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DISCUSSION PAPER

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R&D Grant and Tax Credit Support for Foreign-Owned Subsidiaries: Does It Pay Off?

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Abstract

Foreign-owned subsidiaries make significant contributions to national Research and Development (R&D) in many host countries. Policymakers often support subsidiaries through R&D grants and R&D tax credits. A key objective of this funding is to leverage R&D-driven firm performance benefits for the host economy. However, the subsidiary's parent firm may decide not to exploit the results from publicly-funded R&D projects in the host country. Therefore, supporting subsidiaries' R&D presents a risk that significant amounts of public funding may translate into little, or no payoffs for the host economy. Our study provides the first evaluation of 1) whether public R&D funding stimulates additional R&D investment in subsidiaries, 2) whether policy-induced R&D drives subsidiary performance, and 3) the differential effects of R&D grants and R&D tax credits. Drawing on a unique panel dataset for Ireland (2007-2016), we find that both R&D supports drive subsidiary R&D, resulting in substantial host country firm performance benefits.

Keywords: Public funding for R&D; Firm performance; Firm ownership; Foreign-owned subsidiaries; Multinational enterprise; R&D tax credit; R&D grant; Policy evaluation

JEL classification: D22; O25; F23; F21; O38; D04; H25; O31

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1. Introduction

Firm-level Research and Development (R&D) is a key driver of firm performance and national economic growth (Minniti & Venturini 2017). The subsidiaries of foreign-owned multinational firms make significant contributions to national R&D in many host countries (Kwon & Park 2018), particularly in small, open economies (Appelt et al. 2016). Policymakers often pursue an industrial strategy of incentivising foreign-owned subsidiaries to increase their R&D activities, either through direct subsidies or tax incentives, in anticipation of reaping economic gains (OECD 2015; Rodríguez-Pose & Wilkie 2016; Park et al. 2020). This study provides, to our knowledge, the first evaluation of whether R&D grants and R&D tax credits drive additional R&D investment in foreign-owned subsidiaries, and whether this publicly-funded R&D translates into firm performance improvements for the host economy. While we acknowledge the importance of R&D impacts, for reasons detailed below, the central focus of our study is on firm performance.

The provision of public funding for R&D in foreign-owned subsidiaries presents a crucial conundrum for both academics and policymakers alike. Theoretically, Pearce and Papanastassiou (2009, p. 154-155) highlight that, even in a situation where a subsidiary "has resolved all the scientific questions relating to an innovation…it may still be that the [Multinational Enterprise's] operations in the same country do not provide the ideal context for the fulfilment of the commercial innovation process". A key implication from this feature of multinational firms' globalised R&D strategy is that "policy measures to promote R&D…may only yield a small number of jobs and only provide a weak stimulus to growth when foreign-owned firms decide to produce abroad" (European Commission 2017a, p. 13). Therefore, there is an important dilemma at the heart of Foreign Direct Investment (FDI) R&D policy. On the one hand, allocating public R&D funding to foreign-owned subsidiaries offers a unique opportunity for host countries to leverage R&D-driven firm performance improvements for the domestic economy. On the other hand, subsidiaries may transfer the knowledge produced by government-funded R&D to other locations, and not commercialise R&D results in the host country. This constitutes a unique risk that significant amounts of scarce public R&D funding will translate into little, or no firm performance payoffs in the host economy.

Our study makes two distinct contributions to the literature on public funding for R&D. First, to the best of our knowledge, it is the first study to examine the above issue based on detailed firm-level panel data. Rodríguez-Pose and Wilkie (2016) have emphasised the importance of public funding for R&D in attracting and leveraging economic gains from foreign-owned subsidiaries. They recommend that European countries should tailor their suite of R&D supports to "increase the appeal of their respective countries to the foreign R&D activities of [Multinational Enterprises]" (Rodríguez-Pose & Wilkie 2016, p. 2031). However, the evidence base underpinning this important policy recommendation is remarkably scant. Previous analyses (e.g. Görg & Strobl 2007; Aerts 2008; Liu et al. 2016) have provided some insights. However, the majority of earlier studies have been partial in nature. Previous studies mainly rely on small, cross-sectional datasets, with limited information on R&D support instruments, and firms' R&D and performance outcomes. Our study builds on this work, by overcoming these limitations. As such, we provide detailed insights on the drivers of subsidiary R&D and performance. This forms the basis for policy recommendations that were heretofore not possible. Therefore, our study makes a significant contribution *vis-à-vis* previous studies; by evaluating the impact of government R&D support on R&D additionality, *and* the role of policy-induced R&D, for the economic performance of foreign-owned subsidiaries.

Our study's second contribution centres on the differential impacts of R&D grants and R&D tax credits in foreign-owned subsidiaries. In most countries throughout the world, R&D grants and R&D tax credits are the main policy instruments used by governments to provide R&D support to firms (Lenihan et al. 2020). Previous research has conceptualised key differences in how each type of public R&D support may impact foreign-owned firms' R&D and performance in a host country (IMF 2016; European Commission 2017a). This distinction suggests that R&D tax credits may be particularly powerful at driving subsidiary R&D. However, *the type of R&D* stimulated by R&D grants may be more effective at driving subsidiary performance (European Commission 2017b). Although some recent research has examined both policy instruments in the general population of firms (Marino et al. 2016; Dumont 2017; Nilsen et al. 2020), their relative effectiveness in foreign-owned subsidiaries is completely unaddressed heretofore. Therefore, we advance this field of research by examining which (if any) type of R&D support is most effective at driving subsidiaries' R&D and economic performance.

A distinct novelty of our study concerns the construction of a unique panel dataset for Ireland, containing 24,404 firm-year observations for the period 2007-2016[1]. Since the *First*

[1] Correspondence between the authors and the Department of Business, Enterprise and Innovation in 2020, when questioned as to whether all foreign-owned firms captured in the Annual Business Survey of Economic Impact could be classified as subsidiaries, confirmed that "almost all client companies of IDA Ireland are an expansion

Programme for Economic Expansion in 1958 (see DoF 1958), the Irish state has adopted a six decade-long industrial development strategy focused on attracting (and later embedding) FDI to stimulate its economy[2]. As a result of this strategy, the Irish economy is characterised by a duality, between foreign-owned subsidiaries and domestically-owned Irish firms (Bailey & Lenihan 2015). Therefore, Ireland provides the ideal locale to examine whether public R&D funding drives foreign-owned subsidiaries' firm performance in a host country. Our empirical set-up combines detailed survey data, with access to unique administrative data from all of Ireland's main public R&D support agencies. Drawing on this rich panel dataset, we employ a two-stage estimation similar to that employed by Freel et al. (2019) and Beck et al. (2016). Using this approach, we first analyse whether R&D support induces additional firm-level R&D, and second whether this *policy-induced* R&D is effective at driving firm performance. This is particularly important in the specific case of foreign-owned subsidiaries, where the risk exists that even if public R&D support results in additional R&D spending, publicly-funded R&D may not be commercially exploited in the host country.

Building on previous studies (Girma et al. 2003; Görg & Strobl 2007; Aerts 2008), we split our sample between foreign-owned and domestic firms, and perform our analysis separately in each sample. Our results demonstrate that funding R&D in foreign-owned subsidiaries does benefit the host economy. This happens in terms of increasing the R&D expenditure of subsidiaries, which is linked to firm performance improvements. In addition, both types of R&D funding produce similar impacts on subsidiaries' R&D, and show similar links to performance outcomes. These findings suggest, at least in the case of a small open economy such as Ireland, that R&D policy support for foreign-owned subsidiaries pays off. The type of instrument however, is of limited importance.

The remainder of the paper is organised as follows. In Section 2, we review the literature on R&D grants and R&D tax credits in foreign-owned subsidiaries, and derive our hypotheses. Section 3 outlines our econometric approach and describes our database. Section 4 presents and discusses our results, while Section 5 offers a conclusion and discussion of potential implications for policy, along with limitations and possible avenues for future research.

of an international group into Ireland and have a non-Irish 'country of origin'. This implies that they are operating in Ireland as a subsidiary of an international group of some kind". Based on this correspondence, we infer that all the foreign-owned firms in our dataset are subsidiaries of multinational firms.

[2] For a discussion, see: https://enterprise.gov.ie/en/Publications/Policy-Statement-on-Foreign-Direct-Investment-in-Ireland1.html.

2. Theory and hypotheses

The rationales put forward to justify allocating scarce public finances to support foreign-owned subsidiaries' R&D, are broadly the same as those for firms more generally. The key argument states that firm-level R&D makes a unique and crucial contribution to firm performance, which underpins economic growth and productivity gains (Minniti & Venturini 2017). However, firms struggle to appropriate sufficient returns from their R&D due to knowledge spillovers (David et al. 2000). This dis-incentivises R&D investment, and produces a level of private R&D below the social optimum (Hall & Van Reenen 2000). The presence of these market failures signals a need for policy intervention (Busom et al. 2014). Therefore, policymakers seek to incentivise private R&D, in the anticipation that this will contribute to firm performance benefits (Freel et al. 2019).

2.1. Public support instruments for firm-level R&D

The two main public support instruments, R&D grants and R&D tax credits, influence firms' R&D through different mechanisms (Hall & Van Reenen 2000). R&D tax credits are deductions from a firm's corporation tax, which lower the marginal cost of R&D, and incentivise firms to invest into new or larger R&D projects (Rao 2016). R&D grants are usually provided to firms for specific R&D projects that are prioritised by funding agencies (David et al. 2000). While R&D tax credits can be claimed after the R&D expenditure has occurred (Czarnitzki et al. 2011), firms usually apply for R&D grants prior to starting an R&D project (Karhunen & Huovari 2015). R&D grants are often allocated through a competitive process, based on certain selection criteria (Montmartin & Herrera 2015). These criteria are designed to ensure that public money is only used to fund additional R&D investment (i.e. the concept of input additionality), and not substitute for private investment (Hud & Hussinger 2015). By providing direct support, R&D grants raise the marginal rate of return on R&D, as opposed to reducing the marginal cost (Czarnitzki et al. 2011).

In recent years, a small but rapidly-expanding literature has developed, which examines the impact of both R&D grants and R&D tax credits on firm-level outcomes (e.g. Busom et al. 2014; Neicu et al. 2016; Marino et al. 2016; Dumont 2017; Nilsen et al. 2020). This relatively limited set of detailed empirical studies demonstrates the importance of including *both* R&D grants *and* R&D tax credits in the same analysis. Only then will we get a true picture of the contribution of each R&D support type to firm-level R&D and performance. This is because both policy instruments are designed to stimulate input additionality. As such, examining the effectiveness of one (e.g. R&D grants), whilst not including the other (e.g. R&D tax credits), can act as a crucial omitted variable, and obscure any observed effects. In addition, given their co-existence, the ability to directly compare relative effects is crucial to our understanding of the effectiveness of each policy instrument individually. For example, an analysis focusing solely on R&D grants may reveal that this policy instrument is effective at stimulating firms' R&D. However, if R&D tax credits are also included, the observed effectiveness of R&D grants may change. This would thus alter our understanding of the impact of R&D grants on firms' R&D.

2.2. Impact of R&D grants and R&D tax credits on subsidiaries' R&D

Relative to the full population of firms, many studies have suggested that R&D support may have markedly different impacts in foreign-owned subsidiaries compared to domestic firms (OECD 2015; Görg & Strobl 2007). To account for these different impacts, most studies treat foreign ownership as a control variable, when examining the impact of R&D supports on firm-level outcomes (e.g. Vanino et al. 2019; Marino et al. 2016; Beck et al. 2016; Hud & Hussinger 2015; González & Pazó 2008; Cerulli & Poti 2012; Karhunen & Huovari 2015; Aristei et al. 2017). However, the use of foreign ownership as a control variable alone, provides little insight regarding the impacts of public R&D funding within the specific case of subsidiaries. Subsidiaries have several unique features which may result in distinct effects of policy intervention. For instance, while financing R&D is a key issue for most firms, the subsidiaries of foreign-owned firms can usually allocate considerable internal funds for R&D (Sadowski & Sadowski-Rasters 2006). Additionally, foreign-owned subsidiaries often enjoy ready access to the parent firm's internal funds, as well as international capital markets (Un & Cuervo-Cazurra 2008). This can help subsidiaries to spread R&D-related risk across a wider variety of projects within the enterprise group, which reduces the risk inherent in R&D (Girma et al. 2003).

Foreign-owned firms' advantages in terms of R&D financing and risk mitigation can also influence decisions about using certain types of public R&D support schemes (Un 2011). R&D tax credits reduce the overall cost of R&D, and thus factor into multinational firms' overarching global R&D strategy (Rao 2016). In this way, the availability of R&D tax credits can influence foreign-owned firms' decision making on where to locate R&D capacity (IMF 2016; European Commission 2017b). In terms of direct R&D funding, policymakers may offer R&D grants, designed to incentivise foreign-owned subsidiaries to undertake specific types of R&D

projects. For example, in certain thematic areas, or in co-operation with certain partners. R&D grants may also be used to support the establishment of a long-term R&D facility in the host country (Montmartin & Herrera 2015). This type of direct funding will be particularly important where the multinational parent has yet to decide where to locate specific R&D capacity; and could act as an anchor for a foreign-owned subsidiary to begin, or indeed increase R&D spending in a host country (Appelt et al. 2016). In addition, if the host-country offers grant funding for a certain thematic priority (e.g. R&D in a specific scientific field), foreign-owned firms may enjoy ready access to this funding call, by relying on the global R&D network within the wider multinational group (Görg & Strobl 2007). This may result in the parent firm relocating specific thematic R&D capacities to the host country subsidiary, and away from other locations in the multinational's global network.

In terms of previous empirical findings, a lacuna of literature exists which has focused specifically on the effect of R&D support in foreign-owned firms. Görg and Strobl (2007) found that R&D grants did not produce input additionality in foreign-owned subsidiaries. However, the more common finding is that public funding for R&D has a positive and significant effect on subsidiary R&D. For example, previous studies which find a positive effect of grants on subsidiary R&D include Aerts (2008) for Flanders, Giroud et al. (2012) for South Korea, and Rodríguez-Pose and Wilkie (2016) employing European data. In terms of R&D tax credits, both Rao (2016) and Acheson and Malone (2020) find that this form of indirect support drives R&D in foreign-owned firms, in the United States of America (USA) and Ireland respectively. Using more aggregate indicators of public R&D funding in China, Liu et al. (2016) reinforce this overall trend of positive and significant effects on R&D. Therefore, based on theory and previous empirical findings, we suggest the following hypothesis:

Hypothesis 1*: R&D grants and R&D tax credits produce input additionality in foreign-owned subsidiaries.*

We now turn to likely differential effects of R&D grants and R&D tax credits (Aiello et al. 2019; Hall & Van Reenen 2000). In the general population of firms, decisions about applying for public R&D support and how to use it, are typically part of an in-house strategic decision-making process (Busom et al. 2014), with managers aligning the use of R&D support with the firm's strategic priorities (OECD 2015). However, in the specific case of foreign-owned subsidiaries, a significant level of decision-making power rests with the parent firm in the home country (Pearce & Papanastassiou 2009). For example, the use of R&D tax credits may be part of the multinational firm's overall taxation strategy, with major decisions taken by the financial department in the parent firm's headquarters (Rao 2016). Direct government funding through grants for specific R&D projects is more likely to contribute to what can be termed 'core projects' (Görg & Strobl 2007). Thus, it is likely that grant recipients are more prepared to invest their own private funding into these projects, alongside the public R&D funding (Un & Cuervo-Cazurra 2008). This may disadvantage foreign-owned subsidiaries, who do not have the final say in what to prioritise in their R&D strategy (Kwon & Park 2018). When decisions on where to locate R&D are taken on a global basis, and decided upon by the parent firm, foreign-owned subsidiaries may not be able to tailor applications for direct R&D funding to the specific requirements of host country funding agencies (Hud & Hussinger 2015).

In contrast with R&D grants, relatively few studies have examined the impact of R&D tax credits on foreign-owned subsidiaries. However, the limited previous literature that does exist, suggests that this policy instrument tends to be most effective in older, resource-abundant firms, with significant pre-existing R&D capacity (Busom et al. 2014; Neicu et al. 2016; Acheson & Malone 2020). Additionally, the fact that R&D spending needs to occur before a firm can claim an R&D tax credit, makes it less attractive to resource-constrained firms, and non-R&D active firms (Busom et al. 2014). Due to their multinational group structure, foreign-owned firms can relocate significant R&D spending to countries where the cost of conducting R&D is lower (Montmartin & Herrera 2015). Therefore R&D tax credits can lead to large-scale input additionality in foreign-owned subsidiaries resulting from a relocation of R&D resources within a multinational firm (Appelt et al. 2016). Therefore, although Montmartin and Herrera (2015) conceptualise positive input additionality from both R&D support types for the host country, the European Commission (2017b) suggest that the impact of R&D tax credits will outmatch that of R&D grants. This suggests the following hypothesis:

Hypothesis 2*: R&D tax credits will produce higher input additionality in foreign-owned subsidiaries, relative to R&D grants.*

2.3. Contribution of public R&D support to the economic performance of foreign-owned subsidiaries

In contrast to other firm types, foreign-owned subsidiaries can combine R&D spending with other unique internal characteristics to achieve significant firm performance benefits (Dachs &

Peters 2015). This dynamic may enhance the effectiveness of R&D, induced by public support (Giroud et al. 2012). For instance, subsidiaries often possess superior access to assets in terms of knowledge, technologies, brands, and distribution networks (Kwon & Park 2018); as well as organisational and managerial capabilities and practices (Un 2011). Due to foreign-owned firms' multinational structure, these superior assets can be transferred across the international group, from the parent firm based in the home country, or from other foreign-based affiliates (Aerts 2008). Dachs and Peters (2015) highlight that learning from the experiences of other multinational affiliates is an advantage when it comes to conducting R&D, and crucially, using R&D to drive firm performance. For example, foreign-owned firms can bring new products to market more easily, distribute them more widely, and implement process innovations more effectively than other firms (Kwon & Park 2018). This is because subsidiaries benefit from the experiences of multinational affiliates, in other countries, with similar products and technologies (Pearce & Papanastassiou 2009). These features can help subsidiaries achieve higher performance outcomes, relative to other firms (Sadowski & Sadowski-Rasters 2006; Vanino et al. 2019). These factors suggest the following hypothesis:

Hypothesis 3: *Policy-induced R&D from R&D grants and R&D tax credits, is positively linked to firm performance in foreign-owned subsidiaries.*

When considering the relative impacts of policy-induced R&D from R&D grants and R&D tax credits on subsidiary performance in the host country, several factors bear consideration. As noted in Section 2.1, the R&D firms undertake which is supported by tax incentives is not tied to any specific R&D project deliverables (Aristei et al. 2017). This differs significantly from R&D grants, where firms must apply for R&D funding, and indicate what the firm would not be able to achieve without the support (Hud & Hussinger 2015). As such, it is possible to suggest that the *type of R&D* stimulated by grants may differ to that from tax credits (European Commission 2017b), in that it is more linked to host country-specific activities (IMF 2016). Therefore, direct R&D support is likely to be more closely associated with the subsidiary's economic activities within the host country (European Commission 2017a). In case of R&D tax credits, a likely increase of R&D in the foreign-owned subsidiary, will often result from a reallocation of R&D capacities within the overarching multinational group, towards locations with lower R&D user cost (Rao 2016). The output of the subsidiary's additional R&D efforts (i.e. new knowledge or new technologies) will feed into the multinational's global knowledge network, and may be commercialised as part of a global innovation strategy (Pearce & Papanastassiou 2009). It is hence less likely that the firm performance benefits arising from

R&D tax credit-induced additional R&D spending will emerge in the host country, as compared to additional R&D resulting from R&D grants. Based on these factors, we formulate our final hypothesis:

Hypothesis 4: *Policy-induced R&D from R&D grants will have a stronger link to foreign-owned subsidiaries' performance, relative to R&D tax credits.*

3. Methodology and data

For our empirical approach, we adopt a two-stage method, similar to Freel et al. (2019). We first examine the impact of government R&D support on firm-level R&D, distinguishing between R&D grants and R&D tax credits. For each type of support, we estimate the amount of additional R&D that can be attributed to this support mechanism. Secondly, we estimate the impact of the *policy-induced* R&D from both grants and tax credits on different measures of firm performance.

We apply this method using data on firms based in Ireland. Full details on the policy context of Ireland are provided in Appendix A in Supplementary material. However, it is important to emphasise the dichotomy in the Irish economy between foreign-owned subsidiaries and domestic Irish-owned firms (Bailey & Lenihan 2015). Therefore, as noted in Section 1, in the analysis we split our dataset into two samples: a) foreign-owned subsidiaries based in Ireland; and b) domestically-owned Irish firms. In this regard, we note that it is not possible to directly compare the magnitude of our results for domestic and foreign-owned firms, because they come from distinct samples. However, the decision to split our sample is crucial, as it enables us to verify our results concerning foreign-owned subsidiaries. For example, should we find that public R&D support has no effect on subsidiaries' performance, this may suggest that the key risk associated with funding subsidiaries' R&D has come to pass. However, this may be a spurious conclusion, if the R&D support is simply not effective at driving firm performance *in general*. In this regard, the domestic sample provides a context, where the risk associated with funding subsidiaries is not likely to occur, enabling the verification of our foreign-owned sample findings.[3] As such, the pattern of results which emerges from the domestic firms'

[3] As is common in previous studies (for a discussion, see Kwon & Park 2018), it is not possible for us to identify domestically-owned firms who have their own subsidiaries based outside of Ireland, and who potentially exploit R&D abroad. Although some such firms exist, they constitute a small fraction of the domestic sample (see: https://enterprise.gov.ie/en/Publications/ABSEI-2019.html).

sample is key to achieving an accurate interpretation of our results for foreign-owned subsidiaries.[4]

3.1 Selection into treatment: A two-stage approach

As is common in the literature (e.g. Vanino et al. 2019), we refer to firms that receive R&D support as 'treated', and all other firms as 'untreated'. Selection bias is a key issue when evaluating the impact of public support for R&D on firm performance. This issue arises because firms self-select into the treatment (Cerulli & Poti 2012), and government agencies select better performing firms for funding, the so-called 'picking winners' strategy (Dumont 2017). Thus, recipient firms may not be representative of the population of R&D active firms. Failure to address this form of selection bias might result in over-estimating the impact of policy supports for recipient firms (Czarnitzki et al. 2011).

Several methods have been developed in existing literature to address the issue of selection into treatment (for a review, see Cerulli & Poti 2012). To correct for selection into treatment, we apply a two-stage estimation procedure similar to Beck et al. (2016) and Freel et al. (2019). In stage one, we use Propensity Score Matching (PSM) to estimate the contribution of each R&D policy instrument to firms' R&D expenditure. Stage two uses the results from stage one, to estimate the impact of the policy-induced R&D on firm performance (relative to privately financed R&D). In line with Freel et al. (2019), the second stage applies a fixed effects panel model, which controls for significant firm-level heterogeneity when examining the impact of policy-induced R&D on firm performance.

In stage one, we match treated and untreated firms, based on their propensity to receive the treatment. We calculate the propensity score using a logit model on the probability to receive a treatment:

$$Treatment_{kit} = \beta_0 + \beta_1 X_{it-1} + \varepsilon_{it} \quad (1)$$

The term $Treatment_{kit}$ is a dummy variable indicating whether firm i received instrument k in time period t, X_{it-1} is a set of independent variables for firm i in time period t-1. The βs in

[4] Our domestic sample consists of 18,920 observations, while our foreign-owned sample contains 5,388 observations. Due to the structure of the Irish economy and the quality of our dataset, our sample of foreign-owned subsidiaries is over twice as large as that used by Girma et al. (2003), four times larger than Görg & Strobl (2007), and over 10 times larger than those used by Acheson and Malone (2020), Liu et al. (2016), Giroud et al. (2012), and Aerts (2008).

Equation (1) indicate the model coefficients, and ε_{it} is the error term. Four separate models are estimated, capturing different treatments for different groups of firms: (a) R&D grants for the foreign-owned sample; (b) R&D tax credits for foreign-owned sample; (c) R&D grants for the domestic sample; and (d) R&D tax credits for the domestic sample. In each case, the potential control group consists of only non-treated firms. In the case of R&D grant recipients, the potential control group includes firms which may also claim R&D tax credits (and *vice versa*). These models generate a firm's propensity to receive a treatment. For each treated firm *i*, we assign an untreated firm that shows the lowest difference in the propensity score to firm *i*.[5] In addition, matched untreated firms must operate in the same industrial sector, belong to the same firm size category (i.e. micro, small, medium, and large)[6], and the R&D expenditure data must refer to the same year *t* in which treated firms have received R&D support. As firms can receive multiple treatments over this time period, we ensure that treated firms are only matched with untreated firms from the same year (i.e. treated in *t* is only ever matched with untreated in *t*). In implementing this procedure, we follow the same approach as employed by Beck et al. (2016). They note that exact matching on specific firm characteristics, as well as the propensity score, improves the quality of matching.

Drawing on the results of Equation (1), we calculate the policy-induced R&D for each R&D policy instrument, for both foreign-owned and domestic firms. In doing so, we capture the counterfactual situation of how much a treated firm would have invested in R&D, if it had not received that treatment. The difference between the observed amount and the counterfactual is the policy-induced R&D. This is calculated as follows:

$$\alpha_{k,it} = E\left({}^{T}RD_{it} \,|F_{it} = 1\right) - E\left({}^{C}RD_{it} \,|F_{it} = 1\right) \qquad (2)$$

In Equation (2), $\alpha_{k,it}$ is the treatment effect, which we classify as the policy-induced R&D. We calculate this value for R&D grants as $\alpha_{R\&Dgrant,it}$ and for R&D tax credits as $\alpha_{R\&Dtaxcredit,it}$. Given both values, it is possible to generate a further counterfactual of privately-funded R&D expenditure for treated firms, as follows:

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[5] In line with the recommendation of Guerzoni and Raiteri (2015), we use the 1:1 nearest neighbour matching method for our main stage one analysis, and 1:3 and Kernel density matching to test if our stage one analysis is robust to changes in matching estimator.

[6] We use the European Union recommendation 2003/361 which defines small-sized firms as firms with less than 50 employees, medium-sized firms as firms with at least 50 and fewer than 249 employees, and large firms as firms with at least 250 employees. The recommendation also classifies firms according to their turnover or balance sheet (see http://data.europa.eu/eli/reco/2003/361/oj), but the number of employees is the most used classification (Eurostat 2019). We define micro firms as those employing less than 10 employees.

$$PrivateRD_{it}^{C} = PrivateRD_{it} - \alpha_{R\&Dtaxcredit,it} - \alpha_{R\&Dgrant,it} \quad (3)$$

For untreated firms $PrivateRD_{it}^{C} = PrivateRD_{it}$ as $\alpha_{R\&Dtaxcredit,it}$ and $\alpha_{R\&Dgrant,it}$ are equal to zero. Note that $PrivateRD_{it}^{C}$ can be negative, if matched untreated firms show a higher R&D output than treated firms (i.e. crowding-out).

In stage two of our analysis, we examine whether policy-induced R&D ($\alpha_{taxcredit,it}$ and $\alpha_{grant,it}$) is linked to firm performance, by estimating Equation (4):

$$FirmPerformance_{it} = \beta_0 + \beta_1\alpha_{R\&Dtaxcredit,it-1} + \beta_2\alpha_{R\&Dgrant,it-1} + \beta_3 PrivateRD_{it-1}^{C} + \beta_4 z_{it-1} + \mu_i + \mu_t + \varepsilon_{it} \quad (4)$$

In Equation (4), $FirmPerformance_{it}$ is measured as, respectively, the natural logarithm of the following variables: Turnover, Gross Value Added (GVA), Exports, and Employment[7]. The term z_{it-1} is a matrix of control variables for firm *i* in time period t-1, and β_4 are the associated coefficients, while μ_i are time invariant firm fixed effects, and μ_t are time fixed effects. While the year and firm fixed effects control for significant unobserved heterogeneity, the term z_{it} also captures a series of time-varying independent variables, defined in Table 1. These variables differ to those used in Equation (1) which examine selection into treatment, because they are more closely associated with firm performance[8]. In terms of the time lag used in our model between receiving R&D support and any potential firm performance effects, we measure the impact of receiving a treatment in *t-1* on firm-level R&D in *t* (i.e. the current year); we then measure the impact of policy-induced R&D in *t*, on firm performance in *t+1*. Note that Equation (4) evaluates whether policy-induced R&D expenditure and firm performance are positively linked. However, it does not establish a causal relationship in the strict sense. As recently discussed by Giannopoulou et al. (2019), the inability to infer causality when using most available datasets and commonly used methods, is a limitation of current empirical research in innovation studies. However, it is crucial to highlight this issue, to ensure that our findings are interpreted with the above in mind. Therefore, while we can observe whether the

[7] We estimate four separate models in the foreign-owned and domestic samples, with each of these firm performance outcomes as a dependent variable.

[8] Some previous studies which examine the impact of policy-induced R&D/innovation on firm performance also include a one-year-lagged value of the dependent variable as a control variable in their stage two analysis (see e.g. Aerts 2008; Freel et al. 2019). We do not include such a variable in our analysis. The rationale for this decision is detailed in Appendix C in Supplementary material.

policy-induced R&D from R&D grants and tax credits is positively linked to firm performance improvements, we cannot infer a direct causal relationship.

Table 1: Definition of variables used in the analysis

Variable	Definition
Stage one dependent variable	
R&D	Natural logarithm of firm's total R&D expenditure.
Stage two dependent variables	
Turnover	Natural logarithm of firm's turnover.
Exports	Natural logarithm of firm's exports.
GVA	Natural logarithm of firm's Gross Value Added (GVA).
Employment	Natural logarithm of firm's employment.
Treatment variables	
R&D tax credit	Binary variable equal to 1 if a firm claimed an R&D tax credit; 0 otherwise.
R&D grant	Binary variable equal to 1 if a firm received direct funding for R&D from Industrial Development Agency (IDA) Ireland or Enterprise Ireland; 0 otherwise.
Control variables	
Past turnover	Categorical variables capturing the quartile of firms' turnover (natural logarithm): 1 = Firms in the lowest turnover quartile in a given year; 2 = Firms in the second lowest turnover quartile in a given year; 3 = Firms in the second highest turnover quartile in a given year; 4 = Firm in the highest turnover quartile in a given year.
R&D above median	Binary variable equal to one if firms' past R&D was above the median R&D expenditure; 0 otherwise.
Past public funding for R&D	Binary variable equal to 1 if a firm received an R&D grant or R&D tax credit in the previous period; 0 otherwise.
Other R&D support	Binary variable equal to 1 if a firm received any other form of R&D support; 0 otherwise.
Firm size	Categorical variables: 0 = Micro if a firm has less than 10 employees; 1 = Small if a firm has 10 or more employees and less than 50 employees; 2 = Medium if a firm has 50 or more employees and less than 250 employees; 3 = Large if a firm has 250 or more employees.
Material costs	Natural log of materials and service costs.
Unit labour costs	Firm's payroll divided by GVA.
Sector	Categorical variables representing 12 NACE sectors (defined in Appendix Table B1 in Supplementary material).
Year	Categorical variables: 0 = 2007; 1 = 2008; 2 = 2009; 3 = 2010; 4 = 2011; 5 = 2012; 6 = 2013; 7 = 2014; 8 = 2015; 9 = 2016.

Notes: NACE is the acronym for 'nomenclature statistique des activités économiques dans la Communauté européenne', and is the statistical classification of economic activities used by Eurostat. Other R&D support captures any R&D support which does not provide direct funding through R&D grants or indirect funding through R&D tax credits. The R&D supports in this category are as follows: Innovation Partnerships, Innovation Vouchers, and Science Foundation Ireland research centres.

3.2 Data

Our empirical analysis is based on a merged dataset, comprising the Irish Annual Business Survey of Economic Impact (ABSEI), as well as administrative data on R&D grants and R&D tax credits awarded to firms during the period 2007-2016[9]. ABSEI is an unbalanced annual panel dataset, collected via a postal survey conducted by Ireland's Department of Enterprise, Trade and Employment (DETE), covering a population of approximately 4,000 firms annually, with a response rate of approximately 65 per cent each year[10]. The ABSEI dataset is unique because its sample frame covers all firms that have ever been assisted in any way by Ireland's enterprise development agencies (i.e. EI, IDA). As such, ABSEI is specifically designed to cover a large, representative sample of the foreign-owned and domestic firms who receive policy support each year.[11]

The key administrative data comes from Ireland's two main funding agencies that provide R&D grants to firms: 1) Enterprise Ireland (EI) - supports domestic Irish-owned firms; and 2) Industrial Development Agency Ireland (IDA) - attracts and supports foreign-owned firms. Our analysis also draws on novel administrative data from the Irish Revenue Commissioners on firms' R&D tax credit claims. We aggregate all direct grant support from EI and IDA into one variable, capturing whether firms received any R&D grant support in a particular year[12]. Our merged sample captures 54.26 percent of the IDA administrative data, 63.74 percent of the EI administrative data, and 54.04 percent of the Irish Revenue Commissioners R&D tax credit data. An analysis on the representativeness of our sample, relative to the full populations in these administrative datasets, is presented in Appendix Tables D1, D2 and D3 in Supplementary material. These tables demonstrate that our sample is highly representative across a range of different firm-level characteristics.

3.3 Description of variables

Our analysis measures firm-level R&D as the natural logarithm of firms' total R&D expenditure. Although this definition of firms' R&D is common in the literature (e.g. Aiello et al. 2019), some previous studies used firms' R&D divided by turnover (i.e. the ratio) as a

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[9] For more information on the policy context of Ireland and our dataset, see Appendix A in Supplementary material.
[10] See: https://enterprise.gov.ie/en/Publications/ABSEI-2019.html.
[11] Full details on the sampling strategy for ABSEI can be found in Appendix E in Supplementary material.
[12] Further details on the specific R&D grant programmes included are provided in Appendix Table A1 in Supplementary Material.

dependent variable. However, Alessandri and Pattit (2014) note that the use of such ratio variables can introduce biased correlations into econometric models, which confound the interpretation of results and may lead to spurious findings. Therefore, we follow Alessandri and Pattit's (2014) recommendation to use the logarithm of firms' R&D as the dependent variable, and firms' turnover as a control variable in our stage one analysis. As noted above, our stage two outcome variables are turnover, exports, GVA, and employment.

For the treatment variables in stage one, we employ binary variables which take a value of one if a firm received an R&D grant, or claimed an R&D tax credit in year *t* (or a value of 0 otherwise), over the time period 2007 and 2016[13]. As noted above in Section 3.1, we also include several control variables to account for firm-level characteristics. In line with Nilsen et al. (2020), we include a binary variable which captures whether firms were above, or below the sample median R&D expenditure amount in the year before they received any R&D support. In addition, we include four variables capturing the four quartiles of the turnover distribution in our sample, to capture pre-treatment business quality (Vanino et al. 2019). Based on Busom et al. (2014) and Neicu et al. (2016), we include two dummy variables which capture whether firms received an R&D grant and/or R&D tax credit in the past, and whether firms received any other form of public R&D support[14] (i.e. non-R&D grant/tax credit support). In addition, we use a series of binary variables which indicate whether a firm is in the micro, small, medium, or large size categories, as well as which sector a firm belongs to (defined in Table 1).

For the stage-two model on firm performance, we control for firms' material inputs and unit labour costs (see Table 1). Freel et al. (2019) deem these variables to be key indicators of price and quality advantages when examining the impact of public R&D support on firm performance. Firm-specific determinants of performance such as the accumulated stock of knowledge, market access, reputation, and so forth, are captured by estimating a firm fixed-effect model. In constructing our final sample, we follow a similar procedure to Czarnitzki and Thorwarth (2012), and restrict our sample to only firms that were R&D-active in at least one year over the period 2007-2016. In addition, our sample is characterised by a small number of outliers which have turnover of an order of magnitude above the next largest firm. Therefore, following the recommendation by Falck et al. (2021), we remove the top 1% of firms in this

[13] For further details on the definitions of these variables, see Appendix B in Supplementary material.
[14] This variable does not comprise direct R&D grant funding to firms, but rather includes supports designed to enable collaboration with the higher education system (see Appendix A in Supplementary material).

variable. Appendix Table B2 in Supplementary material provides summary statistics for all variables used in our sample.

4. Empirical results

This section presents the results of our two-stage estimation procedure, to evaluate the impact of R&D grants and R&D tax credits on foreign-owned subsidiaries' R&D, and firm performance.

4.1. Impact of public R&D support on R&D in foreign-owned subsidiaries

To perform our stage one PSM analysis, we match treated and untreated firms based on their propensity to receive the treatment. Table 2 reports the marginal effects from the logit models used to estimate firms' propensity scores (Appendix Table F1 in Supplementary material reports the coefficients these marginal effects are based on).[15] To summarise, our results show that some common factors influence both foreign-owned and domestic firms' likelihood to select into using R&D grants and R&D tax credits, such as pre-treatment R&D and previous public R&D funding. However, notable differences also exist. For example, pre-treatment turnover plays a key role in determining whether subsidiaries receive R&D tax credits, but not R&D grants; and has a negative impact on domestic firms' likelihood to receive R&D grants. Overall, these results suggest there are different factors at play when foreign-owned and domestic firms select into using R&D grants and R&D tax credits, supporting our decision to split the sample.[16]

[15] Due to space constraints, we do not provide a detailed description of these results here. See Appendix F in Supplementary material for further discussion of our propensity score estimation.

[16] Appendix Tables F2 and F3 in Supplementary material demonstrate that our treated and matched untreated samples are well balanced across all covariates.

Table 2: Marginal effects from logit model for firms' probability of receiving public R&D funding

	Foreign-owned firms		Domestic firms	
Variables	R&D grants	R&D tax credit	R&D grants	R&D tax credit
R&D above median	0.0765***	0.0731***	0.0303***	0.198***
	(0.00984)	(0.0133)	(0.00550)	(0.00694)
Past turnover quartile two	-0.0478**	0.0671***	-0.0187**	0.00766
	(0.0194)	(0.0201)	(0.00841)	(0.00908)
Past turnover quartile three	-0.0441**	0.0593***	-0.0181**	-0.0149
	(0.0206)	(0.0212)	(0.00912)	(0.00977)
Past turnover quartile four	-0.0210	0.0553**	-0.0252**	-0.0203*
	(0.0221)	(0.0232)	(0.0109)	(0.0118)
Previous public R&D funding	0.252***	0.358***	0.224***	0.250***
	(0.0185)	(0.0104)	(0.00709)	(0.00570)
Other R&D support	0.0266**	-0.0243	0.0793***	0.0592***
	(0.0111)	(0.0167)	(0.00570)	(0.00700)
Firm size: Small	0.0880*	0.143***	0.00890	0.0167*
	(0.0532)	(0.0516)	(0.00781)	(0.00869)
Firm size: Medium	0.121**	0.131**	0.00171	0.0148
	(0.0536)	(0.0525)	(0.0112)	(0.0123)
Firm size: Large	0.135**	0.0727	0.00952	-0.0419**
	(0.0545)	(0.0544)	(0.0181)	(0.0200)
Observations	4,051	4,023	15,756	15,756

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Standard errors in parentheses. All coefficients from the logit models are presented as marginal effects, for ease of interpretation. Dummy variables for year and NACE sector are included in the propensity score estimation, but the output is not displayed here. The base category for firm size is micro; the base category for R&D intensity quartile is zero R&D; the base category for turnover is the lowest turnover quartile

Drawing on this matching procedure, Table 3 presents the results from our PSM analysis.[17] We first examine Hypothesis 1, which states that R&D grants and R&D tax credits produce input additionality in foreign-owned subsidiaries. The findings presented in Table 3 demonstrate that both support types have a positive and significant impact on subsidiaries' R&D. Table 3 shows the matching. Foreign-owned firms that use R&D tax credits spend, on average, €0.803 million per year on R&D, compared to €0.126 million for matched untreated foreign-owned firms, suggesting a treatment effect of €0.677 million. In the case of R&D grants, the treatment effect is higher at €1.005 million. As such, we find strong support for Hypothesis 1.

[17] Appendix Table G1 in Supplementary material shows that the sign, significance, and magnitude of all estimated results in stage one are robust to changes in the matching estimators.

Table 3: Propensity score matching results for the impact of R&D supports on firm-level R&D

Foreign-owned firms			
Treatment	Treated	Matched untreated	Difference (α)
R&D tax credit	0.803	0.126	0.677***
R&D grant	1.818	0.813	1.005*
Domestic firms			
Treatment	Treated	Matched untreated	Difference (α)
R&D tax credit	0.194	0.056	0.138***
R&D grant	0.076	0.033	0.043***

Notes: * p < 0.1; ** p < 0.05; *** p < 0.01. For ease of interpretation, the results in Table 3 are expressed in millions of Euros. Estimation results based on 1:1 nearest neighbour matching. The α term relates to the average policy-induced R&D from each policy instrument.

The results are consistent with those reported for direct R&D funding by Aerts (2008), Giroud et al. (2012), Rodríguez-Pose and Wilkie (2016), and for R&D tax credits by Rao (2016) and Acheson and Malone (2020). However, unlike the above studies, we capture both R&D support types in the same analysis. As such, in line with Dumont (2017) and Marino et al. (2016), our findings provide a more precise picture than was possible in previous analyses. This is because our input additionality estimates for each type of R&D support take into account likely effects of the other support mechanism. In addition, we observe a similar pattern of positive and statistically significant results in the domestic firm sample. Taken together, these results reveal that public R&D funding is effective *in general* at driving firms' R&D. This suggests that we should expect to see follow-on impacts on subsidiaries' firm performance in stage two, if two conditions are met: 1) the policy-induced R&D from R&D grants and tax credits is used effectively; and 2) foreign-owned subsidiaries commercially exploit the policy-induced R&D in the host country, at least to an extent sufficient to drive a positive and significant impact on firm performance.[18]

We next turn to Hypothesis 2, which states that R&D tax credits will produce larger input additionality in foreign-owned subsidiaries' R&D, relative to R&D grants. In terms of differential effects, it is clear from Table 3 that the magnitude of the result for R&D tax credits

[18] We note that if foreign-owned subsidiaries do not commercially exploit host-country-funded R&D in the host country, their parent firm may exploit it at other locations in their global network, or they may not exploit it at all. Our study had no measure for the global returns to host country-funded R&D. We can only examine whether firm performance benefits accrue in the host country.

is smaller than that for R&D grants. However, the input additionality found for R&D tax credits is statistically much more robust ($p < 0.01$) than for R&D grants ($p < 0.1$). This suggests that R&D tax credits incentivise additional R&D expenditures much more reliably across the entire group of foreign-owned firms, than is the case with R&D grants. The additionality of R&D grants is much more heterogeneous across foreign-owned subsidiaries. Some subsidiaries increase R&D expenditure at a very high rate, resulting in a larger, though less robust average effect.

To examine the statistical significance of the difference in input additionality between the two types of support, we perform a mean comparison test. This is possible because both results come from the same sample of firms (i.e. foreign-owned). Results from this test reveal that there is no statistically significant difference between the impact of R&D grants and R&D tax credits on foreign-owned subsidiaries' R&D. Therefore, we can say that both R&D support types produce a statistically identical percentage increase in subsidiaries' R&D, and thus formally reject Hypothesis 2. These results are in contrast to Marino et al. (2016), who report generally non-significant, or negative impacts from R&D grants and R&D tax credits on firms' R&D. However, our results are more in line with Neicu et al. (2016) and Dumont (2017), who find that both R&D support types can drive additional firm-level R&D. Our analysis builds on these studies, by confirming their findings in the specific case of foreign-owned subsidiaries operating in a host country, a key sub-group within the general population of firms (Un & Cuervo-Cazurra 2008; Un 2011).

4.2. Role of public R&D support for firm performance outcomes

Table 4 presents the results from our stage two analysis[19]. We first focus on Hypothesis 3, which states that policy-induced R&D from R&D grants and R&D tax credits is positively linked to firm performance in foreign-owned subsidiaries. As noted in Section 3.1, policy-induced R&D can be negative, if matched non-treated firms have greater R&D than treated firms (i.e. crowding-out). We define our R&D outcome variable in stage one as the natural logarithm of firms' total R&D. As logarithms cannot take a negative value, we convert this figure into actual monetary terms, by calculating the exponential. The monetary amount can have a negative value, which ensures that our stage two estimations include any potential crowding-out effects. Crowding-out occurs in instances where firms substitute some or all of

[19] Appendix Tables G2 and G3 in Supplementary material test the robustness of our Stage 2 results to changes in the matching technique used in Stage 1. Results from these robustness tests confirm our findings in Table 4.

the public R&D support for their own private R&D spending (David et al. 2000). This often results in lower R&D investment than would have been the case in the absence of the public support (González & Pazó 2008), and is thus vital to capture in our two-stage analysis[20].

Bearing this in mind, rows two and three in Table 4 show the link between policy-induced R&D from each R&D support type, and firms' turnover, exports, GVA, and employment. The results indicate that policy-induced R&D from R&D grants and R&D tax credits is positively and significantly linked to higher performance outcomes of subsidiaries (with the only exception being R&D grants and employment). These results suggest strong support for Hypothesis 3. Our findings are similar to those presented by Freel et al. (2019) and Aerts (2008). However, we build on, and extend these studies by focusing on the specific case of foreign-owned subsidiaries, including both main R&D support types in the same analysis, along with using a wider range of firm performance outcomes.

To further test our support for Hypothesis 3, we compare the results of privately-funded R&D to those of policy-induced R&D. Focusing on the foreign-owned firm sample in Table 4, as anticipated, privately-funded R&D has a positive and significant link to all firm performance measures. To interpret these results, we perform the following calculations. Firstly, the privately-funded and policy-induced R&D variables are defined in Euro-terms, while the dependent variables are given in logarithm. Therefore, we can interpret the coefficients as semi-elasticities. As such, our results for subsidiaries show that a €1,000,000 increase in private R&D relates to 0.879% higher turnover, 0.865% higher GVA, 0.801% higher exports, and 0.301% higher employment. These findings are in line with those reported by Siliverstovs (2016), when reviewing the literature on the impact of private R&D on firm performance.

Secondly, we formally examine whether the two estimated coefficients for policy-induced R&D are statistically different, by performing a series of t-tests. Results show that there is no statistically significant difference at the 5% level for policy-induced and privately-funded R&D. This holds for all statistically significant coefficients of policy-induced R&D. Therefore, we find further support Hypothesis 3, by showing that the policy-induced R&D from R&D grants and R&D tax credits is equally relevant as privately-funded R&D for subsidiaries' performance outcomes.

[20] For a more detailed discussion of crowding-out effects in a two-stage model, see Beck et al. (2016).

Table 4: The link between policy-induced R&D and firm performance in foreign-owned and domestic firms (fixed effects panel model)

	Foreign-owned firms				Domestic firms			
Variable	Turnover (log)	GVA (log)	Exports (log)	Employment (log)	Turnover (log)	GVA (log)	Exports (log)	Employment (log)
Privately-funded R&D	0.00879***	0.00865***	0.00801**	0.00301*	0.174***	0.151***	0.182***	0.131***
	(0.00326)	(0.00277)	(0.00339)	(0.00160)	(0.00378)	(0.00371)	(0.004.20)	(0.002.71)
Policy-induced: R&D tax credit (α)	0.00751**	0.00725**	0.00683**	0.00281*	0.178***	0.155***	0.152***	0.139***
	(0.00323)	(0.00345)	(0.00331)	(0.00159)	(0.00327)	(0.00330)	(0.00384)	(0.00238)
Policy-induced: R&D grant (α)	0.00841**	0.00726**	0.00765**	0.000256	0.168***	0.141***	0.196***	0.121***
	(0.00343)	(0.00310)	(0.00359)	(0.00176)	(0.00384)	(0.00377)	(0.00429)	(0.00276)
Firm size: Small	0.174	0.0550	0.196	0.346***	0.404***	0.437***	0.372***	0.441***
	(0.184)	(0.163)	(0.185)	(0.0916)	(0.0262)	(0.0301)	(0.0436)	(0.0226)
Firm size: Medium	0.694***	0.497***	0.607***	0.932***	0.802***	0.830***	0.721***	0.864***
	(0.192)	(0.177)	(0.193)	(0.108)	(0.0376)	(0.0437)	(0.0646)	(0.0366)
Firm size: Large	1.107***	0.875***	1.017***	1.439***	1.193***	1.252***	0.980***	1.327***
	(0.202)	(0.192)	(0.211)	(0.126)	(0.0776)	(0.0907)	(0.145)	(0.0753)
Materials	0.213	-0.895***	0.158	-0.0457	0.0275	-0.778***	0.0596***	0.0191
	(0.169)	(0.181)	(0.158)	(0.0645)	(0.0393)	(0.0782)	(0.0214)	(0.0141)
Unit labour costs	-0.0458***	-0.0543***	-0.0545***	-0.00373*	-0.000486	0.00209	-0.000319	0.000362
	(0.0137)	(0.0169)	(0.0171)	(0.00199)	(0.000576)	(0.00176)	(0.00100)	(0.000405)
Constant	16.45***	16.39***	16.28***	3.890***	14.49***	14.07***	13.04***	2.709***
	(0.191)	(0.176)	(0.195)	(0.107)	(0.0331)	(0.0508)	(0.0460)	(0.0240)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,604	3,552	3,441	3,604	14,169	13,865	12,388	14,169
R^2	0.5471	0.4891	0.4591	0.8224	0.5306	0.4651	0.2456	0.7347

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors in parentheses. The policy-induced R&D variables correspond to the α term defined in Equation (2). The number of observations changes in each model due to missing values in the dependent variables. For ease of interpretation, the variables *Privately-funded R&D*, *Policy-induced: R&D tax credit (α)*, and *Policy-induced: R&D grant (α)* have been scaled by 1 million.

Moreover, as detailed in Section 3, it is reasonable to assume that, if effective, supporting domestic firms' R&D activities is linked to firm performance benefits in the domestic economy. However, for foreign-owned firms, this is not necessarily a reasonable assumption. In the case of subsidiaries, a risk exists that publicly-funded R&D may not be commercially exploited in the host country, leading to few performance benefits. Therefore, it is important to note that we observe a similar pattern of positive and statistically significant results in both the foreign-owned and domestic samples. These results suggest that foreign-owned subsidiaries do exploit the results from host country-funded R&D in the host country, at least to an extent sufficient to increase firm performance. Overall, these results reinforce our support for Hypothesis 3.

We next turn to Hypothesis 4, which states that policy-induced R&D from R&D grants has a stronger link to foreign-owned subsidiaries' performance, relative to R&D tax credits. In this regard, a further series of t-tests reveal no statistically significant difference between the coefficients of each R&D support type at the 5% level. However, as noted above, the policy-induced R&D from R&D grants shows a positive, but not statistically significant coefficient for subsidiary employment, while a significant employment coefficient is found for R&D tax credits. Therefore, although the R&D induced by grants is not significantly linked to subsidiary turnover, exporting, and GVA, we find no support for Hypothesis 4. In this regard, our results are similar to Nilsen et al. (2020), who find that R&D grants appear to be somewhat less effective than R&D tax credits at driving firm performance. It is important to highlight that Nilsen et al. (2020) focus on the *direct effects* of R&D support on firm performance in a general sample of firms. In contrast, our analysis focuses on the role of *policy-induced R&D* from each R&D support type for firm performance, in the specific case of foreign-owned subsidiaries. Our results suggest that the *type of R&D* stimulated by R&D grants in subsidiaries does not significantly differ from that induced by R&D tax credits. Therefore, our results build on those presented by Nilsen et al. (2020), by extending our understanding to the specific case of foreign-owned subsidiaries operating in a host country.

5. Discussion and conclusions

Policymakers in many countries allocate vast sums of scarce public money to fund the R&D activities of foreign-owned subsidiaries based in their host economies (European Commission 2017a). This is a particularly important issue in small, open economies (Appelt et al. 2016), which often pursue a strategy of attracting and embedding FDI as a means of leveraging R&D-

driven firm performance (OECD 2015; Rodríguez-Pose & Wilkie 2016; Park et al. 2020). In this study, we provide, to our knowledge, the first comprehensive evaluation of the link of public R&D funding to firm performance in foreign-owned subsidiaries considering both grant-based and tax-based R&D funding schemes. All previous analyses have been hindered by lack of data availability. We overcome this issue by constructing a unique panel dataset for Ireland, with 24,404 observations over 10 years. Our main finding is that public funding for R&D has a strong link with subsidiary performance in the host country. The result holds for both R&D grants and R&D tax credits. Our findings suggest that an industrial strategy of attracting and embedding FDI to achieve R&D-linked firm performance improvements may be a viable strategy for economies beyond the Irish context. The choice of policy instrument does not seem to have an important role in this respect.

Through investigating these key issues, our study makes two important contributions to the literature on public funding for R&D. Our first contribution is that we examine the unique risk that foreign-owned firms may conduct R&D in a host country with the support of public funding, but not exploit the R&D results in their host country (Pearce & Papanastassiou 2009). Our results show that, at least to a sufficient extent, this key risk does not materialise. Both R&D grants and R&D tax credits are equally effective at driving subsidiaries' R&D. Moreover, the additional R&D induced by these policy supports, translates on average, into higher performance of the subsidiaries.

Our second contribution focuses on evaluating the relative impacts of R&D grants and R&D tax credits. In most countries, these policy instruments account for the vast majority of all public R&D funding directed at private firms (Lenihan et al. 2020). Despite this, the relative effectiveness of these instruments at driving R&D and firm performance improvements in foreign-owned subsidiaries is completely unaddressed in previous analyses (e.g. Acheson & Malone 2020; Liu et al. 2016; Giroud et al. 2012). In this regard, our study fills an important gap in the literature. Our results show that both R&D grants and R&D tax credits, produce a similar impact on foreign-owned subsidiaries' R&D and performance.

From a policy perspective, our study contributes to the debate on FDI R&D policy, and the R&D grants versus R&D tax credits debate more generally. While we do not find substantial differences in input additionality of both R&D support types, it is noteworthy that R&D tax credits account for approximately twice the monetary amount of public R&D funding *vis-à-vis* R&D grants (Lenihan et al. 2020). Given that each R&D support type functions through different mechanisms, the European Commission (2017b) has suggested that a lack of balance in funding amounts such as this, is potentially important from a policy perspective. R&D tax credits can help firms to engage in R&D spending which may not otherwise have been possible, but this spending is completely at the firm's discretion (Czarnitzki et al. 2011). In contrast, R&D grants enable governments to direct firms towards specific R&D projects, which are deemed strategically important, but lack sufficient market incentives (Hud & Hussinger 2015). As such, our findings may be relevant for countries beyond the Irish case, such as the UK, France, and Belgium, where the level of R&D tax credit support has also grown to almost double that of R&D grants since circa 2012 (Lenihan et al. 2020). In addition, countries such as Germany, where an R&D tax credit programme has recently been launched (in 2020), could also learn from the Irish experience. Our results suggest that policymakers might usefully consider a greater balance between the use of R&D grants and R&D tax credits, as a means to achieve R&D policy goals.

When considering the relative impacts of R&D grants and R&D tax credits, it is interesting to place our results in the context of the OECD's (2018) recommendation for Ireland. The OECD recommends that Ireland shift away from R&D tax credits, which it suggests favour foreign-owned subsidiaries, at the expense of domestic firms. Instead, the OECD suggests that Ireland should focus on direct funding for R&D in domestic firms, to build their technological capabilities. The IMF (2016) echo this recommendation at the global scale (2016). However, the European Commission (2017a; 2017b) and Rodríguez-Pose and Wilkie (2016) suggest the opposite - R&D tax credits can play a key role in attracting foreign R&D investment, which can have important economic impacts for host countries. Based on our results, a reduction in the R&D tax credit programme seems premature. In case the government would decide to reduce R&D tax credits, a shift towards grant funding would be beneficial for the Irish innovation system in order to keep the positive contribution of policy-induced R&D at a high level. Today, in Ireland the lowest funding category concerns R&D grants in domestic firms, despite this being by far the largest number of firms in the country (Lenihan et al. 2020). Therefore, our results may suggest that direct and targeted R&D funding for domestic firms could be increased, in an effort to bring these firms towards an equivalent level of R&D capacity as foreign-owned subsidiaries. At this level, domestic firms could also start to benefit from the highest levels of R&D tax credit claims, in a similar way to foreign-owned subsidiaries.

Although our study makes significant contributions to the literature on public funding for R&D, it is not without limitations. Firstly, we focus only on direct firm-level impacts. Minniti and Venturini (2017) highlight that indirect effects such as spillovers, multipliers, and competition may influence direct impacts. Whilst beyond the scope of the current study, future research is necessary to examine these issues. Secondly, our study is not able to comment on the marginal returns to R&D. This will depend to a large extent on the type of R&D firms conduct (e.g. basic research, applied research, and development; developing new technologies versus improving existing technologies), as opposed to how much firms spend on R&D (Neicu et al. 2016). Thirdly, our theoretical background, model set-up choices, and results discussion have focused solely on foreign-owned subsidiaries. This is due to the key gap in the literature identified in this regard. However, our results also reveal important effects in the case of domestically-owned firms. Therefore, future research would benefit from a dedicated analysis of domestic firms (and also in the context of other countries, beyond the Irish case). Finally, it is important to highlight that our analysis can only claim to examine the correlation between policy-induced R&D and firm performance impacts, as opposed to causal effects. Future research would benefit from the implementation of a causal effects analysis, should data availability facilitate this. Such a methodological advancement is likely to require a sophisticated type of instrumental variable analysis, which is not possible with our dataset, despite its richness. Therefore, we echo the recent call from Giannopoulou et al. (2019) for access to datasets that would facilitate such causal effects analysis. The latter would also have the potential to significantly improve the interpretation of results, as well as any potential policy implications. Notwithstanding these limitations, by focusing on the specific case of foreign-owned subsidiaries based in a host country, our study makes significant contributions, and represents an important step forward to the literature on public funding for R&D.

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Supplementary material

Appendix A: Policy context of Ireland

Examining the link between public R&D support, and the R&D and economic performance of foreign-owned subsidiaries is particularly relevant in Ireland, given the duality (in terms of foreign-owned and domestically-owned firms) of the Irish economy (Lenihan & Hart 2006; OECD 2018). The Irish economy is characterised by a large presence of foreign-owned firms in certain key high-technology sectors such as electronics, pharmaceuticals, software, and international services[21]. It is widely acknowledged that foreign-owned firms have had a transformative effect on the Irish economy (DBEI 2014; OECD 2018). For example, Figure A1 below shows that over the period 2007-2018, foreign-owned firms accounted for two-thirds of Ireland's total business expenditure on R&D[22]. Since 1949, Ireland has had a specific funding agency responsible for attracting FDI into Ireland: Industrial Development Agency (IDA) Ireland.

Notwithstanding the above, the Irish government's continued pursuit of an FDI-led growth model has also been questioned over several decades for leaving the economy vulnerable to external shocks, coupled with what some commentators regard as a neglect of domestic Irish firms (OECD 2018; Bailey & Lenihan 2015). Following recommendations on the development of a strong domestic industrial base, Enterprise Ireland (EI) was created in 1998 to provide tailored support for domestically-owned firms. EI provides a range of different R&D/innovation supports to domestic firms, while IDA focuses on a smaller number of large R&D supports targeted at foreign-owned firms. Over the period 2007-2016, 68 per cent of foreign-owned firms in Ireland supported by IDA Ireland originated from the USA[23]. Finally, in terms of financial support for R&D, the R&D tax credit is by far the largest form of R&D support in Ireland[24], in terms of the number of firms who claim it, and the amount of public

[21] See: https://www.cso.ie/en/releasesandpublications/ep/p-fdi/foreigndirectinvestmentinireland2019/.

[22] See: https://www.cso.ie/en/releasesandpublications/er/berd/businessexpenditureonresearchdevelopment2017-2018/.

[23] See Appendix Table D1, which provides representativeness tests for our sample against the full IDA data. Appendix Tables D2 and D3 provide representativeness tests for the Enterprise Ireland and R&D tax credit data, respectively.

[24] From 2007-2010 and also in 2016, the Irish government implemented a knowledge development box. In contrast to R&D tax credits, which are cost-based, knowledge development boxes are income-based. They function through tax deduction on income earned from qualifying assets such as patents or intellectual property. However, no data is available to our study on whether firms availed of the knowledge development box, and it was a relatively small policy instrument in the Irish context, with only 10 firms availing of it in 2016 (see:

funding dedicated through it (Lenihan et al. 2020). The Irish R&D tax credit provides a 25 per cent refund on qualifying R&D expenditures, and is available to both domestic and foreign-owned firms undertaking qualifying R&D activity in Ireland[25].

While the number of foreign-owned firms supported by IDA is significantly lower relative to the domestic firms supported by EI, the scale of funding that IDA provides is significantly higher. In our sample, (detailed in Table A1 below), IDA allocated approximately €501 million in direct funding for R&D, in contrast to €241 million for EI. This highlights that a much smaller number of foreign-owned firms are in receipt of larger R&D grants, as well as the fact EI provides a much wider range of R&D supports, meaning its funding is more dispersed. Foreign-owned firms are also by far the largest recipient of R&D tax credits (see Table A2 below). Indeed, the OECD (2018) has recently recommended that Ireland move away from the use of R&D tax credits, which it suggests mainly benefit foreign-owned firms, and focus more on R&D grants, targeted at building domestic firms' technological capabilities. However, it is crucial to determine whether supports such as the R&D tax credit are producing an economic return for the Irish economy (a key component of which culminates in firm level performance benefits) before such recommendations are implemented.

Another factor which may directly influence firms' R&D expenditure is collaboration with Higher Education Institutions (HEIs) facilitated by Irish government policy programmes. Several such programmes exist in Ireland, but *do not* involve direct R&D grant payments, or tax incentives to conduct R&D. The main schemes available to firms in Ireland are the Innovation Vouchers programme and the Innovation Partnerships programme, which are implemented by EI, but can also be availed of by IDA client firms.[26] In addition, Science Foundation Ireland (SFI), a separate national funding agency, implements a research centres programme available to both domestic and foreign-owned firms. SFI research centres do not provide R&D funding directly to firms, but rather provide access to world-leading scientific knowledge through research collaborations between research centres located at HEIs and firms.[27] Although the focus of our study is on R&D grants and R&D tax credits, we

https://data.oireachtas.ie/ie/oireachtas/committee/dail/32/committee_of_public_accounts/reports/2018/2018-06-13_examination-of-matters-in-relation-to-receipts-from-corporation-tax_en.pdf).

[25] See: https://www.revenue.ie/en/companies-and-charities/reliefs-and-exemptions/research-and-development-rd-tax-credit/index.aspx.

[26] For more information, see: https://www.enterprise-ireland.com/en/Research-Innovation/Companies/Collaborate-with-companies-research-institutes/.

[27] For more information, see: https://www.sfi.ie/sfi-research-centres/.

nevertheless control for the presence of these other R&D supports, as they too are designed to influence firm-level R&D. Also, by including these other supports, our study captures the full/holistic system of firm-level R&D supports in Ireland.

Figure A1: Firm-level expenditure on R&D in Ireland (2007-2018), by firm ownership

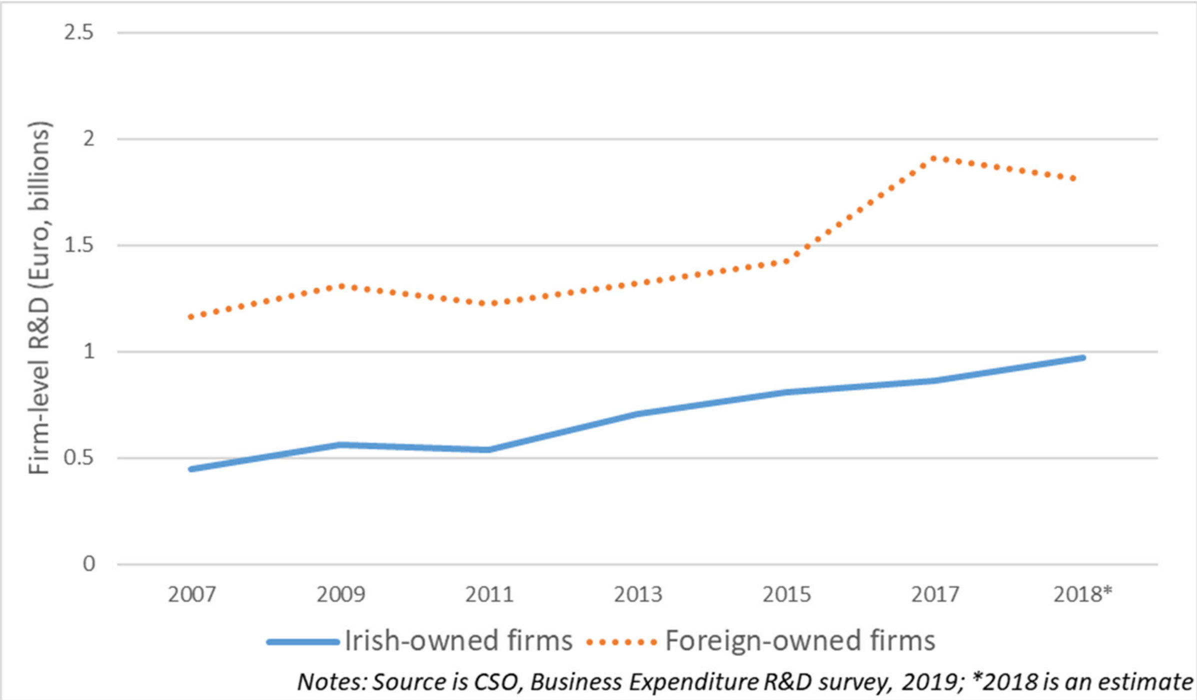

Table A1: Direct funding programmes for R&D allocated to foreign-owned and domestic firms based in Ireland (2007-2016)

	Foreign-owned firms	
IDA Ireland funding programme name	Number of grants allocated	Euro value of funding (millions)
R&D Innovation	301	€ 483.41
RD&I Feasibility	55	€ 7.64
R&D Capability	7	€ 10.47
Total	363	€ 501.51
	Domestically-owned firms	
Enterprise Ireland funding programme name	Number of grants allocated	Euro value of funding (millions)
R&D fund	1,099	€ 156.59
Innovative High Potential Start-Up (HPSU) fund	216	€ 52.23
Company Expansions including R&D	97	€ 23.60
Intellectual Property Assistance Scheme (IPAS)	7	€ 0.10
Technical Feasibility grant	418	€ 9.33
Total	1,837	€ 241.87

Notes: Direct funding programmes for foreign-owned firms are implemented by IDA Ireland, while direct funding programmes for domestically-owned firms are implemented by Enterprise Ireland. This table is based on the merged IDA Ireland and Enterprise Ireland administrative data and the Annual Business Survey of Economic Impact (ABSEI) used in our analysis, not the full population of R&D grant recipients. See Appendix D for descriptive statistics on the full IDA Ireland and Enterprise Ireland data, and representativeness tests against our merged sub-sample.

Table A2: R&D tax credit claims by foreign-owned and domestic firms based in Ireland (2007-2016)

	Claims by foreign-owned firms	Claims by domestically-owned firms
Total amount (approximate)	€1,004,607,500	€473,847,500
Total claims	989	3,710

Notes: This table is based on the merged Irish Revenue Commissioners R&D tax credit claims data and the Annual Business Survey of Economic Impact (ABSEI), not the full population of R&D tax credit claimants. The full population data does not contain an indicator of whether firms are foreign-owned, and therefore cannot be used to split the sample based on ownership type. See Appendix Tables D3 for representativeness tests of our merged sub-sample against the full sample. The figure for total amount is an approximation. This is because the Irish Revenue Commissioners and Central Statistics Office (CSO) provide the R&D tax credit claim data in Euro amount bands (16 categories, ranging from €1 to €25,000, to Greater than €10 million), rather than actual Euro amounts. The Irish Revenue Commissioners and CSO provide the data in this way to anonymise individual claims. However, the individual claim bands are deemed to be disclosive under the CSO's policy on Statistical Disclosure Control. Therefore, we present the approximate total claims for foreign-owned firms and domestic firms, rather than claims in each band. The approximate total is calculated based on the mid-point of each claim band (the value of €15 million is used for the top claim band, as it is open ended).

Appendix B: Variable definitions and descriptive statistics

In addition to defining and providing descriptive statistics for our key variables (in Tables B1 and B2 below respectively), here we also provide additional details on how our treatment variables (R&D tax credits and R&D grants) are measured in the analysis. For the R&D tax credit, we define a firm as treated in the year before it files an official R&D tax credit claim. The rationale for measuring the R&D tax credit in this way is that the actual R&D spending which necessitates the claim takes place in the year before the claim is filed. The timing here is important because any policy-induced R&D will pre-date the actual claim by one year. For the R&D grant, we measure the treatment variable as any year firms received a direct financial payment from Enterprise Ireland or IDA Ireland. In many countries, firms are often approved for R&D grants in a specific year, and they draw down on this grant funding over the following years. Therefore, one grant can be associated with several individual financial payments to the firm over many years. As a result, our definition of the R&D grant variable helps to ensure that we capture the link between policy-induced R&D in each year that firms receive direct R&D funding. Defining the R&D grant variable in this way is only possible because we have detailed administrative data on R&D grant allocations.

Table B1: NACE codes and description of NACE sectors included in the analysis

NACE codes	Description of sector
1-12	Food, Drink & Primary Production
13-18, 22-25, 27-33	Traditional Manufacturing
19-21	Chemicals
26	Computer, electronic & optical products
34	Medical devices
35-43	Energy, water, waste & construction
45-56, 68-96	Business, education & other services
58-61	Publishing, broadcasting & telecommunications
62-62.01	Computer programming
62.02	Consultancy & related facilities
62.03-63	Other Information Technology and computer services
64-66	Financial services

Notes: NACE is the acronym for 'nomenclature statistique des activités économiques dans la Communauté européenne', and is the statistical classification of economic activities used by Eurostat. Sector descriptions are those specified in DETE's (2021) report on the ABSEI survey, which uses NACE Rev. 2 classifications (see: https://www.cso.ie/en/qnhs/qnhsmethodology/naceclassificationslist/).

Table B2: Descriptive statistics in full sample and treatment sub-samples

	Full sample	Foreign-owned firms	Domestic firms	R&D grant recipients, foreign	R&D grant recipients, domestic	R&D tax credit recipients, foreign	R&D tax credit recipients, domestic
Variables	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
R&D tax credit (1/0)	0.192 (0.394)	0.184 (0.387)	0.196 (0.397)	0.432 (0.495)	0.443 (0.496)	\	\
R&D grant (1/0)	0.110 (0.313)	0.081 (0.273)	0.105 (0.307)	\	\	0.190 (0.392)	0.239 (0.427)
R&D (log)	7.746 (6.065)	7.682 (7.046)	7.759 (5.760)	14.34 (3.720)	11.22 (3.800)	13.60 (3.455)	12.23 (2.645)
R&D above median (1/0)	0.675 (0.468)	0.729 (0.444)	0.659 (0.473)	0.707 (0.455)	0.589 (0.492)	0.471 (0.499)	0.266 (0.442)
Turnover quartile one (1/0)	0.230 (0.421)	0.226 (0.418)	0.231 (0.421)	0.141 (0.349)	0.282 (0.450)	0.133 (0.339)	0.241 (0.428)
Turnover quartile two (1/0)	0.251 (0.433)	0.251 (0.434)	0.251 (0.433)	0.157 (0.365)	0.220 (0.414)	0.253 (0.434)	0.235 (0.424)
Turnover quartile three (1/0)	0.257 (0.437)	0.261 (0.439)	0.256 (0.436)	0.194 (0.396)	0.251 (0.433)	0.244 (0.430)	0.250 (0.433)
Turnover quartile four (1/0)	0.260 (0.439)	0.260 (0.438)	0.260 (0.439)	0.505 (0.500)	0.245 (0.430)	0.368 (0.482)	0.271 (0.444)
Turnover (log)	8.482 (1.978)	10.20 (1.962)	7.987 (1.687)	11.32 (2.201)	7.778 (1.837)	10.77 (1.924)	8.023 (1.728)
Exports (log)	7.566 (2.540)	9.975 (2.174)	6.800 (2.140)	11.25 (2.274)	6.889 (2.146)	10.62 (2.125)	7.259 (1.999)
Gross Value Added (log)	7.769 (1.831)	9.427 (1.839)	7.290 (1.527)	10.59 (2.172)	7.207 (1.592)	9.945 (1.835)	7.413 (1.521)
Past public R&D funding (1/0)	0.355 (0.478)	0.336 (0.472)	0.362 (0.480)	0.958 (0.198)	0.867 (0.339)	0.872 (0.333)	0.873 (0.332)
Other R&D support (1/0)	0.093 (0.291)	0.079 (0.270)	0.097 (0.297)	0.247 (0.431)	0.291 (0.454)	0.163 (0.369)	0.259 (0.438)
Micro firm size (1/0)	0.174 (0.379)	0.038 (0.175)	0.215 (0.411)	0.004 (0.067)	0.233 (0.423)	0.008 (0.089)	0.198 (0.398)
Small firm size (1/0)	0.479 (0.499)	0.287 (0.452)	0.534 (0.498)	0.121 (0.326)	0.531 (0.499)	0.176 (0.381)	0.533 (0.498)
Medium firm size (1/0)	0.256 (0.436)	0.424 (0.494)	0.206 (0.405)	0.343 (0.475)	0.197 (0.398)	0.456 (0.498)	0.226 (0.418)
Large firm size (1/0)	0.090 (0.286)	0.256 (0.436)	0.042 (0.202)	0.530 (0.499)	0.037 (0.191)	0.358 (0.479)	0.042 (0.200)
Material costs (log)	0.956 (35.65)	0.655 (5.928)	1.043 (40.37)	0.747 (2.620)	1.290 (16.08)	0.622 (1.759)	1.173 (13.54)
Unit labour costs (log)	1.173 (8.710)	0.905 (3.734)	1.249 (9.698)	1.058 (4.377)	1.822 (15.37)	0.907 (3.447)	1.600 (11.64)
Observations	24,404	5,388	18,920	437	2,005	992	3,710

Notes: NACE sectors included but not displayed; for a description see Appendix B1. The acronym SD stands for 'Standard Deviation'.

Appendix C: Lagged dependent variables

Some previous studies which examine the impact of policy-induced R&D/innovation on firm performance also include a one-year-lagged value of the dependent variable as a control variable in their stage two analysis (see e.g. Aerts 2008; Cin et al. 2017; Freel et al. 2019). We do not include such a variable in our analysis for two reasons. Firstly, Allison et al. (2017) argue that including lagged dependent variables in dynamic panel models (using fixed or random effects) is a major source of estimation bias. In this type of model, the constant term represents the combined effect of all time-invariant unobserved variables on the dependent variable. A key assumption underpinning this process is that it is not influenced by the independent variables included in the model. However, Allison et al. (2017) detail that lagged dependent variables (i.e. in time t-1) interact with all unobserved time-invariant factors that impact the dependent variable in time t. Including such a variable therefore, violates a key underpinning assumption necessary for reliable estimation. Secondly, as discussed by Cin et al. (2017), correcting for the bias introduced by including a lagged dependent variable in our type of empirical set-up would require the implementation of a Generalised Method of Moments (GMM) model. Implementing a GMM model requires a minimum of three consecutive observations on each firm in the dataset to generate the instrumental variables necessary for accurate estimation. Although our sample size is large, we are using an unbalanced panel dataset. Therefore, the requirements of the GMM model would reduce our sample size by 37 percent, severely impacting the predictive power and representativeness of our analysis. For these reasons, we chose not to include lagged dependent variables in our stage two estimations. Instead, we include firm and year fixed effects, and a series of time varying control variables which previous studies (e.g. Freel et al. 2019) indicate are associated with firm performance.

Appendix D: Sample representativeness

Table D1: Sample representativeness based on firm characteristics in the IDA Ireland data

	(a) Mean full population	(b) Mean matched sub-sample	Column (a) minus (b)
Funding amount (log)	13.2	13.17	0.03
Number of grants received	1.423	1.501	0.078
Owner location: USA	0.678	0.706	0.028
Owner location: Other	0.322	0.294	-0.028
Region: Dublin	0.375	0.281	-0.094***
Region: Mid-east	0.056	0.061	0.005
Region: Mid-west	0.1	0.107	0.007
Region: Midlands	0.023	0.023	0
Region: North-east	0.015	0.017	0.002
Region: North-west	0.03	0.029	-0.001
Region: South-east	0.065	0.081	0.016
Region: South-west	0.199	0.235	0.036
Region: West	0.133	0.162	0.029
Sector: High-tech manufacturing	0.253	0.305	0.052*
Sector: Medium high-tech manufacturing	0.199	0.247	0.048*
Sector: Medium low-tech manufacturing	0.048	0.061	0.013
Sector: Low-tech manufacturing	0.034	0.04	0.006
Sector: Knowledge intensive services	0.433	0.325	-0.108***
Sector: Less knowledge intensive services	0.03	0.02	-0.01
Observations (2007-2016)	756	376	49.74%

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. The variable 'Owner location: Other' captures all foreign-owned firms where the parent firm was not located in the USA. This aggregation is necessary because the majority of foreign-owned firms' home country is the USA. For the representativeness tests, we classify the IDA Ireland sector variable using Eurostat's six manufacturing and services industry sector aggregations (see: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf). Our rationale for classifying the sector variable in this way is that IDA does not use a standard sectoral classification of their client firms (e.g. NACE). The large group of sectors, and low observation numbers in each sector, means that aggregating the sectors is necessary. Because IDA does not use standard sector classifications, we must aggregate the IDA sectors based on how similar the name of each IDA sector is to those which compose the EU aggregations. Therefore, we cannot assume the companies within each IDA sector fall into each EU sector aggregation as we propose, and we must treat the IDA sector representativeness tests as an approximate estimation. However, this method provides a good estimate of which IDA sectors fit into each EU aggregation, because the majority of the IDA sector names are clearly similar to those used in the EU aggregations. Importantly, this method of aggregation is the only available avenue to this study of estimating whether our sample is (approximately) representative of the full population of IDA client companies on the basis of sector.

Table D2: Sample representativeness based on firm characteristics in the Enterprise Ireland data

Variable	(a) Mean full population	(b) Mean matched sub-sample	Column (a) minus (b)
Funding amount (log)	11.81	11.77	-0.04
Number of grants received	1.47	1.542	0.072**
Region: Border	0.084	0.103	0.019*
Region: Midlands	0.036	0.037	0.001
Region: West	0.081	0.073	-0.008
Region: Dublin	0.449	0.406	-0.043**
Region: Mid-east	0.076	0.087	0.011
Region: Mid-West	0.095	0.105	0.01
Region: South East	0.065	0.063	-0.002
Region: South West	0.116	0.126	0.01
Sector: High-tech manufacturing	0.335	0.288	-0.047***
Sector: Medium high-tech manufacturing	0.157	0.182	0.025*
Sector: Medium low-tech manufacturing	0.055	0.065	0.01
Sector: Low-tech manufacturing	0.08	0.077	-0.003
Sector: Knowledge intensive services	0.352	0.37	0.018
Sector: Less knowledge intensive services	0.021	0.018	-0.003
Observations (2007-2016)	2670	1202	45.02%

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. For the representativeness tests, we classify the Enterprise Ireland (EI) sector variable using Eurostat's six manufacturing and services industry sector aggregations (see: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf). Our rationale for classifying the sector variable in this way is that EI does not use a standard sectoral classification of their client firms (e.g. NACE). Over the period of this analysis (2007-2016), there are 95 individual EI sectors, 32 of which have less than 10 observations. The large group of sectors, and low observation numbers in each sector, means that aggregating the sectors is necessary. Because EI does not use standard sector classifications, we must aggregate the EI sectors based on how similar the name of each EI sector is to those which comprise the EU aggregations. Therefore, we cannot assume the firms within each EI sector fall into each EU sector aggregation as we propose, and we must treat the EI sector representativeness tests as an approximate estimation. However, this method provides a good estimate of which EI sectors fit into each EU aggregation, because the majority of the EI sector names are clearly similar to those used in the EU aggregations. Importantly, this method of aggregation is the only available avenue to this study of estimating whether our sample is (approximately) representative of the full population of EI client companies on the basis of sector.

Table D3: Sample representativeness based on firm characteristics in the Revenue Commissioners R&D tax credit data

	(a) Mean full population	(b) Mean matched sub-sample	Column (b) minus (a)
Region: Border	0.071	0.064	-0.007
Region: West	0.101	0.104	0.003
Region: Mid-west	0.08	0.082	0.002
Region: South-east	0.058	0.057	-0.001
Region: South-west	0.158	0.155	-0.003
Region: Dublin	0.377	0.379	0.002
Region: Mid-east	0.104	0.106	0.002
Region: Midlands	0.046	0.05	0.004
Sector: High-tech manufacturing	0.067	0.082	0.015***
Sector: Medium high-tech manufacturing	0.101	0.115	0.014**
Sector: Medium low-tech manufacturing	0.054	0.059	0.005
Sector: Low-tech manufacturing	0.199	0.208	0.009
Sector: Knowledge intensive services	0.498	0.466	-0.032***
Sector: Less knowledge intensive services	0.078	0.066	-0.012**
Firm size: Micro	0.272	0.187	-0.085***
Firm size: Small	0.386	0.417	0.031***
Firm size: Medium	0.261	0.311	0.05***
Firm size: Large	0.082	0.085	0.003
Age	18.39	20.007	1.617***
Observations (2007-2016)	8,048	4,858	60.36%

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. This table is based on the Irish Revenue Commissioners R&D tax credit data and the Central Statistics Office's Business Demography Database (BDD). All R&D tax credit claim variables come from the Irish Revenue Commissioners. All other variables (i.e. region, sector, size, age) come from the BDD. It is possible to merge the Revenue Commissioners data and the BDD based on a unique firm identifier number present in both datasets (this variable is not present in the IDA Ireland or Enterprise Ireland data, presented in Tables D1 and D2). For the representativeness tests, we classify the sector variable using Eurostat's six manufacturing and services industry sector aggregations (see: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf), based on NACE Rev. 2 sector classifications obtained from the CSO's BDD. It is not possible to use age as a control variable in our main analysis, because this information is only present in the BDD, not the ABSEI survey. We also test for representativeness based on firms' R&D tax credit claim amounts, using 16 claim bands provided by the CSO, which range from €1-€25,000 to greater than €10 million. These tests reveal that our sample is representative across 14 of the 16 claim bands. The only exceptions are that our sample is slightly under-represented in two claim categories: €1 million-€5 million, and greater than €10 million. We do not report the results for these tests here, because they are deemed to be disclosive under the CSO's policy on statistical disclosure control.

Appendix E: Sample frame for Annual Business Survey of Economic Impact (ABSEI)

The *ABSEI Survey Information Booklet* (DBEI 2018) details that the sampling base covers the client base of all the Irish enterprise development agencies, and the population comprises all manufacturing and internationally traded services firms in Ireland. The population covered by the survey is compiled annually from the client base of the development agencies. In terms of sampling strategy, each of the enterprise agencies provides the Department of Enterprise, Trade and Employment (DETE) with a list of clients, who are then included in the survey (DBEI 2018). To ensure that ABSEI is based on an up-to-date population of firms, DETE's Annual Employment Survey (AES), which provides a complete listing of establishments within the remit of each agency, is used as a sample base (DBEI 2018). To ensure that the responding firms are representative of all firms in the AES population, weighting strata are applied, based on ownership, sector, size, and region. This design feature of ABSEI leaves it ideally placed to investigate the impact of R&D support on foreign-owned subsidiaries based in Ireland (DBEI 2018).

Appendix F: Propensity score matching analysis

Table F1 below presents the results from our logit models, estimating firms' propensity to receive a treatment. For ease of interpretation, Table 2 presents the marginal effects from the coefficients in Table F1. In line with previous studies (e.g. Czarnitzki & Lopes-Bento 2013; Hud & Hussinger 2015; González & Pazó 2008), our results demonstrate that higher levels of pre-treatment R&D, and previous public R&D funding have a major influence on whether firms receive R&D tax credits or R&D grants. While these results are common for both types of R&D support and both firm ownership types, Table F1 also reveals several notable differences. Focusing first on foreign-owned firms, it is clear that past turnover plays a key role in determining whether subsidiaries claim R&D tax credits, but has little impact on the likelihood of receiving R&D grants. In contrast, when examining domestic firms, past turnover has no significant impact on the likelihood of claiming R&D tax credits, and a pronounced negative impact on receiving R&D grants. In general, these results concur with those reported by Vanino et al. (2019), who report that past turnover has a limited impact on firms' likelihood of receiving public R&D support. The main exception is the case of R&D tax credits in foreign-owned firms. Here, our results seem to accord with Appelt et al. (2016), who suggest that multinational firms' decisions to use R&D tax credits in a host country may be driven by unique factors, such as reducing their global R&D cost base (relative to the use of R&D grants, and firms that do not have a foreign parent).

Table F1 reveals that receiving other R&D policy supports (i.e. besides R&D grant/tax credit) has a strong positive impact on domestic firms' likelihood of receiving both R&D grants and R&D tax credits. In contrast, other R&D supports have no significant impact on foreign-owned firms' likelihood of receiving either R&D grants or R&D tax credits. This result is in line with those reported by Hewitt-Dundas and Roper (2010) and Busom et al. (2014), which suggest that firms with more limited technological capabilities (likely domestic firms), may need to draw on other forms of public R&D support (i.e. beyond supports such as R&D grants and R&D tax credits). Finally, Table F1 shows that large and medium-sized foreign-owned firms are more likely to receive R&D grants, relative to smaller firms. These results concur with those reported by González and Pazó (2008) and Aristei et al. (2017), who show that the process of allocating grants often favors larger firms.

Overall, Table F1 suggests there are different factors at play when foreign-owned and domestic firms select into using R&D grants and R&D tax credits. The results from Table F1, therefore, support our decision to split the sample, and examine the impact of public R&D funding separately in each ownership type. Tables F3 and F4 below test whether our matching process achieved sufficient balance between treated and untreated firms to perform a robust analysis. The results reported in these tables show that the covariates in matched untreated and treated firms are well balanced.

Table F1: Logit model for firms' probability of receiving public R&D funding

	Foreign-owned firms		Domestic firms	
Variables	R&D grants	R&D tax credit	R&D grants	R&D tax credit
R&D above median	1.070***	0.577***	0.334***	1.570***
	(0.140)	(0.104)	(0.0604)	(0.0536)
Past turnover quartile two	-0.661***	0.558***	-0.200**	0.0687
	(0.256)	(0.171)	(0.0892)	(0.0814)
Past turnover quartile three	-0.601**	0.496***	-0.194**	-0.136
	(0.268)	(0.182)	(0.0965)	(0.0892)
Past turnover quartile four	-0.266	0.464**	-0.275**	-0.186*
	(0.277)	(0.198)	(0.120)	(0.109)
Previous public R&D funding	3.600***	2.911***	2.484***	2.278***
	(0.265)	(0.121)	(0.0800)	(0.0611)
Other R&D support	0.380**	-0.198	0.878***	0.539***
	(0.159)	(0.136)	(0.0649)	(0.0645)
Firm size: Small	1.256*	1.164***	0.0986	0.152*
	(0.760)	(0.421)	(0.0865)	(0.0792)
Firm size: Medium	1.722**	1.063**	0.0189	0.135
	(0.766)	(0.428)	(0.124)	(0.112)
Firm size: Large	1.932**	0.591	0.105	-0.382**
	(0.780)	(0.442)	(0.201)	(0.182)
Constant	-6.613***	-5.579***	-3.731***	-5.116***
	(0.886)	(0.521)	(0.185)	(0.194)
Observations	4,051	4,023	15,756	15,756
Log likelihood	-1535.2	-914.82	-5485.35	-4677.96
R^2	0.3073	0.3154	0.3536	0.2027

Notes: * p < 0.1; ** p < 0.05; *** p < 0.01. Standard errors in parentheses. Dummy variables for year and NACE sector are included in the propensity score estimation, but the output is not displayed here. The base category for firm size is micro; the base category for R&D intensity quartile is zero R&D; the base category for turnover is the lowest turnover quartile.

Table F2: Balance of the control variables after matching, foreign-owned firms

	Treatment: R&D grant (foreign-owned firms)					
	Mean			Bias	t-test	
Variable	Treated	Control		%	t-value	p-value
R&D above median	0.64444	0.63519		2.1	0.32	0.752
Past turnover quartile two	0.13519	0.12222		3.2	0.64	0.525
Past turnover quartile three	0.20926	0.22222		-3	-0.52	0.605
Past turnover quartile four	0.57222	0.57407		-0.4	-0.06	0.951
Previous public R&D funding	0.78889	0.78889		0	0	1
Other R&D support	0.20741	0.20556		0.6	0.08	0.94
Firm size: Small	0.08148	0.08148		0	0	1
Firm size: Medium	0.32407	0.32407		0	0	1
Firm size: Large	0.59074	0.59074		0	0	1
Ps-R2	LR-chi2	p>chi2	MeanBias	MedBias	Rubin's B	Rubin's R
0.001	0.85	1	0.3	0	5.6	1.02
On support	Off support		Not treated		Total	
327	109		4,931		5,367	
	Treatment: R&D tax credit (foreign-owned firms)					
	Mean			Bias	t-test	
Variable	Treated	Control		%	t-value	p-value
R&D above median	0.51397	0.50547		1.9	0.34	0.73
Past turnover quartile two	0.23572	0.2661		-7	-1.42	0.155
Past turnover quartile three	0.26002	0.23572		5.6	1.14	0.254
Past turnover quartile four	0.3949	0.39004		1.1	0.2	0.84
Previous public R&D funding	0.84812	0.84812		0	0	1
Other R&D support	0.15553	0.14095		4.7	0.83	0.405
Firm size: Small	0.14581	0.14581		0	0	1
Firm size: Medium	0.45079	0.45079		0	0	1
Firm size: Large	0.40219	0.40219		0	0	1
Ps-R2	LR-chi2	p>chi2	MeanBias	MedBias	Rubin's B	Rubin's R
0.002	4.14	1	0.7	0	10	1.18
On support	Off support		Not treated		Total	
828	161		4,369		5,358	

Notes: Year and NACE sector variables are included in the analysis but are not presented. Columns 1 and 2 present the mean value of each control variable for firms in the treated and control groups after matching. Column 3 displays the median standard bias across all the covariates after matching. Columns 4 and 5 report the t-tests of mean values between treated and matched untreated firms. The bottom rows present diagnostic tests developed by Leuven and Sianesi (2018), and summary statistics on the matched sample. The Rubin's B score captures the absolute standardised difference of means of a linear index of the propensity score in treated and matched non-treated groups. A Rubin's B score of below the 25 per cent is considered reliable. The Rubin's R score shows the ratio of treated to matched non-treated variances of the propensity score index. If this ratio is within the required range of 0.5 and 2, the samples are considered to be sufficiently balanced. Total observations falls from that reported in Table B2 due to missing values in the R&D expenditure variable.

Table F3: Balance of the control variables after matching, domestic firms

	Treatment: R&D grant (domestic firms)					
	Mean			Bias	t-test	
Variable	Treated	Control		%	t-value	p-value
R&D above median	0.55057	0.55003		0.1	0.03	0.973
Past turnover quartile two	0.22417	0.22198		0.5	0.16	0.874
Past turnover quartile three	0.25424	0.27009		-3.6	-1.09	0.276
Past turnover quartile four	0.24549	0.24604		-0.1	-0.04	0.969
Previous public R&D funding	0.8573	0.8573		0	0	1
Other R&D support	0.25752	0.25697		0.1	0.04	0.97
Firm size: Small	0.55221	0.55221		0	0	1
Firm size: Medium	0.19574	0.19574		0	0	1
Firm size: Large	0.02952	0.02952		0	0	1
Ps-R2	LR-chi2	p>chi2	MeanBias	MedBias	Rubin's B	Rubin's R
0.001	3.13	1	0.2	0	5.8	1.06
On support	Off support		Not treated		Total	
1,820	181		16,828		18,829	

	Treatment: R&D tax credit (domestic firms)					
	Mean			Bias	t-test	
Variable	Treated	Control		%	t-value	p-value
R&D above median	0.7104	0.71009		0.1	0.03	0.978
Past turnover quartile two	0.2435	0.24412		-0.1	-0.06	0.954
Past turnover quartile three	0.25371	0.26083		-1.6	-0.65	0.513
Past turnover quartile four	0.27568	0.26918		1.5	0.59	0.557
Previous public R&D funding	0.86108	0.86108		0	0	1
Other R&D support	0.21535	0.21194		1	0.33	0.739
Firm size: Small	0.56405	0.56405		0	0	1
Firm size: Medium	0.22525	0.22525		0	0	1
Firm size: Large	0.03342	0.03342		0	0	1
Ps-R2	LR-chi2	p>chi2	MeanBias	MedBias	Rubin's B	Rubin's R
0	1.07	1	0.1	0	2.6	1.22
On support	Off support		Not treated		Total	
3,271	415		15,143		18,829	

Notes: Year and NACE sector variables are included in the analysis but are not presented. Columns 1 and 2 present the mean value of each control variable for firms in the treated and control groups after matching. Column 3 displays the median standard bias across all the covariates after matching. Columns 4 and 5 report the t-tests of mean values between treated and matched untreated firms. The bottom rows present diagnostic tests developed by Leuven and Sianesi (2018), and summary statistics on the matched sample. The Rubin's B score captures the absolute standardised difference of means of a linear index of the propensity score in treated and matched non-treated groups. A Rubin's B score of below the 25 per cent is considered reliable. The Rubin's R score shows the ratio of treated to matched non-treated variances of the propensity score index. If this ratio is within the required range of 0.5 and 2, the samples are considered to be sufficiently balanced. Total observations fall from that reported in Table B2 due to missing values in the R&D expenditure variable.

Appendix G: Robustness tests

Table G1: Robustness tests of propensity score matching analysis for the input additionality of R&D supports in foreign-owned and domestic firms

Matching estimator: 1:3 nearest neighbour matching			
Foreign-owned firms			
Treatment	Treated	Matched untreated	Difference (α)
R&D tax credit	0.803	0.108	0.695***
R&D grant	1.818	0.486	1.332***
Domestic firms			
Treatment	Treated	Matched untreated	Difference (α)
R&D tax credit	0.194	0.06	0.134***
R&D grant	0.076	0.038	0.038***

Matching estimator: Kernel density matching			
Foreign-owned firms			
Treatment	Treated	Matched untreated	Difference (α)
R&D tax credit	0.799	0.084	0.715***
R&D grant	1.665	0.396	1.269***
Domestic firms			
Treatment	Treated	Matched untreated	Difference (α)
R&D tax credit	0.194	0.058	0.136***
R&D grant	0.075	0.03	0.045***

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. These robustness tests examine the sensitivity of our analysis using 1:1 nearest neighbour matching (reported in Table 3), to a change of matching estimator. For ease of interpretation, results are expressed in millions of Euros. The α term relates to the average policy-induced R&D from each policy instrument.

Table G2: Robustness tests for the link between policy-induced R&D and firm performance in foreign-owned and domestic firms, based on 3 nearest neighbour matching

	Foreign-owned firms				Domestic firms			
Variable	Turnover (log)	GVA (log)	Exports (log)	Employment (log)	Turnover (log)	GVA (log)	Exports (log)	Employment (log)
Privately-funded R&D	0.00470***	0.00503***	0.00447***	0.00144**	0.124***	0.104***	0.130***	0.0937***
	(0.00155)	(0.00129)	(0.00114)	(0.000686)	(0.0244)	(0.0156)	(0.0203)	(0.0889)
Policy-induced: R&D grant (α)	0.00730**	0.00797***	0.00745***	0.00243*	0.153***	0.122***	0.105***	0.124***
	(0.00328)	(0.00266)	(0.00237)	(0.00143)	(0.0251)	(0.0219)	(0.0282)	(0.0124)
Policy-induced: R&D tax credit (α)	0.00504**	0.00550**	0.00472**	0.00145	0.123***	0.101***	0.153***	0.0879***
	(0.00204)	(0.00232)	(0.00207)	(0.00125)	(0.0254)	(0.0190)	(0.0246)	(0.0108)
Firm size: Small	0.173	0.0538	0.195*	0.346***	0.405***	0.438***	0.374***	0.442***
	(0.184)	(0.114)	(0.102)	(0.0616)	(0.0262)	(0.0232)	(0.0322)	(0.0131)
Firm size: Medium	0.694***	0.497***	0.607***	0.932***	0.813***	0.841***	0.733***	0.873***
	(0.192)	(0.122)	(0.110)	(0.0659)	(0.0374)	(0.0343)	(0.0471)	(0.0195)
Firm size: Large	1.109***	0.876***	1.019***	1.440***	1.211***	1.270***	1.002***	1.340***
	(0.202)	(0.133)	(0.120)	(0.0715)	(0.0768)	(0.0708)	(0.0962)	(0.0404)
Materials	0.218	-0.890***	0.163**	-0.0438	0.0287	-0.774***	0.0608***	0.0199**
	(0.169)	(0.0877)	(0.0806)	(0.0464)	(0.0386)	(0.0383)	(0.0231)	(0.00992)
Unit labour costs	-0.0462***	-0.0549***	-0.0552***	-0.00388**	-0.000451	0.00210**	-0.000297	0.000392
	(0.0137)	(0.00406)	(0.00383)	(0.00187)	(0.000579)	(0.00104)	(0.000943)	(0.000317)
Constant	16.46***	16.39***	16.29***	3.892***	14.50***	14.08***	13.05***	2.714***
	(0.191)	(0.125)	(0.113)	(0.0676)	(0.0327)	(0.0318)	(0.0375)	(0.0152)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,604	3,552	3,441	3,604	14,169	13,865	12,388	14,169
R^2	0.5355	0.4775	0.4475	0.8214	0.5428	0.4689	0.2387	0.7487

Notes: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors in parentheses. The policy-induced R&D variables correspond to the α term defined in Equation (2). This table uses the findings presented in Table G1, which calculates the input additionality from R&D support using 1:3 nearest neighbour matching. The number of observations changes in each model due to missing values in the dependent variables. For ease of interpretation, the variables *Privately-funded R&D*, *Policy-induced: R&D tax credit (α)*, and *Policy-induced: R&D grant (α)* have been scaled by 1 million.

Table G3: Robustness tests for the link between policy-induced R&D and firm performance in foreign-owned and domestic firms, based on kernel density matching

	Foreign-owned firms				Domestic firms			
Variable	Turnover (log)	GVA (log)	Exports (log)	Employment (log)	Turnover (log)	GVA (log)	Exports (log)	Employment (log)
Privately-funded R&D	0.00421***	0.00466***	0.00398***	0.00129**	0.119***	0.101***	0.123***	0.0897***
	(0.000962)	(0.00121)	(0.00107)	(0.000645)	(0.0116)	(0.0154)	(0.0200)	(0.00879)
Policy-induced: R&D grant (α)	0.00734***	0.00874***	0.00750***	0.00253*	0.141***	0.117***	0.0879***	0.114***
	(0.00210)	(0.00263)	(0.00234)	(0.00141)	(0.0158)	(0.0211)	(0.0272)	(0.0120)
Policy-induced: R&D tax credit (α)	0.00434**	0.00454**	0.00401*	0.000114	0.118***	0.0994***	0.147***	0.0830***
	(0.00185)	(0.00230)	(0.00206)	(0.00124)	(0.0140)	(0.0186)	(0.0242)	(0.0106)
Firm size: Small	0.173*	0.0533	0.194*	0.346***	0.405***	0.438***	0.374***	0.442***
	(0.0919)	(0.114)	(0.102)	(0.0616)	(0.0172)	(0.0232)	(0.0322)	(0.0131)
Firm size: Medium	0.693***	0.496***	0.607***	0.932***	0.815***	0.842***	0.735***	0.875***
	(0.0983)	(0.122)	(0.110)	(0.0659)	(0.0256)	(0.0343)	(0.0471)	(0.0195)
Firm size: Large	1.109***	0.876***	1.018***	1.440***	1.212***	1.270***	1.005***	1.341***
	(0.107)	(0.133)	(0.120)	(0.0715)	(0.0531)	(0.0708)	(0.0962)	(0.0404)
Materials	0.217***	-0.890***	0.162**	-0.0440	0.0287**	-0.774***	0.0609***	0.0199**
	(0.0691)	(0.0877)	(0.0805)	(0.0464)	(0.0130)	(0.0383)	(0.0231)	(0.00992)
Unit labour costs	-0.0462***	-0.0550***	-0.0552***	-0.00389**	-0.000455	0.00209**	-0.000305	0.000388
	(0.00278)	(0.00406)	(0.00383)	(0.00187)	(0.000417)	(0.00104)	(0.000943)	(0.000317)
Constant	16.46***	16.40***	16.29***	3.893***	14.50***	14.08***	13.05***	2.714***
	(0.101)	(0.125)	(0.113)	(0.0675)	(0.0200)	(0.0318)	(0.0375)	(0.0152)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,604	3,552	3,441	3,604	14,169	13,865	12,388	14,169
R^2	0.5442	0.4695	0.2374	0.7503	0.5538	0.4763	0.4455	0.8215

Notes: * p < 0.1; ** p < 0.05; *** p < 0.01. Robust standard errors in parentheses. The policy-induced R&D variables correspond to the α term defined in Equation (2). This table uses the findings presented in Table G1, which calculates the input additionality from R&D support using Kernel density matching. The number of observations changes in each model due to missing values in the dependent variables. For ease of interpretation, the variables *Privately-funded R&D*, *Policy-induced: R&D tax credit (α)*, and *Policy-induced: R&D grant (α)* have been scaled by 1 million.

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