{S} \alpha_s D_{i,s} + \sum_{r=2}^{3} \alpha_r D_{i,r} + \sum_{t=2}^{T} \alpha_t D_t + \sum_{j=2}^{4} \beta^{\lambda j}\, \hat{\lambda}_{it}^{j} + \varepsilon_{it} \end{aligned}$$

RD_{it} denotes the number of R&D employees (or the shares of specific educational groups of R&D employees) of company *i* in year *t*, the X variables indicate the amount of the regional subsidy (reg) or the amount of one of the four measures of partial exemption from advance payment: coop (research cooperation with a university, higher education institution or a registered scientific institution); YIC (Young Innovative Company); List 1 (PhD degree in exact or applied sciences, doctor degree in (veterinary) medicine or a civil engineering degree) and List 2 (master's degree with the exception of master in social or human sciences). The construction of the variables and some descriptive statistics are provided in table A.1 in appendix.

In empirical studies, size; industry classification and internal funding are found to be important determinants of the R&D expenditures of a company (see for example, Bassanini and Ernst, 2002; Kahn, 2006, Gelabert et al., 2009). Therefore value added (VA), the number of employees and industry (NACE 2-digit industry dummy $D_{i,s}$) are included as control variables. A dummy denoting in which of the three regions the company operates ($D_{i,r}$) as well as year dummies (D_t) are included in the estimation, as is the usual residual term, ε_{it}. $\hat{\lambda}_{it}^{j}$ is the inverse Mills ratio for category *j* of public support. Considering the group of companies that do not receive public support as benchmark, three ratios are included (firm only receives a subsidy; firm only receives a partial exemption from advance payment; firm receives both a subsidy and partial exemption). As pointed out by Heckman (1979), the standard errors in the second step are not consistent if the additional variance due to the inclusion of the first step estimate of the inverse Mills ratio is not accounted for. Standard errors of the second step are therefore corrected following the formula provided by Dumont et al. (2005).

A final econometric issue that is acknowledged, distinct from the self-selection of companies, is the possible endogeneity of the amount of public support received by a firm. Both a subsidy and a tax benefit have to be applied for by the firm and therefore imply action by the firm. Endogeneity can be accounted for through the use of instrumental variable (IV) estimation. We follow Chang (2012) and Rao (2013) who use changes in tax policy to construct instruments for the public support variables. More specifically the changes – exogenous to decisions of firms - in the rate of partial exemption from advance payment that occurred during the period under consideration are used to compute the cost of real R&D expenditures in a given year as if the policy change would not have occurred.

4.2. Estimation results

The partial exemption from advance payment of withholding tax on the wages of R&D employees with a degree in List 1 or in List 2 targets specific groups of R&D employees. Although these groups do not match perfectly with the educational mix considered in the R&D survey, the information can be used to assess the impact of regional subsidies and the tax incentives, on specific groups of R&D workers. The breakdown of R&D employees by education degree is only available for the uneven years that the biennial R&D survey covers. Therefore, a panel is constructed for which the years 2005, 2007 and 2009 are considered as consecutive observations over time. The results of the Multinomial logit estimation of the selection equation, accounting for unobserved firm heterogeneity, are reported in table A.2 in Appendix. The fact that a firm received partial exemption for research cooperation in the previous period raises the probability that the firm receives a subsidy, partial exemption or both in the current period, although the coefficients are only statistically significant at 10%. The only effect that is significant at 5% is the fact that a firm received a regional subsidy in the previous period which increases the likeliness that the firm will receive a subsidy as well as partial exemption in the current period. The fact that a company was granted a subsidy appears to have increased the awareness of tax incentives or to have incited companies with little experience in R&D activities to set up an R&D project which is then followed up in later years with support of tax incentives. This seems in line with the conclusions of Corchuelo and Martinez-Ros (2009) for Spain that obtaining a grant increases the probability of consequently using tax incentives. In a Multinomial Logit estimation that does not account for unobserved firm heterogeneity, the coefficient of lagged R&D expenditures is significant for category 3 and 4 as is the coefficient of the number of employees for category 4.[2] This indicates that these variables capture part of unobserved firm heterogeneity. That the coefficient of List 1 is not statistically significant can probably be explained by the fact that this measure was only introduced in 2006 and gained popularity towards the end of the period under consideration.

2 Results not reported but available upon request.

Employment effect

Before we consider the impact of tax incentives and subsidies on the educational mix of R&D personnel, we test whether these public support measures increased the overall number of R&D employees of firms. As many OECD countries, Belgium witnessed a drop in real GDP in 2009, the last year in the period under consideration. Given the macro-economic situation firms may have been reluctant to hire new employees and the main impact of the tax incentives may have been that firms simply sustained their actual number of R&D employees. Some questions in the opinion poll provide insight into this issue.

Regression results, with the total number of full time equivalent R&D employees as the dependent variable, are reported in table 2. As mentioned before, we follow Chang (2012) and Rao (2013) by using changes in the extent of partial exemption from advance payment to instrument for the public support variables. The regression includes the three inverse Mills ratios from the first step Multinomial logit estimation, to account for the self-selection of firms.

Table 2 The impact of subsidies and partial exemption from advance payment for R&D employees (FTE number)

	Random effects GLS	Random effects IV	Random effects IV (firm heterogeneity)
Dependent variable: Number of R&D employees (Full Time Equivalent)			
Research cooperation	0.0310 (1.79)*	0.0203 (1.11)	0.0195 (0.76)
Young Innovative Company	0.0693 (5.11)***	0.0582 (3.37)***	0.0567 (2.38)**
Exemption List 1	0.0587 (2.01)*	0.0597 (2.05)**	0.0585 (3.28)***
Exemption List 2	0.0306 (0.58)	0.0302 (0.57)	0.0296 (0.61)
Value added	0.2858 (0.11)	0.2852 (0.11)	0.3002 (0.10)
Regional subsidy	0.0222 (1.23)	0.0246 (1.35)	0.0234 (2.97)***
Number of employees	0.3596 (0.68)	0.3485 (0.66)	0.3483 (0.63)
Lambda 1	-0.09 (-0.31)	-0.10 (-0.33)	-0.09 (-0.25)
Lambda 2	0.03 (0.77)	0.03 (0.69)	0.03 (0.73)
Lambda 3	0.13 (5.80)***	0.14 (7.14)***	0.14 (4.78)***
Number of observations: 788			

Note: The table reports the results of a regression of the number of R&D employees on the amount of public support received by firms. The second column shows the results for a regression in which three inverse Mills ratios are included that are estimated in a first step Multinomial Logit estimation that does not account for unobserved firm heterogeneity. In the third column the results are reported for instrumental variable (IV) estimation, including the same inverse Mills ratios. The last column shows the results of an IV estimation in which three inverse Mills ratios are included that result from a Multinomial Logit estimation that does account for unobserved firm heterogeneity (as reported in table A.1 in Annex). The t-values (reported in brackets) are based on standard errors that have been corrected for the additional variance due to the inclusion of the three estimates of the inverse Mills ratio, as explained in the text. Lambda1-Lambda3 show the coefficients of the three inverse Mills ratios. Statistical significance of the coefficients indicates the need to account for self-selection of firms in terms of public support for R&D. Dummies for industry (NACE two-digit), region and year were included in the estimation but not reported.
*, **, *** denotes statistical significance at 10%, 5% and 1% respectively.

The second column shows the results of a Generalized Least Squares random effects regression without instruments, including the three inverse ratios Mills that result from a first step Multinomial Logit estimation that does not account for unobserved firm heterogeneity.[3] The third column shows the result of a random effects instrumental variable (IV) regression, accounting for the potential endogeneity of public support, again including the three inverse Mills from a Multinomial Logit estimation that

[3] Generalized Least Squares takes heteroskedasticity into account. Given the short period under consideration, i.e. a maximum of three observations for each firms, estimations with fixed effects or first differences are not appropriate.

does not account for unobserved firm heterogeneity. In the last column, the results are reported of a random effects IV regression, with three inverse Mills resulting from a Multinomial Logit estimation that does account for unobserved firm heterogeneity (results reported in table A.2 in Appendix). The table shows the coefficients of the three inverse Mills ratios (Lambda 1- Lambda 3). The statistical significance of an inverse Mills ratio indicates that ignoring the self-selection of companies would provide biased estimates of the impact of public support. The high significance of Lambda 3 shows that the self-selection bias is important for companies that receive a subsidy as well as partial exemption from advance payment. All standard errors reported in table 2 have been corrected for the additional variance due to the fact that the three inverse Mills ratios have been estimated rather than computed.

Considering a significance level of at least 10%, the three alternative estimation procedures provide robust evidence that the partial exemption for Young Innovative Companies and for researchers with a degree on List 1 have a positive impact on the total number of full time R&D employees employed by companies. The positive impact of regional subsidies is only statistically significant in the regression with the inverse Mills ratios from a Multinomial Logit estimation that accounts for unobserved firm heterogeneity. Accounting for unobserved firm heterogeneity seems to be important as indicated by the corrected standard errors. The variance related to the self-selection is substantially reduced when unobserved firm heterogeneity is accounted for in the Multinomial Logit estimation of selection equation. Accounting for additional variance also reduces the significance of the coefficient of regional subsidies in the last column but to a far lesser extent than for the estimations reported in the second and third column. In the rest of the paper we will report the results of second step estimations including three inverse Mills ratios from a first step estimation of a selection equation in which unobserved firm heterogeneity is accounted for.

Educational mix of R&D employees

In most previous studies, the estimation of the impact of public support for R&D is mainly concentrated on the total number of R&D employees. This approach falls short of accounting for possible shifts in the educational mix of R&D personnel. We assess whether the partial exemption and regional subsidies have had a more pronounced impact on researchers with a specific education degree. Although two of the four measures of partial exemption target specific groups of researchers (List 1 and List 2), companies have no obligation with respect to the money they save through the partial exemption from advance payment on the wages of their eligible researchers. But given that hiring specific researchers becomes less expensive, the partial exemption can be expected to raise the demand for those researchers for which the measure is most advantageous.

As mentioned before, minimization of a translog cost function provides cost share equations for flexible production factors.[4] Under the assumption that wages are not fully flexible, cost shares are often replaced by employment shares (e.g. Berman et al., 1994; Machin and Van Reenen, 1998; Strauss-Kahn, 2004).

To assess the impact of tax benefits and subsidies on the educational mix we run a seemingly unrelated regression (SUR) that accounts for correlation between the error terms of the different share equations.

4 The share equations are often derived from a short-run cost function, under the assumption that capital is quasi-fixed.

As the shares sum to 1, one of the share equations has to be dropped. We alternatively drop the equation for R&D employees with a degree below tertiary (other qualification) education, reported in table 3, and the equation for R&D employees with a first stage higher education degree, reported in table 4. A finding in both tables is that three of the four federal tax incentives increase the share of PhDs in R&D personnel. There are also some indications as to which type of researchers are substituted, in a relative sense. The results in table 3 indicate that the partial exemption for researchers with a degree on List 1 decreases the share of R&D employees with a first stage higher education degree. The results in table 4 suggest that the partial exemption for research cooperation and the one for Young Innovative Companies raise the share of researchers with a PhD at the cost of researchers with a university or second stage higher education degree.

Table 3 The impact of subsidies and tax incentives on specific skill groups of R&D employees (FTE) - SUR

	PhD	University or higher education (second stage)	Higher education (first stage)
Dependent variable: Share in total number of R&D employees (Full Time Equivalent)			
Research cooperation	0.0086 (2.96)***	-0.0051 (-1.10)	-0.0023 (-0.59)
Young innovative Company	0.0154 (4.38)***	-0.0054 (-0.97)	-0.0034 (-0.71)
Exemption List 1	0.0059 (3.01)***	0.0007 (0.24)	-0.0059 (-2.24)**
Exemption List 2	0.0030 (1.38)	0.0013 (0.36)	-0.0055 (-1.84)*
Regional subsidy	-0.0018 (-1.03)	-0.0012 (-0.43)	-0.0019 (-0.83)
Value added	0.0086 (1.01)	0.0290 (2.15)**	0.0116 (1.01)
Number of employees	-0.0050 (-0.75)	-0.0144 (-1.39)	0.0143 (1.63)*
Lambda 1	0.0120 (2.90)***	0.0016 (0.24)	-0.0041 (-0.74)
Lambda 2	-0.0074 (-2.28)**	0.0072 (1.40)	-0.0004 (-0.09)
Lambda 3	0.0040 (1.09)	0.0108 (1.85)*	0.0004 (0.08)
Number of observations: 863			

Note: The table reports the results of seemingly Unrelated Regression (SUR) that accounts for correlations between the error terms of the different share equations. The equation of R&D employees with a non-tertiary degree (other qualifications) is dropped due to the sum restriction. Three inverse Mills ratios are included that result from a Multinomial Logit estimation that does account for unobserved firm heterogeneity (as reported in table A.2 in Annex). Lambda 1-Lambda 3 show the coefficients of the three inverse Mills ratios. Statistical significance of the coefficients indicates the need to account for self-selection of firms in terms of public support for R&D. Dummies for industry (NACE two-digit), region and year were included in the estimation but not reported.
*, **, *** denotes statistical significance at 10%, 5% and 1% respectively.

Table 4 The impact of subsidies and tax incentives on specific skill groups of R&D employees (FTE) – SUR

	PhD	University or higher education (second stage)	Other qualifications
Dependent variable: Share in total number of R&D employees (Full Time Equivalent)			
Research cooperation	0.0086 (1.84)*	-0.0099 (-2.53)**	0.0030 (1.13)
Young innovative Company	0.0134 (2.39)**	-0.0101 (-2.17)**	-0.0020 (-0.62)
Exemption List 1	0.0065 (2.14)**	0.0000 (0.00)	-0.0027 (-1.53)
Exemption List 2	0.0034 (0.99)	0.0004 (0.13)	0.0019 (0.96)
Regional subsidy	-0.0011 (-0.42)	0.0033 (1.46)	-0.0004 (-0.24)
Value added	0.0091 (0.69)	0.0247 (-1.64)*	0.0147 (1.89)*
Number of employees	-0.0070 (-0.69)	-0.0139 (1.82)*	0.0026 (0.44)
Lambda 1	0.0129 (1.96)**	-0.0016 (-0.30)	0.0002 (0.05)
Lambda 2	-0.0077 (-1.54)	0.0109 (2.63)***	-0.0033 (-1.07)
Lambda 3	0.0032 (0.55)	0.0084 (1.72)*	-0.0099 (-2.91)***
Number of observations: 851			

Note: The table reports the results of seemingly Unrelated Regression (SUR) that accounts for correlations between the error terms of the different share equations. The equation of R&D employees with a first stage higher education degree is dropped due to the sum restriction. Three inverse Mills ratios are included that result from a Multinomial Logit estimation that does account for unobserved firm heterogeneity (as reported in table A.2 in Annex). Lambda 1-Lambda 3 show the coefficients of the three inverse Mills ratios. Statistical significance of the coefficients indicates the need to account for self-selection of firms in terms of public support for R&D. Dummies for industry (NACE two-digit), region and year were included in the estimation but not reported.
*, **, *** denotes statistical significance at 10%, 5% and 1% respectively.

The SUR estimations reported in tables 3 and 4 do not account for potential endogeneity and the standard errors are not corrected for additional variance due to the inclusion of the estimated inverse Mills ratio's. Table 5 reports the results of IV estimations with corrected standard errors of separate share equations, i.e. not accounting for possible correlation between the error terms of the different share equations. The estimations confirm the statistically significant positive impact on the share of researchers with a PhD for the federal tax incentives except for the partial exemption of researchers with a degree on List 2. In table 5 the impact of regional subsidies on the share of researchers with a PhD is also positive but only statistically significant at 10%. The different estimations of the share equations provide robust evidence that three of the four federal tax incentives increase the share in R&D personnel of researchers with a PhD. There are also indications of substitution of PhDs for R&D employees with a lower degree but these are less robust and less precisely estimated. The results of the estimation of share equations provide some indications of relative substitution. In table A.3 (in appendix) we show the results of estimations in which the number of full time researchers in the different educational groups are used as dependent variable rather than shares in R&D personnel. The results again confirm the positive impact of three federal tax incentives, as well as a positive impact of regional subsidies, on researchers with a PhD. The absence of statistically significant negative effects on other groups suggests that to the extent that the tax incentives result in substitution, this is in relative terms rather than in absolute terms.

Table 5 The impact of subsidies and tax incentives on specific skill groups of R&D employees (share in total R&D employees) – Random effects IV estimation

	PhD	University or higher education (second stage)	Higher education (first stage)	Other qualifications
Dependent variable: Share in total number of R&D employees of specific skill group				
Research cooperation	0.0624 (1.92)*	0.0030 (0.08)	-0.0291 (-0.74)	0.0484 (1.31)
Young innovative Company	0.1850 (5.33)***	0.0604 (1.46)	0.0352 (0.76)	-0.0181 (-0.43)
Exemption List 1	0.0829 (3.72)***	0.0313 (1.22)	-0.0223 (-0.82)	0.0050 (0.20)
Exemption List 2	0.0158 (0.31)	0.0261 (0.50)	-0.0180 (-0.34)	0.0340 (0.65)
Regional subsidy	0.0165 (1.19)	-0.0110 (-0.61)	0.0020 (0.10)	0.0274 (1.52)
Value added	-0.1617 (-0.06)	-0.2233 (-0.08)	-0.3437 (-0.12)	-0.1064 (-0.04)
Number of employees	0.0036 (0.01)	0.0911 (0.16)	0.3653 (0.66)	0.1525 (0.27)
Lambda 1	-0.04 (-0.11)	-0.04 (-0.11)	-0.05 (-0.14)	-0.10 (-0.25)
Lambda 2	0.01 (0.20)	0.09 (1.71)*	0.04 (0.68)	0.00 (0.07)
Lambda 3	0.03 (0.64)	0.14 (2.86)***	0.10 (1.85)*	0.04 (0.89)
Number of observations	779	662	725	711

Note: The table reports the results of an IV regression of the number of R&D employees in a specific skill group on the amount of public support received by firms. Three inverse Mills ratios are included that result from a Multinomial Logit estimation that does account for unobserved firm heterogeneity (as reported in table A.1 in Annex). The t-values (reported in brackets) are based on standard errors that have been corrected for the additional variance due to the inclusion of the three estimates of the inverse Mills ratio, as explained in the text. Lambda 1-Lambda 3 show the coefficients of the three inverse Mills ratios. Statistical significance of the coefficients indicates the need to account for self-selection of firms in terms of public support for R&D. Dummies for industry (NACE two-digit), region and year were included in the estimation but not reported.
*, **, *** denotes statistical significance at 10%, 5% and 1% respectively.

In the opinion poll conducted by the Belgian Science Policy Office, firms were asked to rate their agreement with statements on a Likert scale, ranging from 1 (disagree completely) to 5 (agree completely). Table 6 reports the results of the answers to the opinion poll with regard to the motives of firms to perform additional R&D activities. For the statements related to the employment effects, 185 useful answers are obtained from firms benefitting from partial exemption of advance payment for R&D employees. Table 6 provides an overview of the answers to the statements on the employment effects of the tax incentives. Respondents agree most (average score of 3.52) with the statement that current R&D employment is sustained by tax incentives. This result seems to support the view that in the recent economic downturn the tax incentives, by lowering the wage cost, permit firms to retain R&D employees with essential tacit knowledge that is part and parcel of the knowledge base of the firm. Many respondents even state that they created more employment and more R&D jobs[5]. The average score for higher qualified employees as a result of the tax incentives is significantly larger than 3 (i.e., neutral) but only slightly so.

5 The polychoric correlation (correlation between two observed ordinal variables) between the item "sustaining R&D employment" and "more employment" or "more R&D employment" is only 0.116 resp. 0.126 at a 10% level of significance.

Table 6 Opinion poll on the effects of the partial exemption from advance payment for R&D employees

	Agree completely	Agree	Neutral	Disagree	Disagree completely	Average score (sign.)
Employment effects (N=185)						
Sustaining R&D employment	17.3	31.4	41.6	5.9	3.8	3.52***
More R&D employment	15.1	24.9	47.0	8.6	4.3	3.38***
More employment	11.4	26.5	48.6	8.1	5.4	3.30***
Larger share R&D jobs	9.7	21.6	51.4	11.9	5.4	3.18**
Higher qualified personnel	11.4	17.3	51.4	15.1	4.9	3.15*
Higher salaries researchers	1.6	10.3	48.6	27.0	12.4	2.62***
Motives of firms to perform additional R&D related to R&D employment (N=181)						
Tax incentives for R&D employees	19.3	40.3	29.8	7.7	2.8	3.66***
R&D subsidies	16.6	42.0	29.3	9.9	2.2	3.61**
Cost of R&D employees	13.8	41.4	33.1	8.3	3.3	3.54****
Availability high-skilled employees	6.1	31.5	43.1	16.6	2.8	3.22**

Source: Spithoven (2013)

Note: Respondents to the opinion poll conducted by the Belgian Science Policy Office were asked to rate statements on a Likert scale ranging from 1 (disagree completely) to 5 (agree completely).
The symbols *, ** and *** refer to whether the average score differs significantly from 3 (neutral) at respectively 5%, 1%, and 0.1%.

The bottom panel in table 6 looks at the motives to perform additional R&D. The table only reports the responses to questions related to R&D employees. Considering average scores, poll respondents rated technological change and/or changes in the knowledge base and changes in the demand for products or services as the main reasons for additional R&D.[6] However, the existence of both tax benefits and R&D subsidies are ranked almost of equal importance. Nevertheless, the cost of R&D employees, i.e. wages, remains a cause of concern to the respondents as almost 5 times as many respondents agree with the issue as playing a role in their motivation to engage in additional R&D than those disagreeing with the issue. Hence, the tax incentive is crucial in reducing this wage cost. The availability of high-skilled employees is also an important motive to perform additional R&D. This is related to the elasticity of the supply of highly skilled labour, and thus also to the cost/wage issue.

Wage effect

In their investigation of the effects of Dutch R&D tax incentives on the wages of researchers, Lokshin and Mohnen (2013) consider the ratio of senior research staff to research assistants as a proxy of the skill composition of R&D personnel. They find no significant impact of the tax incentives on this ratio, in line with their hypothesis that the tax credit does not affect the composition of R&D personnel. Lokshin and Mohnen rightly argue that ignoring the characteristics of R&D employees may result in an omitted variable bias in the estimation of public support on the wages of researchers. Our more detailed breakdown by the education degree of R&D employees provides indications that Belgian tax incentives had a statistical significant impact on the educational mix of R&D personnel, i.e. raise the share of researchers with a PhD. In this section we investigate whether the change in the educational mix has an impact on the average wage of researchers.

6 As these results do not relate to R&D employees, they are not reported in table 6. Other non-reported factors for which the average score is significantly higher than 3 (neutral) are the time horizon of a R&D project; the availability of private or public R&D partners and the cost of materials or infrastructure for R&D.

From the OECD business R&D survey for Belgium, average wages of R&D employees in companies can be computed (total wage sum of R&D personnel/ total number of R&D employees). In table 7 we report the results of a regression, in line with Lokshin and Mohnen (2013), of the wage of researchers on the effective rate of subsidy or tax incentive, including the average wage of researchers in the industry (two-digit NACE) the company belongs to.

Table 7 The impact of subsidies and tax incentives on the average wage of R&D employees - IV

	IV (no shares)	IV (shares)	IV (no shares) Selection bias	IV (shares) Selection bias
Dependent variable: Log (average wage researchers)				
Research cooperation	0.0135 (1.60)*	0.0121 (1.46)	0.0138 (1.77)*	0.0126 (1.63)*
Young Innovative Company	0.0145 (1.30)	0.0119 (1.07)	0.0125 (1.05)	0.0086 (0.72)
Exemption List 1	0.0127 (2.70)***	0.0112 (2.41)**	0.0113 (1.95)**	0.0095 (1.63)*
Exemption List 2	0.0016 (0.29)	0.0019 (0.36)	-0.0024 (-0.43)	-0.0020 (-0.35)
Regional subsidy	0.0031 (0.56)	0.0020 (0.37)	-0.0004 (-0.08)	-0.0006 (-0.14)
Share R&D personnel with PhD	-	0.4603 (5.18)***	-	0.4615 (3.42)***
Share R&D personnel with University or 2nd stage higher education degree	-	0.1998 (3.36)***	-	0.2240 (2.55)***
Share R&D personnel with first stage higher education degree	-	0.1971 (2.97)***	-	0.2553 (2.66)***
Average wage industry	0.0000 (8.09)***	0.0000 (8.04)***	0.0000 (4.39)***	0.0000 (4.37)***
Value added	0.0404 (1.47)	0.0481 (2.59)***	-0.0145 (-0.19)	-0.0021 (-0.03)
Number of employees	0.1164 (7.23)***	0.1133(7.24)***	0.0461 (1.93)**	0.0439 (1.86)*
Lambda 1			-0.0236 (-1.90)*	-0.0236 (-1.92)*
Lambda 2			0.0197 (2.57)***	0.0187 (2.46)**
Lambda 3			0.0403 (3.80)***	0.0368 (3.49)***
Number of firms	1188	1188	575	575
Number of observations	1673	1673	731	731
R-squared (overall)	0.13	0.16	0.21	0.23

Note: The table reports the results of an IV regression of the average wage of R&D employees (in logs) on the log of the effective rate of regional subsidies and the four categories of partial exemption, the share of three education groups in R&D personnel, the average wage of researchers in the industry of the company, value added and the number of employees. Dummies for industry (NACE two-digit), region and year were included in the estimation but not reported.
*, **, *** denotes statistical significance at 10%, 5% and 1% respectively.

In the second column we report the results of an IV regression without accounting for the shares of different education groups in R&D personnel. The partial exemption for researchers on List 1 and the partial exemption for research cooperation appear to increase the average wage of R&D employees, although the latter effect is only statistically significant at 10%. The coefficients are moreover rather low, indicating that the impact on wages is not substantial. If we include the shares of three educational groups (leaving out other qualifications because of the sum restriction), all three coefficients are positive and statistically significant, as shown in the third column. Not surprisingly the share of researchers with a PhD has a strong impact on the average wage of researchers. The results indicate the need to account for the educational mix of R&D personnel in assessing the impact on the wages of researchers. The estimated impact of all measures of public support is smaller when including the shares and the statistical significance is lower. The effect of the partial exemption for research cooperation is no longer significant at 10% and the partial exemption for researchers with a degree on List 1 is significant at 5%

rather than 1%. The last two columns show the results of IV regressions, without (fourth column) and with the shares of the three education groups (last column), accounting for a possible selection bias and unobserved firm heterogeneity.

The statistical significance of the inverse Mills ratio's indicates the need to account for selection issues. A limitation of the latter approach is the substantial reduction in the number of observations. Moreover, the correction of standard errors to account for additional variance due to the inclusion of the estimates from the estimation of the selection equation also has a strong impact as no coefficient is statistically significant after correction. To assess the impact of including the share variables, the standard errors reported in table 7 are therefore the standard errors without the correction. Despite the different estimation procedure and the difference in the number of observations, the last two columns provide fairly similar conclusions, i.e. the effects of public support on the wages of researchers are smaller and statistically less significant when controlling for the composition of R&D personnel. Whereas the impact of the partial exemption for researchers with a degree on List 1 is significant at 5% in the estimation without the share variables, when including these variables the coefficient is only significant at 10%. The coefficients of the tax incentives in columns 3 and 5 provide an estimate of the impact of public support on the wages that is not explained by their impact on the educational mix, i.e. due to rising demand for researchers with inelastic supply.

As shown in table 6, respondents to the opinion poll, on average, disagreed with the statement that the tax incentives for R&D resulted in higher wages for the current researchers in the firm. These results corroborate the low estimates of the impact of the tax incentives on the average wage of researchers and the low statistical significance of the effects when controlling for the education mix of R&D employees.

As wages are not broken down by education degree in the R&D survey, it is not possible to estimate the impact of subsidies and the tax incentives on the wages of specific skill groups of R&D employees.

5. Conclusions

The educational mix of R&D personnel has largely been ignored in studies that assess the impact of public support on corporate R&D activities. This paper assesses to what extent public support for R&D not only affects the total number of R&D employees but also its composition, distinguishing R&D workers by education degree. We also account for the educational mix in investigating the potential effects of public support on the wages of researchers.

The results presented in this paper show that some measures of public support indeed affect the composition of the R&D personnel. Indications of substitution of PhDs or civil engineers for R&D employees with a lower degree are in relative terms rather than in absolute terms. In effect, no indications are found that tax incentives actually result in the reduction of the number of employees with a specific degree. Although firms are free to decide how to use the money freed by the partial exemption from withholding tax on the wages of researchers, the partial exemption for researchers with a PhD or civil engineering degree is found to have a substantial impact on the share of researchers with that specific degree. The partial exemption for researchers with a master degree is not found to have had a significant impact on the number of R&D employees or the share of researchers with a master degree.

In line with previous studies, we find evidence that public support raises the average wage of researchers. However, our estimates of these effects are smaller than those reported by Goolsbee (1998) and Marey and Borghans (2000) but also smaller than the estimates of Lokshin and Mohnen (2013). As pointed out by Lokshin and Mohnen (2013), the more aggregate level considered by Goolsbee (1998) and Marey and Borghans (2000) may capture spillover effects that are not taken into account at the firm level. We do not find support for the other explanation put forward by Lokshin and Mohnen (2013), i.e. that tax incentives are more neutral compared to subsidies. We only find indications of a statistically significant impact of tax incentives for R&D employees with a PhD or civil engineers and for researchers involved in industry-science collaboration. For the other target groups of tax benefits and for R&D subsidies, there are no indications of a significant impact on the wages of researchers. The different results may be due to differences in the (in) elasticity of the supply of researchers, or the prevalence of researchers in the public sector, in the Netherlands and Belgium. Data from Eurostat show a higher number of science and technology graduates per 1000 inhabitants in the age group 20-29 for Belgium than for the Netherlands, and the United States, over the period 2001-2011. This conjecture requires further investigation. Our results however clearly show the need to disentangle the impact on wages due to changes in the educational mix of R&D personnel from the impact public support may have by raising demand for researchers when supply is inelastic. Estimates of the impact of public support on the wages of researchers are smaller and less significant when the educational mix of R&D employees is accounted for. In some specifications the estimated effects of public support are actually no longer statistically significant at conventional levels when controlling for the educational mix of R&D personnel.

There are a number of limitations to the assessment reported in this paper. Given the rather recent introduction of the tax incentives, the estimates are likely to be more informative about short-run effects than about the impact in the long run. Future research could assess whether results hold in the long run. It would also be interesting to establish whether a cross-country comparison could reveal differences in the elasticity of supply although this analysis would preferably be carried out within a framework that fully acknowledges the demand for as well as the supply of researchers. If a breakdown of wages by skill group is available, it would be worthwhile to assess which part of the rise in the wages of R&D employees may be due to the inelastic supply of researchers and which part to the increased average skill level. Although companies in Belgium are not obliged to use the money saved through the tax benefits, on eligible R&D employees, the incentives favour researchers with a specific education degree and it is therefore necessary to investigate countries with less specific tax incentives to confirm our results.

A more in-depth estimation of the impact of changes in the educational mix of R&D personnel on the orientation of R&D activities (e.g., the share of R&D dedicated to basic research, applied research or experimental development) seems warranted. If analysis bears out that public support results in the increase of basic research activities, further investigation could reveal whether this reinforces geographical fragmentation, with domestically isolated research hubs and manufacturing being offshored. Tassey (2014) points at the synergies that arise in advanced product development from the co-location of manufacturing plants and research and development facilities. It is therefore important to assess whether tax incentives succeed, not only in raising basic research activities, but also in supporting firms in the translation of basic research into commercial products and thereby to ensure the crucial integration of domestic manufacturing activities in a global value chain. Further analysis is necessary to shed light on whether or not changes in the educational mix translate into changes in innovative performance. This would also help in the debate on the relation between policy support and the wages of R&D personnel, in effect, the extent to which rising wages reflect the rising education level of researchers and whether the latter has a positive impact on the long-term innovative capacity of firms.

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Appendix

Table A.1 Construction of variables and descriptive statistics

Variable	Construction	Mean (standard deviation)
Dependent		
Number of R&D employees	Total number of full time employees working in the R&D department	19.11 (68.06)
Number of R&D employees by education degree:	Total number of full time employees working in the R&D department, grouped by degree	
- PhD		1.95 (9.32)
- University or higher education (second stage)		8.93 (37.10)
- Higher education (first stage)		4.69 (19.19)
- Other qualification (at most secondary degree)		3.39 (15.81)
Average wage of R&D employees	Total wage sum of R&D personnel/ total number of R&D employees (euro)	59283 (37875)
Explanatory		
R&D expenditures	Intra-muros R&D expenditures (1000 euro)	2591 (13.300)
Regional subsidy	Amount received from one of three Belgian regions as direct support for a R&D project (1000 euro).	372.54 (956.11)
Partial exemption research cooperation	Amount of money saved by partial exemption from advance payment on the wages of researchers (1000 euro).	131.82 (374.15)
Partial exemption Young Innovative companies		69.26 (106.50)
Partial exemption List 1		217.52 (730.71)
Partial exemption List 2		182.55 (486.10)
Value added	1000 euro	80.800 (57.300)
Number of employees	Full Time Equivalent	172.5 (435.3)

Table A.2 Multinomial logit accounting for unobserved firm heterogeneity
2005-2007-2009

	Subsidy (only)	Exemption (only)	Both
R&D expenditures (lagged)	0.0257 (0.17)	0.1544 (0.90)	0.2204 (1.28)
Research cooperation (lagged)	0.0004 (1.65)*	0.0004 (1.64)*	0.0004 (1.64)*
Exemption List 1 (lagged)	0.0001 (0.13)	0.0001 (0.13)	0.0001 (0.12)
Regional subsidy (lagged)	0.0000 (1.77)*	0.0000 (1.45)	0.0000 (1.94)**
Value added	0.0000 (-0.82)	0.0000 (0.59)	0.0000 (-0.25)
Number of employees	0.0007 (0.52)	0.0005 (0.53)	0.0012 (0.88)
Number of observations: 799			

Note: The table shows the results of a Multinomial logit estimation in which the potential self-selection of companies in terms of public support for R&D is assessed. Four categories are considered: 1 (firm receives no public support for its R&D); 2 (firm only receives a subsidy); 3 (firm only receives a partial exemption from advance payment); 4 (firm receives both a subsidy and partial exemption). Group 1 is the reference category. The variables of public support are lagged one period. To account for unobserved firm heterogeneity the GLLAMM procedure is used. The t-values (reported in brackets) are based on robust (cluster) standard errors.
*; ** and *** denote that the coefficient is statistically significant at 10%; 5% and 1% respectively. The lagged amount of partial exemption for Young Innovative companies and List 2 could not be included in the estimation due to convergence problems.

Table A.3 The impact of subsidies and tax incentives on specific skill groups of R&D employees (FTE) – IV estimation *2005-2007-2009*

	PhD	University or higher education (second stage)	Higher education (first stage)	Other qualifications
Dependent variable: Number of employees in specific skill group of R&D employees (Full Time Equivalent)				
Research cooperation	0.1848 (2.57)***	0.0184 (0.28)	0.0181 (0.21)	0.1654 (1.89)*
Young innovative Company	0.4830 (5.35)***	0.1706 (2.13)**	0.1582 (1.41)	-0.0562 (-0.51)
Exemption List 1	0.2865 (5.86)***	0.1420 (3.20)***	0.0304 (0.51)	0.0469 (0.80)
Exemption List 2	0.0989 (1.43)	0.0802 (1.22)	0.0215 (0.27)	0.1415 (1.81)*
Regional subsidy	0.0800 (2.03)**	-0.0222 (-0.61)	0.0191 (0.38)	0.1145 (2.28)**
Value added	0.3471 (0.12)	0.3549 (0.12)	-0.2567 (-0.09)	0.7586 (0.25)
Number of employees	0.2841 (0.49)	0.4094 (0.71)	1.1144 (1.87)*	0.5326 (0.90)
Lambda 1	-0.29 (-0.72)	-0.12 (-0.31)	-0.17 (-0.39)	-0.31 (-0.72)
Lambda 2	0.04 (0.41)	0.19 (2.22)**	0.06 (0.48)	-0.05 (-0.48)
Lambda 3	0.22 (2.31)**	0.38 (4.37)***	0.31 (2.64)***	0.21 (1.80)*
Number of observations	788	770	752	738

Note: The table reports the results of an IV regression of the number of R&D employees in a specific skill group on the amount of public support received by firms. Three inverse Mills ratios are included that result from a Multinomial Logit estimation that does account for unobserved firm heterogeneity (as reported in table A.1 in Annex). The t-values (reported in brackets) are based on standard errors that have been corrected for the additional variance due to the inclusion of the three estimates of the inverse Mills ratio, as explained in the text. Lambda1-Lambda3 show the coefficients of the three inverse Mills ratios. Statistical significance of the coefficients indicates the need to account for self-selection of firms in terms of public support for R&D. Dummies for industry (NACE two-digit), region and year were included in the estimation but not reported.
*, **, *** denotes statistical significance at 10%, 5% and 1% respectively.