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Are Subsidies to Business R&D Effective? Regression Discontinuity Evidence from the TA CR ALFA Programme

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Matěj Bajgar, Martin Srholec

IDEA CERGE EI
PROJEKT NÁRODOHOSPODÁŘSKÉHO ÚSTAVU AKADEMIE VĚD ČR

O AUTORECH | ABOUT THE AUTHORS

Matěj Bajgar

Vystudoval ekonomii na Institutu ekonomických studií Univerzity Karlovy a na University of Oxford, kde v roce 2016 obhájil doktorát. V letech 2015–2020 působil jako ekonom v OECD. Od roku 2021 je výzkumníkem think-tanku IDEA a přednáší na IES UK. Zaměřuje se na ekonomii inovací, odvětvovou ekonomii a mezinárodní obchod.

Matěj studied economics at the Institute of Economic Studies of Charles University and at the University of Oxford, where he defended his doctorate in 2016. Between 2015–2020 he worked as an economist at the OECD. Since 2021, he has been a researcher at the IDEA think tank and a lecturer at the Institute of Economic Studies of Charles University. His research interests include the economics of innovation, industrial organization, and international trade.

Martin Srholec

Doktorské studium absolvoval na Národohospodářské fakultě VŠE a na Centre for Technology, Innovation and Culture při Univerzitě v Oslu. Od roku 2010 působí jako vědecký pracovník na CERGE-EI v Praze. Mezi roky 2011 a 2017 zároveň působil v rámci Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE) v Lundu. S think-tankem IDEA spolupracuje od roku 2013. Zaměřuje se na ekonomii inovací, problematiku inovačních systémů a otázky inovační politiky.

Martin completed his doctoral studies at the Faculty of Economics of the Prague University of Economics and Business and the Centre for Technology, Innovation and Culture at the University of Oslo. Since 2010 he has been a researcher at CERGE-EI in Prague. Between 2011 and 2017 he was also an associate professor at the Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE) in Lund. He has been working with the IDEA think tank since 2013. His research focuses on the economics of innovation, innovation systems, and innovation policy.

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Are Subsidies to Business R&D Effective? Regression Discontinuity Evidence from the TA CR ALFA Programme[1]

MAY 2023

MATĚJ BAJGAR, MARTIN SRHOLEC

Summary

- Governments subsidise business research and experimental development (R&D) to promote development of the economy, because externalities and information asymmetries inherent to the innovation process make private funding of these activities fall short of what is socially desirable. Nevertheless, how effective such subsidies are and whether they achieve their goals is an open question that needs to be studied empirically.
- This study leverages the state-of-the-art method of regression discontinuity (RD) that allows us to come very close to making causal inferences about the effects of subsidies, to find out whether the Technology Agency of the Czech Republic's (TA CR) ALFA programme stimulated new business R&D inputs, outputs, and positive economic impacts that would not have happened otherwise.
- Our results show that the subsidies significantly stimulated R&D expenditures in small and medium size enterprises (SMEs), but not in large ones. In SMEs, the effect is strongly positive on both publicly and privately funded R&D, both during a subsidised project and afterwards, so there is evidence of persistent crowding in. For large firms, in contrast, the subsidy appears to have only changed the structure of R&D expenditure during the project – increasing funding from public sources at the expense of private ones and capital expenditures at the expense of current expenditures – and the effects largely fizzle out after the project expires.

[1] This study represents the authors' own views and not the official position of the Czech Academy of Sciences' Economics Institute nor the Charles University Centre for Economic Research and Graduate Education (CERGE). An earlier draft of this study was presented to TA ČR on 24th May 2022. We would like to thank Dan Münich, Štěpán Jurajda and the staff of TA ČR, in particular Martin Bunček, for their invaluable comments. We also thank the Czech Statistical Office (CZSO) and TA ČR for providing access to their microdata. The authors have undertaken the econometric estimations in this study on the basis of a confidentiality agreement in place during Martin Srholec's work for the CZSO, which was part of a collaboration on the OECD microBeRD project. The study was produced with support from the Czech Academy of Sciences as part of its Center for Research, Development and Innovation Analysis programme (RaDIAC). All remaining omissions and errors are our own.

- When looking at R&D outputs and economic performance, our results do not provide any evidence of significant effects of the subsidies on patenting, employment, sales, or labour productivity of the firms regardless of their size category either during or after a project. However, given the limited size of our sample and the typically small amount of a subsidy relative to the size of the recipient, these subsidies making a recognizable difference in the overall economic performance of their recipients would require an annual rate of return to the additional R&D expenditure generated by the subsidies in the order of hundreds of percent, which is not feasible. Furthermore, it should be pointed out that, using this methodology, we are only able to pin down direct impacts of the subsidies on the economic performance of their recipients, whereas their broader impacts on the economy as a whole through knowledge spillovers – positive externalities that are crucial for justifying the subsidies – remain hidden to us.
- Overall, the results indicate that similar programmes, including the follow-up ALFA programmes, could potentially become more efficient by reallocating funding from large firms to SMEs, for which positive additionality effects on R&D inputs have been identified. It is also noteworthy that some of the most prominent programmes abroad, such as R&D subsidies in the Small Business Innovation Research (SBIR) program in the United States and the Small and Medium Enterprise Instrument (SMEI) of the European Commission, target not only small but specifically young innovative firms (median age 5 years in both programmes), whereas their Czech counterparts support relatively more established firms (median age 19 years in ALFA). Because small and young firms are also more likely to be credit constrained, policymakers should seriously consider shifting the focus of support to these groups of firms.
- Given the universal design of similar programmes, spreading subsidies relatively thinly over many firms, it is extremely hard to test empirically whether they deliver positive impacts on economic performance and on the competitiveness of the economy, on which grounds they are primarily justified. Admittedly, this should be acknowledged ex-ante when funding for these programmes is considered by the government.

PROJEKT NÁRODOHOSPODÁŘSKÉHO ÚSTAVU AKADEMIE VĚD ČR

Studie 7/2023

Jsou dotace na podnikatelský VaV účinné? Závěry z regresní diskontinuity v ALFA programu TA ČR[2]

KVĚTEN 2023

MATĚJ BAJGAR, MARTIN SRHOLEC

Shrnutí

- Vláda dotuje podnikový výzkum a experimentální vývoj (VaV) s cílem podpořit rozvoj ekonomiky. Vlivem externalit a informačních asymetrií, které jsou spjaté s inovačními procesy, je totiž rozsah soukromého financování těchto aktivit nižší než je žádoucí z celospolečenského hlediska. Nicméně je třeba empiricky vyhodnocovat, do jaké míry jsou takové dotace skutečně účinné a jestli se vládě jejich poskytováním daří dosahovat vytyčených cílů.
- Smyslem této studie je využít moderní metodu regresní diskontinuity (RD), která nám umožňuje se hodně přiblížit k určení kauzálních dopadů dotací, pro zjištění, zda program ALFA poskytovaný Technologickou agenturou České republiky (TA ČR) dokázal ve firmách stimulovat dodatečné výdaje na VaV, výsledky VaV anebo ekonomické dopady, ke kterým by jinak nedošlo.
- Výsledky ukazují, že tyto dotace stimulovaly výdaje na VaV malých a středních podniků (MSP), avšak nikoliv těch velkých. V sektoru MSP vychází účinky dotací silně pozitivní pro výdaje na VaV financované z veřejných i soukromých zdrojů během dotovaného projektu i po jeho skončení, což ukazuje na dlouhodobý stimulační efekt. V sektoru velkých firem tyto dotace naopak vedly pouze ke změně struktury výdajů na VaV během dotovaného projektu – ke zvýšení financování z veřejných na úkor soukromých zdrojů a investičních na úkor běžných výdajů – zatímco po jeho skončení tyto změny z velké části vyprchaly.

[2] Tato studie reprezentuje pouze názor autorů, a nikoli oficiální stanovisko Národohospodářského ústavu AV ČR, v. v. i. či Centra pro ekonomický výzkum a doktorské studium UK (CERGE). Předběžná verze studie byla 24. 5. 2022 prezentována TA ČR. Za cenné komentáře a připomínky děkujeme Danielu Münichovi, Štěpánu Jurajdovi a zaměstnancům TA ČR, zejména Martinu Bunčekovi. Za poskytnutí přístupu k mikrodatům děkujeme ČSÚ a TA ČR. Autoři provedli prezentované ekonometrické odhady pod slibem mlčenlivosti během pracovního úvazku Martina Srholce na ČSÚ v rámci spolupráce na řešení projektu OECD microBeRD. Zpracování studie bylo podpořeno dotací Akademie věd České republiky na činnost Centra analýz výzkumu, vývoje a inovací (RaDIAC). Veškeré případné zbývající nepřesnosti a chyby jdou na vrub autorů.

- Co se týče výsledků VaV a ekonomické výkonnosti, prezentované odhady neprokazují významné dopady těchto dotací na vytváření patentů, zaměstnanost, tržby ani produktivitu práce podporovaných firem, a to bez ohledu na jejich velikostní kategorii a načasování během či po skončení projektu. Nicméně vzhledem k omezené velikosti vzorku pozorování a relativně malé výši dotací v poměru k celkové velikosti jejich příjemců, musela by dosahovat roční návratnost dodatečných VaV výdajů, které tyto dotace stimulovaly, v řádku stovek procent, což nelze realisticky očekávat. Zároveň je třeba přiznat, že tímto způsobem měříme pouze přímé dopady dotací na ekonomickou výkonnost jednotlivých příjemců, zatímco jejich širší dopady na ekonomiku jako celek skrze efekt přelévání znalostí – pozitivní externality jsou pro jejich opodstatnění nejdůležitější – nám zůstávají skryty.
- Celkově tato studie naznačuje, že podobné programy, včetně těch navazujících na program ALFA, by mohly zvýšit svoji účinnost přesměrováním podpory od velkých firem do MSP, ve kterých jsme zaznamenali pozitivní účinky na straně VaV vstupů. V této souvislosti stojí za pozornost, že přední programy v zahraničí, jako dotace na VaV v rámci Small Business Innovation Research (SBIR) programu v USA anebo Small and Medium Enterprise Instrument (SMEI) programu Evropské komise, jsou zacíleny nejenom na malé, nýbrž konkrétně na mladé inovativní firmy (mediánový věk 5 let v obou těchto programech), zatímco jejich české protějšky podporují již poměrně zavedené firmy (mediánový věk 19 let v programu ALFA). Jelikož malé a mladé firmy mívají rovněž největší potíže získat financování, tvůrci politik by se měli vážně zamyslet na tím, jestli nepřesměrovat zacílení těchto podpor na tuto skupinu firem i u nás.
- Z důvodu obecného zaměření podobných programů, které rozdrobují podporu po menších částkách mezi relativně velký počet firem, se ukazuje velmi obtížné empiricky zjišťovat, jestli měly zamýšlené dopady na zvýšení výkonnosti firem a konkurenceschopnosti ekonomiky, které jsou prezentovány jako hlavní důvody pro jejich poskytování. Skutečnost, že tyto dopady nemusí být vůbec nikdy měřitelné, je třeba si otevřeně přiznat ex-ante již v době, kdy vláda rozhoduje o financování těchto programů.

Introduction

Governments use public funds to subsidise business research and experimental development (R&D), because externalities and information asymmetries that are inherent to the innovation process make private funding of these activities fall short of what is socially desirable (Arrow 1962, Klette et al. 2000, and Hall 2002). Whether governments do this effectively is an empirical question that has already been extensively examined in academic literature (David et al. 2000; Cunningham et al. 2012, Zúñiga-Vicente et al. 2014, Testa et al. 2019).

However, the vast majority of research on this topic relies on empirical approaches, such as propensity score matching, which infer causality based on problematic assumptions and may entail a strong bias. In the meantime, studies that leverage explicit, quasi-experimental variation to estimate the effects of subsidies to business R&D remain surprisingly rare and, importantly, none of them uses data on firms' R&D activities (see Bronzini and Iachini 2014, Bronzini and Piselli 2016, Howell 2017, Wang et al. 2017, Zhao and Ziedonis 2020 and Santoleri et al. 2022. This is no doubt due to data limitations, yet it could seem that evaluating the effects of R&D subsidies – and testing the underlying assumptions of the RD design – without actual R&D data is like presenting 'Hamlet' without the prince.

In addition, no well-identified study to date has examined the longitudinal structure of subsidy effects or distinguished short-term effects from long-term ones. As argued by Cunningham et al. (2012), however, when it comes to evaluating R&D subsidies, the difference between immediate effects during the treatment versus persistent effects that continue after the treatment expires is crucial for making policy conclusions, because this indicates whether the effects are transient and tend to quickly fizzle out, or whether they result in durable changes in whichever characteristics of the recipients are under consideration.

This study brings fresh evidence of the effects of business R&D subsidies in Czechia, and helps to bridge these gaps in the literature by examining additionality effects of the ALFA programme administered by the Technology Agency of the Czech Republic (TA CR) in years 2011–2018. Exploiting administrative information on the scores assigned to each project proposal by independent evaluators, we apply a regression discontinuity estimator to a longitudinal micro dataset combining information from R&D surveys, patenting data, structural business statistics, business registers, and administrative data. We estimate to what extent participation in the ALFA programme stimulated new R&D activities that would not have occurred without the subsidy. To the best of our knowledge, this is the first time this has been estimated based on quasi-experimental variation worldwide. Additionally, we investigate the effects of the subsidies on R&D outputs and economic performance of firms. Hence, we trace the whole chain of effects that such subsidies have been hypothesized to entail, from R&D all the way to the market.

The effects of R&D grants might be greater for small and medium-sized enterprises (SMEs) than for large firms, for at least three reasons. Firstly, SMEs are more likely to be credit constrained and may find it more difficult to finance their R&D investments in the absence of a subsidy (Hall and Lerner 2010). Secondly, large firms tend to undertake more R&D projects in parallel and, consequently, can more easily identify a project that is likely to succeed in a grant competition among projects that they would undertake in any case, with or without a subsidy. Thirdly, smaller firms can be expected to disproportionately benefit from the "certification" effects of receiving a competitive subsidy (Feldman and Kelley, 2006; Meuleman & De Maeseneire, 2012). Given the theoretical reasons for expecting different results for SMEs and large firms, together with empirical evidence supportive of such differential effects (see, for example, González and Pazó 2008, Bronzini and Iachini 2014 and Romero-Jordán et al. 2014), we conduct all analyses separately for SMEs (defined as firms with <250 employees) and for large firms.

Our results show that the subsidies significantly stimulated R&D expenditures in small and medium size enterprises (SMEs), but not in large ones. In the SMEs, the effect is strongly positive both on publicly and privately funded R&D, and both during a subsidised project and afterwards; thus, there is strong support for persistent crowding in. In the large firms, the subsidy appears to have changed only the structure of R&D expenditure during a project, by increasing funding from public sources at the expense of private sources, and by increasing capital expenditure at the expense of current expenditure. The results thus suggest crowding-out effects in large firms in the short term, and largely insignificant effects after the project expires. When looking at the outputs of innovation and economic outcomes, however, we do not find any evidence of positive effects of the subsidies on patenting, employment, sales, or labour productivity, regardless of subsidy size, either during or after the project.

The prime reason, up to now, why no study has been able to apply the RD design to estimate the effects of subsidies on R&D inputs is probably that the requisite administrative microdata from the evaluation of project proposals, such as project scores or rankings, is not only difficult to obtain from funding providers, but is also difficult to merge with information from R&D surveys. This is because R&D surveys are typically collected by national statistical offices and are only available for research purposes at the firm level in an anonymized form, making it difficult to merge them with other sources. We have been able to overcome these challenges thanks to research cooperation with the Czech Statistical Office in the framework of the OECD microBeRD project (OECD, 2020), which allowed us to merge the official R&D microdata with project data from TA CR.

In the Czech Republic, econometric estimates of the impact of R&D subsidies on business enterprises remain scant in general, despite repeated calls for systematic assessment of their impact based on principles of what has been dubbed "counterfactual evaluation" in the evaluation community (Arnold and Mahieu, 2011, Office of the Government of the Czech Republic, 2015, Srholec, 2015, and Horák, 2016). Previous studies have been limited to using matching estimators to infer causality based on observables without information on R&D activities (Sidorkin and Srholec, 2017, 2021; TA CR, 2019; Ratinger et al.; 2020). The only exception is an analysis by Palguta and Srholec (2016), a pilot attempt to use the RD design to examine input additionality of R&D subsidies that have been awarded in only one out of four calls of the ALFA programme. This paper follows up with significantly more complete and extensive examination. Hence, for the first time in the Czech context, this line of work brings much-needed evidence on the effectiveness of business R&D subsidies based on a research design that allows for relatively reliable causal interpretation of the estimated effects.

The ALFA programme

In the Czech Republic, direct support for R&D in business enterprises through subsidies awarded on a competitive basis has traditionally been a prominent tool of innovation policy. Direct R&D subsidies have been provided by a variety of programmes since the early 1990s, including ALFA, which is the focal point of this study. A system of indirect support for R&D in the form of tax deductions was introduced in 2005 and gradually grew in volume, but never accounted for more than half of the total support for business R&D (CZSO, 2022).

The ALFA programme was administered by the Technology Agency of the Czech Republic (TA CR) and provided funding to projects during the period 2011–2018. The TA CR was established in 2009 with the aim to consolidate funding for applied research and innovation, and ALFA was its first flagship programme. In total, ALFA provided funding of 9.3 billion CZK (approximately 340 million EUR) financed exclusively from the national budget, which makes it the second largest programme of this kind to date. Other similar major programmes include IMPULS (2004–2010), TIP (2009–2017) and TRIO (2016–2022), administered by the Ministry of Industry and Trade of the Czech Republic, and EPSILON (2015–2026) and TREND (2020–2027), which superseded ALFA at the TA CR (Office of the Government of the Czech Republic, 2022).

ALFA was organized in four annual calls for proposals that took place in 2010, 2011, 2012, and 2013. The calls are dated by the year in which the call was announced, which is denoted as base year “t” in this paper. The calls were announced and proposals evaluated during the same year, and funding was provided from January of the following year. One exception to this was the last call, in which the funding started from July, rather than January, of the year following the year of the announcement. The primary target group was business enterprises, but research organizations were also eligible for funding. The programme allowed for proposals from both individual entities and consortia of several partners. The participation of research organizations in consortia was rewarded by extra points in the evaluation in order to promote public-private collaboration. A typical proposal, therefore, consisted of a consortium headed by a firm, with a research organization and possibly other firms as partners.

The main objectives of ALFA were defined quite broadly: to boost performance of business enterprises, to increase competitiveness in the economy and the society, and to enhance the standard of living (TA CR, 2010, 2022). The programme was divided into three sub-programmes focused respectively on: 1) advanced technologies, materials and systems; 2) energy resources and environmental protection; and 3) sustainable development of transport. The latter two subprogrammes were focused on relatively specific topics and, crucially for us, proved to be unsuitable for RD analysis due to the small number of projects that met binary criteria for being eligible to receive support and that received evaluator scores reasonably close to the cutoff, but ended up not being supported.[3] In contrast, the first subprogramme was designed more broadly and ultimately accounted for a majority of the total projects submitted, and a majority of the total funding .[4] For these reasons, we focus on Subprogramme 1, and henceforth all discussion and results refer to that subprogramme only.

Given the rules of the European Commissions, a proposed project budget could be a maximum of 3 million EUR. Fundable R&D expenses covered the whole spectrum of costs, including personnel, material and travel costs, purchases of services, and tangible and intangible investments, except in the last call, in which investment was not eligible. The projects had to commit to produce at least one applied research output as defined at the time of the call announcement by the Office of the Government of the Czech Republic (2022). This could be, for example, a patent, utility model, prototype, pilot plant, verified technology, or software. The subsidy covered eligible costs of the proposed project up to a maximum of 45–80% in small enterprises, 35–75% in medium enterprises and 25–65% in large enterprises, depending on the call, the type of research, and collaboration with a research organization. The average subsidy size was 3.4 million CZK (approx. 130,000 EUR) for SMEs and 3.7 million CZK (approx. 150,000 EUR) for large business enterprises. For comparison, the average and the median R&D expenditure of firms that received subsidies were, respectively, 24.2 and 12.4 million CZK for SMEs and 81.3 and 26.7 million CZK for large firms, and the average and median sales of subsidised firms were 217 and 136 million CZK for SMEs and 3.453 and 1.462 million CZK for large firms. Hence, the subsidies were relatively small.

[3] In call 2 of Subprogramme 2 and calls 2 and 4 of Subprogramme 3, there were no projects at all that met the binary criteria but that ended up below the cutoff score for receiving funding. The number of such projects that were additionally within the bandwidth of 5 points around the score cutoff was also very low for call 1 of Subprogramme 2 (2 projects), and call 1 (9 projects), and call 3 (10 projects) of Subprogramme 3.

[4] *Over the 4 calls,* Subprogramme 1 accounted for 55% of submitted project proposals, 44% of funded projects, and 51% of the disbursed funding.

The proposals were evaluated by an expert panel with the help of external reviewers. Each project was assessed by two (calls 1 and 2) or three (calls 3 and 4) external reviewers and one rapporteur from the panel. In the first step, several binary criteria, such as whether the project was within the scope of the programme, were used to eliminate ineligible proposals. In the second step, the evaluators awarded points to each project (0 to 100 in total) based on seven-scale criteria for: i) the research team; ii) expected impacts; iii) market opportunities; iv) collaboration with a research organization; v) topicality and motivation effect; vi) economic efficiency; and vii) the consortium. The projects were then ranked according to the average number of points (score) across the three or four evaluators.

The final decision on whether a proposal was recommended for funding was made by the Board of the Programme and ultimately the Board of TA CR, which had the power to adjust the points, and hence the ranking, for well-founded reasons. However, in practice, the Board of TA CR exercised this power only rarely, for instance, when inconsistencies in a project budget were exposed ex-post. Even in such cases, it almost never happened that a change in the ranking would affect which proposals were actually funded or not. Whether a proposal that met the binary criteria was awarded a grant depended on the amount of funding in a given call.[5] The preliminary budgets were known ex-ante, except for call 3, where the funding was unexpectedly increased during the evaluation period. In the other three calls, the bodies involved in the selection procedures had a rough idea of where the cutoff was likely to appear, which raises concerns about possible manipulation of rankings around the cutoff. Because of these concerns, we test the validity of our research design later in the paper using a battery of tests standard in the RD literature.

Table 1 provides an overview of the number of projects in each annual call. In total, 424 proposed projects were subsidised and 1,451 were not. This means that slightly fewer than one in four proposals was funded. The number of proposals increased between calls 1 and 2 and even more between calls 2 and 3, while the number of subsidised projects remained roughly the same; hence, the competition significantly intensified and the success rate dropped in the second half of the programme. The share of proposals

[5] Note that various adjustments were made in the evaluation procedures over the course of the programme implementation, especially between calls 1 and 2 and calls 3 and 4. These adjustments, however, did not affect the comparability of the evaluation points across calls. Details of the adjustments are available upon request from the authors.

that were eliminated based on the binary criteria declined over time from 48% in the 1st call to 27% in the 4th call, leaving a greater role for evaluator scores. Consequently, the cutoff for funding rose steadily from 71 to 77, 83 and 85 evaluation points in the consecutive calls. The number of proposals within our baseline bandwith of 5 points around the cutoff increased even more than the total number of proposals in subsequent calls, because the distribution of the proposals is skewed toward higher scores.[6]

By the duration of a supported project, which is denoted by *d* in this paper, we mean the number of years from the first to the last calendar year in which at least one of the project participants received public support; in the estimation, this defines the years "during the project" and "after the project".[7] According to the programme rules, the minimum duration oscillated between 1 to 2 years and the maximum duration gradually decreased with the approaching end of the programme from 6, 5, 4, to 3.5 years in the consecutive calls. In practice, however, the projects typically spanned 3 or 4 years. In fact, of the total 424 subsidised projects, only 14 concluded within the first 2 years and 18 lasted 5 or 6 years. The vast majority of projects lasted for either 3 (157 projects) or 4 years (235 projects).

[6] 9 projects in call 1, 40 projects in call 2, 6 projects in call 3, and 19 projects in call 4 were recommended for funding and ranked above the cutoff, but eventually did not take place because the potential recipients did not sign the funding contract due to unanticipated events such as a break-up of the consortium, loss of key personnel, unfavourable market conditions, or because the potential recipients violated the contract; these projects were eliminated from our analysis and hence are not included in the figures presented here.

[7] Note that the administrative duration of the project could be longer, because some projects included additional years without drawing public funding as a formal extension for the purpose of reporting projects outputs that take longer to deliver, such as obtaining a granted patent.

Table 1. Number of project proposals by calls

Call Year	Call 1 2010	Call 2 2011	Call 3 2012	Call 4 2013	Total
Total					
Supported	114	107	101	102	424
Unsupported	211	297	496	447	1451
Binary criteria affirmatory					
Supported	114	107	101	102	424
Unsupported	54	113	278	297	742
Bandwith of 5 points around cutoff					
Supported	17	49	75	84	225
Unsupported	29	51	118	113	311

Source: Based on micro data from ISVaV (2022) and TACR (2017).

Data

Our analysis is based on a large micro dataset of participants in the ALFA programme proposals. The database combines detailed data on the proposals with rich information on R&D activities, patenting, public support for R&D, economic and financial variables, and structural characteristics of the participating firms. The data was obtained from the following sources:

1. MicroBeRD+ database CZE – statistical database compiled from R&D surveys, patent data, R&D tax credits records, structural business statistics, and the business register under the OECD project MicroBeRD+ at the Czech Statistical Office (CZSO, 2022).
2. The Research, Development and Innovation Information System of the Czech Republic (ISVaV) – complete administrative data on projects supported by programmes of direct public funding for R&D from the national budget (Office of the Government of the Czech Republic, 2022).

3. TA CR internal information system – ALFA programme data on evaluation points and ranking of proposals, information on whether a proposal was recommended for funding, whether a proposal was supported, and the composition of a proposal consortium (TA CR, 2017).[8]

The datasets were merged at the micro level using the unique taxpayer identification number (IČO), which is standardized at the national level and allows unequivocal identification of each organization. The database provides longitudinal panel data over the period 2007–2021, which allows us to look back three years before the first call of the programme (t-2) was announced and forward three years after the end of funding of projects in the last call (d+3).

In addition to business enterprises, as noted above, the ALFA programme subsidised research organizations as members of project consortia, including universities, as well as various state-owned and/or state-funded organizations, and in a few cases, individuals. However, the question of the subsidies' additionality effects is most relevant to profit-oriented private businesses that operate in competitive markets and face hard credit constraints. Hence, we exclude from the sample:

1. Higher education institutions and research organizations that conduct primarily non-business activities, according to the lists by MSMT (2016) and RVVI (2016).
2. Public non-financial corporations, according to the classification by Institutional Sectors and Subsectors (CISS) in the business register of the CZSO (2022).
3. Other organizations with out-of-scope legal forms, according to the business register of the CZSO (2022), such as state-funded institutions, state enterprises, associations, sole proprietors, and others.

The resulting estimation sample includes 449 business enterprises with the following legal forms:

1. Private limited company.
2. Limited partnership.
3. Joint-stock company.
4. Cooperative.

[8] Since approximately 2013 (the timing varies slightly depending on programme), the TA CR has been publishing rankings of funded and non-funded project proposals on its website. For the present research, the TA CR also provided other related administrative data, in particular, the exact score received by each project (only rankings are published).

The database provides a broad range of dependent variables that are relevant for testing the additionality effects, which fits well with the fact that the ALFA programme not only provided subsidies for business R&D, but also mandated the recipients to produce specific R&D outputs for the project to be deemed successfully completed, including patents as one output. As noted earlier, at the general level, the programme was justified by increasing competitiveness, and thereby, probably increasing growth and productivity. We therefore consider effects of the treatment on the following:

1. R&D inputs – R&D expenditures, not only total, but also by the source of funding (private vs. public) and the type of R&D costs (current vs. capital).
2. R&D outputs – patent applications filed in the Industrial Property Office of the Czech Republic.
3. Economic performance – employment (full-time equivalent), sales and labour productivity (value added per employee).

In addition, we use a number of other variables as covariates and to test the underlying assumptions of the RD design, including time since incorporation, whether the firm is foreign-owned, incorporated as a stockholding company, classified in the manufacturing sector, and located in the capital city of Prague, and proposal-level characteristics with regards to the number of partners in the consortium and whether the consortium included a research organization. For more detailed definitions of the variables, see Appendix Table A1.

Throughout the analysis we make a distinction between small and medium size enterprises (SMEs) versus large firms, defined as firms with 250 or fewer employees versus firms with more employees in the pre-treatment year (t). First, this is because the maximum subsidy of 3 million EUR is relatively small and with data at the firm-level it is difficult to trace the impact of the subsidy in large firms, with typically much larger overall cash flows. Admittedly, for large firms, receiving such a subsidy often amounts to a mere accounting operation with little to no impact on actual allocation of resources. Without more fine-grained data for sub-units, which is not available to us, the estimates we present could prove to be rather imprecise for large firms. Second, existing studies on additional effects of R&D subsidies, as we review in the introduction, confirm that there are noteworthy differences between SMEs and large firms. For the sake of transparency, we report results for both groups of firms, but the estimated coefficients for large firms should be interpreted with caution.

In total, there is a panel of 7,293 observations, of which nearly three-fourths are SMEs. A closer look at the data confirms that SMEs are significantly different from their large counterparts not only in size, but also in many other structural characteristics, including the likelihood of foreign ownership and operating in the manufacturing sector. However, there do not seem to be significant differences between SMEs and large firms in terms of their time since incorporation, labour productivity, and, interestingly, in their access to public funding for R&D. The average number of proposed project participants is three, and almost all proposals include a research organization. For detailed descriptive statistics of the complete dataset, see Appendix Table A2.

Because the characteristics of proposals are derived from administrative data, they are available for all observations and indicate the maximum size of the sample at our disposal. The drop-out rate due to missing data for other variables ranges between 14 to 18% in SMEs and 7 to 9% in large firms, which is arguably very small for this type of study. It is also noteworthy that the drop-out does not differ significantly above and below the cutoff. The size of effective samples for estimation is lower, because data for all variables included in the estimate need to be available at once, but in none of the estimates presented below does the drop-out rate reach a level which could be expected to entail a significant bias.

Methodology

Estimation strategy

To identify the causal effects of the subsidies, we exploit the fact that the project proposals submitted are evaluated and ranked by independent referees, but the final decision on which will be funded, i.e., where the line is drawn, depends on available funds, which are not known at the time the evaluation and ranking takes place. Intuitively, we can expect firms just above or just below the threshold evaluation points to be very similar, except for the fact that the former group received a grant and the latter did not. If that is the case, subsequent differences in performance between the two groups can be interpreted as effects of the grants.

To formalize this intuition, we adopt the RD approach first proposed by Thistlethwaite & Campbell (1960). It assumes that assignment of treatment conditional on the running variable – in our case, the score assigned to a project – around the threshold is approximately random. We estimate the following stacked RD regression:

$$Y_{iptc} = \beta T_p + \gamma_-(1 - T_p)X_p + \gamma_+ T_p X_p + \sum_{j=1}^{J} \delta_j Z_{ipt_0c}^{j} + \theta_c + \theta_t + \varepsilon_{ipt}.$$

Y_{iptc} is the outcome in year t for firm i participating in project p submitted to call c. Our primary outcome of interest is the firm's total R&D expenditure, but we also consider additional outcomes: privately-funded R&D expenditure, publicly-funded R&D expenditure (in total and individual components: domestic direct funding, EU direct funding, R&D tax relief), current R&D expenditure, capital R&D expenditure, a dummy for having filed a patent, and employment, sales, and labour productivity. With the exception of the patenting dummy, all outcome variables are included as natural logarithms.[9]

T_p is a dummy variable marking whether project p received an ALFA grant, and X_p is the running variable, given by each project's average score (number of points) across 3 or 4 evaluators. We normalise the score so that it equals zero at the threshold, i.e., projects with a zero or a positive score were funded, and projects with a negative score were not.[10] Use of higher degree polynomials in the running variable has been shown to lead to noisy estimates, to results that are highly sensitive to the degree of the polynomial, and to poor coverage of confidence intervals, frequently offering empirical support for evidently nonsensical results (Gelman & Imbens, 2019). For this reason, we use a linear polynomial in our running variable and test the robustness of the results to using a quadratic polynomial instead. As is standard in RD analysis, we use local polynomials that are independently estimated on each side of the threshold (Lee & Lemieux, 2010).

Consistent identification of causal effects in RD designs generally does not require, and is not helped by, inclusion of additional controls in regressions. Controlling for additional predetermined covariates can, however, increase the precision of estimates (Calonico

[9] The individual components of the total R&D expenditure by the source of funding and the type of costs are equal to zero for many firms. For this reason, we calculate the logarithm for R&D variables other than the total R&D expenditure as $log\ (K(x) + x)$, where x is a given component of R&D expenditure and $K(x)$ is constant specific to variable x. Chen & Roth (2023) show that estimation results with this widely-used transformation are not scale-invariant (i.e., they depend on the value of $K(x)$) and the transformation affects the relative weight of the extensive margin (e.g., firms with strictly positive expenditures on R&D-related buildings and machinery) and the intensive margin (the size of the expenditure) in the regressions. We take one of the approaches suggested by Chen & Roth to tackle this issue, which is to establish an explicit trade-off between the extensive and intensive margins. Specifically, we set $K(x)$ to the 5th percentile among all non-zero values of x as observed in 2010 (the year before the start of projects in the 1st call of the ALFA programme). This implies that going from zero expenditure to expenditure on the 5th percentile (among strictly positive values) increases the logarithmised value by 1, and is, thus, considered in the estimation as equivalent to an intensive-margin change of $log(2) \cong 70\%$.

[10] 4 projects in calls 1 and 2 received exactly the same threshold scores, but were not funded. To match the stated interpretation of the normalized score, we subtract 0.01 point from the normalized score from these 4 projects. Dropping these 4 projects, or dropping all projects, both funded and unfunded with scores exactly at the threshold in calls 1 and 2, has no material effects on the results (results available from the authors upon request).

et al., 2019).[11] For this reason, we include a set of controls $Z^{j}_{ipt_0c}$ in our baseline specification. All controls are measured in the pre-treatment year t_0, defined as the year in which the project was submitted and evaluated, or, equivalently, as the year before the year in which the project was to start, provided it won a grant. Firstly, they include pre-treatment values of all the outcome variables we examine, as listed above. This allows us to keep the list of controls fixed across various outcomes while ensuring that we always control for the pre-treatment value of a given outcome. In addition, the controls include demographic characteristics describing firms' age, legal form, sector, and location, and the project-level characteristics. Finally, we control for year dummies θ_t and call dummies θ_c.

The assumption that projects above and below the threshold are similar, conditional on their score, is unlikely to hold for projects further away from the threshold. Therefore, we restrict the analysis to projects with scores that lie within bandwidth h around the threshold. For the total R&D expenditures, our main outcome of interest, the mean square error (MSE) optimal bandwidth selection procedure with covariates by Calonico et al. (2019) suggests a bandwidth of 5.8 points for SMEs and 3.7 for large firms. To make the bandwidth consistent across firm-size samples and across outcomes, we use a fixed bandwidth of 5 points in our baseline specification. We estimate the equation above using weighted least squares, with weights given by a kernel function $K(X_p/h)$.[12] As a baseline, we use a triangular kernel function, which assigns a linearly smaller weight to observations further away from the threshold. We test the robustness of the results to using alternative bandwidth values and kernel functions. We report bias-corrected RD estimates and robust standard errors clustered at the firm level (Calonico et al., 2019).[13]

Validity tests

The identification in our RD design rests on the assumption that scores were not manipulated around the cutoff. Such manipulation by the evaluators was made unlikely by the fact that the score received by each project was an average of points awarded independently by three or four evaluators, and that the exact location of the cutoff was not known at the time the points were assigned. That said, the Board of the Programme and the Board of TA CR, in principle, had the right to adjust the number of points allocated

[11] For similar reasons, researchers often include pre-treatment covariates when analysing randomised experiments.

[12] The estimation is performed in Stata using command rdrobust (Calonico et al., 2014, 2017).

[13] To estimate the bias of the regression function estimator, we use a second order polynomial and bandwidth $b = 10$, which is close to the MSE-optimal bias bandwidth of 10.6 for SMEs and 7.1 for large firms. We test the robustness of the results to this choice.

to a project. However, based on our conversations with TA CR representatives, in practice, they did so very rarely, and even in those cases the change typically did not affect which projects were ultimately funded.

We test the validity of the identifying assumptions in two ways. Firstly, in Figure A1 in the appendix, we show the results of running a McCrary (2008) test, which compares the density of the distribution of project scores below and above the cutoff. We see no significant discontinuity in density at the cutoff in calls 1, 3, and 4. In contrast, we observe a substantial and statistically significant discontinuity in the case of call 2. To avoid the risk that the scores were indeed manipulated around the cutoff in call 2 and that this would bias our results, we exclude call 2 from all subsequent analyses. In Figure A2, we subsequently show the results of the McCrary test that we obtain when we combine all projects in calls explored in the analysis, i.e., calls 1, 3, and 4. The figure shows no evidence of discontinuity in the density around the cut-off for these projects.

If the assignment of treatment conditional on the score received by a project around the cut-off is approximately random, we should not observe any differences between the treated and control observations around the cut-off. To see if this is the case, we conduct placebo tests in which we estimate a version of our estimating equation with outcomes given by various firm and project characteristics observed in the 4 years before the start of the project (years t-3 to t). As in the analysis of post-treatment effects below, we conduct the estimation separately for SMEs and large firms. We report the results in Appendix Table A3. In total, over 19 outcomes and 2 firm size classes, we estimate 38 placebo tests. The definition of significance levels means that, in the absence of any pre-treatment differences around the cut-off, on average, 3.8 tests should be significant at the 10% level and 1.9 tests at the 5% level out of pure luck. This is exactly what we see, with 4 of the 38 tests proving to be significant at the 10% level, 2 at the 5% level, and 0 at the 1% level. In other words, we see no evidence of differences in pre-treatment characteristics of firms below and above the cut-off.

In summary, after excluding call 2, we see no evidence of score manipulation based on the McCrary (2008) test, and no evidence of differences in pre-treatment characteristics around the cut-off. These two facts together make us reasonably confident that any differences in post-treatment firm outcomes, as presented in the next section, have a causal interpretation.

Results

In this section, we present the results of the RD estimates of the additionality effects of the programme. The results are presented separately both for SMEs and large firms, and for the period during (d) and after the subsidy (d+3), or by individual years relative to the period before the subsidy (t), which allows us to analyse the longitudinal structure of the estimated effects.[14] First, we show the results for innovation input additionality in terms of R&D expenditures, and then we examine results for innovation output additionality in terms of patenting and estimated impacts on economic performance.

Innovation input additionality

Table 2 shows the results for R&D expenditures. The main outcome is that the subsidies significantly stimulated R&D expenditures in SMEs, and that this positive effect is not limited to the period in which the subsidy was received, but in fact seems to accelerate in the period after the subsidy expired, which signals both strong and persistent crowding-in effects. In contrast, there is no evidence that the subsidies stimulated R&D expenditures in large firms either during the project or afterwards, as the coefficient proves to be actually negative, albeit it is imprecisely estimated.

A more detailed look by the source of R&D funding shows that, for SMEs, the crowding-in effect is strongly positive and increasing in time, not only for R&D funded from public sources, especially national funds that include support from the ALFA programme itself, but are actually even more positive and increasing in time for privately funded R&D. Hence, the subsidies seem to stimulate SMEs to devote more resources to R&D, either from their own pockets, or they enable the firms to acquire private funding from elsewhere that they would not otherwise have acquired. In large firms, though, the subsidies only seem to increase public R&D funding at the expense of the private funding for the duration of a project. There is even some support for crowding out of private sources. The results are largely inconclusive after the project expires.

[14] For the projects that were funded, the project duration is given by the years in which the projects received funding from the ALFA programme. For projects that did not receive a grant, we set the duration to 4 years, which is the duration of a majority of funded projects.

Table 2. RD estimates for R&D expenditure (logs)

	SMEs						Large firms					
	During the treatment			After the treatment			During the treatment			After the treatment		
	Coef.	St. err.	N	Coef.	St. err.	N	Coef.	St. err.	N	Coef.	St. err.	N
Total												
R&D expenditure	0.48***	0.17	765	0.73***	0.27	526	-0.16	0.14	376	-0.08	0.35	290
Source of R&D funding												
Private	0.75***	0.26	765	0.96**	0.41	526	-0.33**	0.15	376	-0.10	0.31	290
Public	0.35*	0.19	765	0.51	0.36	526	0.53***	0.18	376	-0.26	0.46	290
o/w national funds direct	0.61***	0.2	765	0.74**	0.35	526	0.86***	0.24	376	-1.08	0.66	290
EU funds direct	-0.23	0.26	765	-0.35	0.36	526	-0.24	0.16	376	-0.42*	0.22	290
tax incentive	-0.25	0.38	765	-0.27	0.49	526	0.12	0.43	376	0.46	0.7	290
Type of R&D costs												
Current	0.31***	0.11	765	0.54**	0.21	526	-0.31**	0.12	376	-0.04	0.28	290
Capital	0.00	0.24	765	-0.11	0.27	526	1.36***	0.42	376	-0.80*	0.42	290

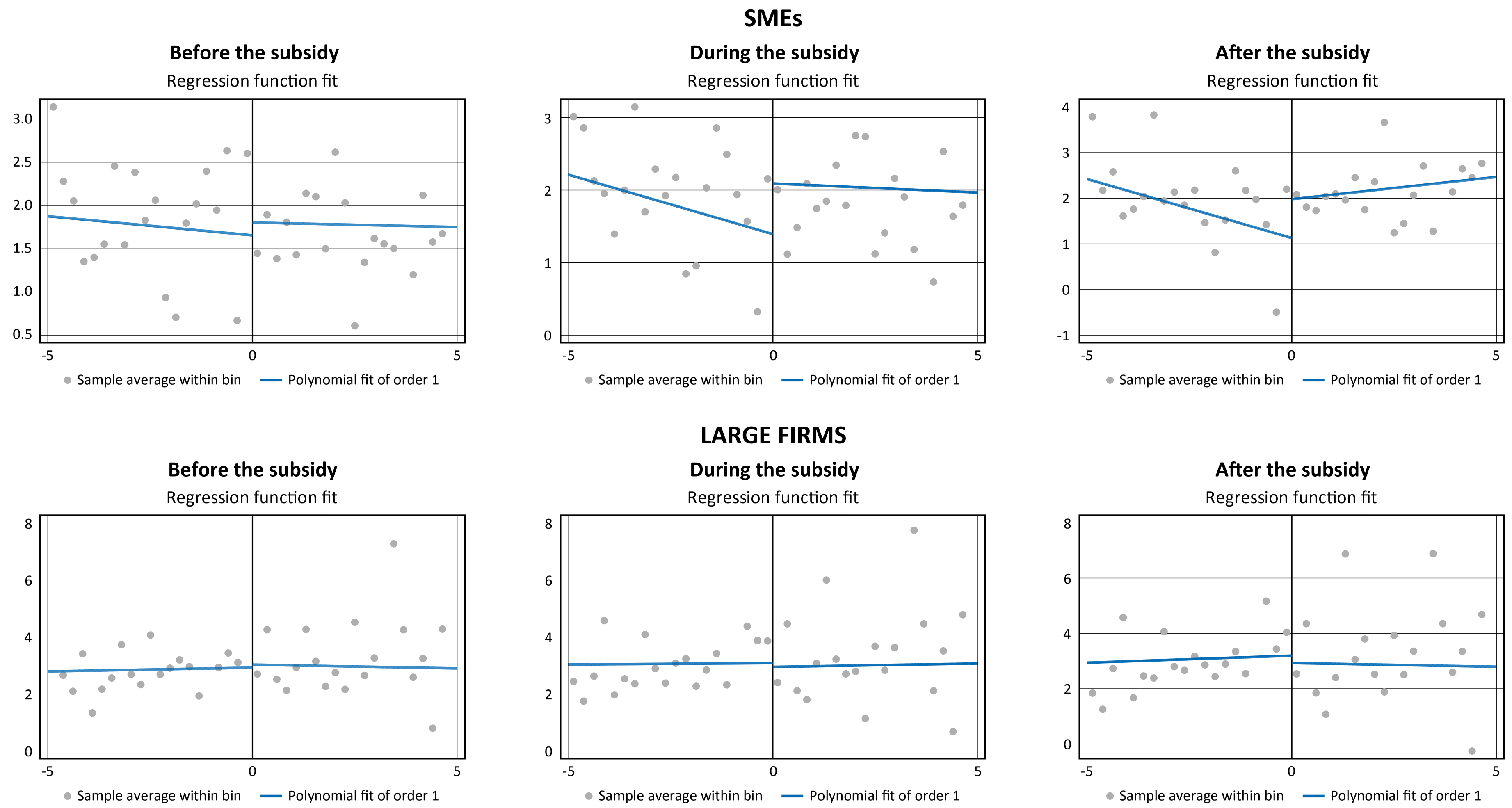
*Note: RD estimates for a bandwith of 5 points around the cutoff. Columns 2–7 report results for SMEs and Columns 8–13 for large firms. The effects are estimated during (d) and after (d+3) the period of receiving a subsidy, where d varies by project. All estimates include the pre-treatment logs of total R&D, R&D components by the source of funding and the type of expenditures, a patenting dummy, logs of employment, sales and labour productivity, age, dummies for foreign ownership, shockholding, Prague location, and co-operation with a research organisation, the number of project participants, and year and call fixed effects as controls. Standard errors are clustered at the firm level. N is the number of observations. * p<0.1, ** p<0.05, *** p<0.01.*

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TACR (2017).

As far as the type of R&D costs is concerned, the results indicate another major difference by the size categories of firms. While in SMEs, the subsidies stimulate current R&D expenditures, such as personnel, material, and energy costs, large firms tend to use the additional resources to cover capital R&D expenditures. In fact, our estimates indicate that the primary consequence of a subsidy in large firms is that the firms temporarily redirect their R&D funds between the categories by increasing the capital element, but cutting the current one, which they counterbalance after the subsidy expires, because perhaps they primarily use the projects as an opportunity to saturate their R&D capital needs.

Figure 1 demonstrates the discontinuity graphically with the help of RD plots. The graphs depict the (log of) privately funded R&D expenditures of successful applicants in comparison with unsuccessful ones around the cut-off in the pre-subsidy, subsidy, and post-subsidy periods. The cut-off is delineated by zero on the horizontal axis and the fitted lines that facilitate the comparison are estimated by linear repressions separately above and below the cut-off. The graphs confirm a noticeably positive discontinuity for SMEs (upper panel) after receiving a subsidy, while there was little difference beforehand. But in large firms (lower panel), if anything, the discontinuity is negative, as if the subsidy did not happen.

Figure 1: RD plots for privately funded R&D expenditure (logs)

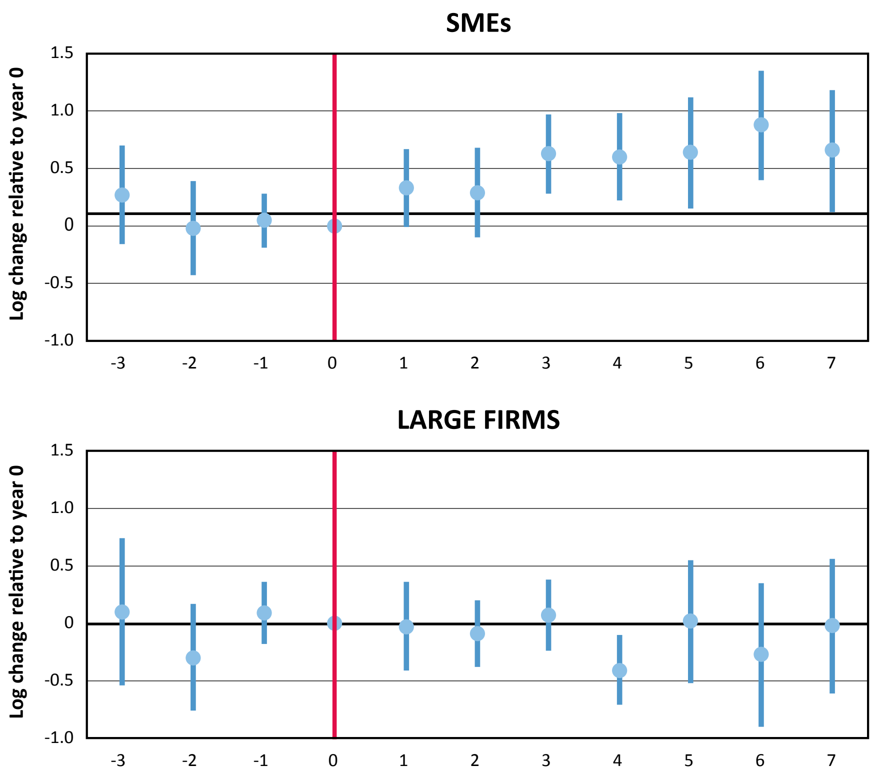


Note: The RD plots depict firms in a bandwith of 5 points around the cut-off. The upper panel is for SMEs and the lower panel shows large firms. The left plot refers to the period before (d-3), the central plot during (d), and the right plot after a subsidy (d+3). The dots represent points-level means of the outcome using 20 bins. The fitted lines are derived from local linear regressions with year and call fixed effects (all panels) and additional pre-treatment firm and project characteristics (middle and right panels) included as controls.

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TACR (2017).

Figure 2 complements the analysis by depicting results of the RD estimates for total R&D expenditures by years, which allows us to examine the effects regardless of the formal duration of the subsidised project (see Appendix Table A4 for details). The dot shows the point estimate, while the bars indicate 90% confidence intervals. The base year before the subsidy (t) is depicted by zero on the horizontal axis; thus, the funding starts to the right of the red vertical line, but for comparison we also show results for several years that precede the subsidy. In SMEs, there is a positive effect immediately from the start of the project, though the difference is not statistically significant during the first two years, but gains steam from the third year onwards and does not tend to evaporate over time. As could be expected at this point, however, in large firms not much changes after receiving a subsidy, and the results even indicate a statistically significant decrease in the fourth year, when most projects expire. It is also reassuring that in both groups there is no significant effect estimated before the subsidy actually starts to kick in.

Figure 2: RD estimates for total R&D expenditure by year (logs)



*Note: RD estimates for a bandwith of 5 points around the cutoff. Columns 2–7 report results for SMEs and Columns 8–13 for large firms. The effects are estimated during (d) and after (d+3) the period of receiving the subsidy, where d varies by project. All estimates include the pre-treatment logs of total R&D, R&D components by the source of funding and the type of expenditure, a patenting dummy, logs of employment, sales and labour productivity, age, dummies for foreign ownership, stockholding, Prague location, and co-operation with a research organisation, the number of project participants, and year and call fixed effects as controls. Standard errors are clustered at the firm level. N is the number of observations. * p<0.1, ** p<0.05, *** p<0.01.*

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TACR (2017).

Innovation output additionality and economic performance

Table 3 provides the results for innovation output additionality in terms of patenting, and economic performance in terms of employment, sales, and labour productivity. Across the board, regardless of firm size and timing of the effects, the results indicate that there is little to say with regards to the impact of the subsidies in these respects. In fact, most of the coefficients prove to be actually negative, although they are estimated too imprecisely to be statistically significant, which signals that the recipients did not manage to convert the subsidy into something of significant benefit for their development that would not have materialized without the subsidy.

A pessimistic interpretation of this (non)finding is that the additional projects realized by the SMEs thanks to the subsidy were of relatively low quality and, thus, have low economic returns. A more nuanced interpretation, however, is that the additional projects have low private returns, because otherwise they would be undertaken even without the subsidy, but their social returns are greater due to spillover effects, which we do not observe. In this respect, it needs to be noted that what matters most is not necessarily the direct impact of the subsidies on their recipients, but knowledge spillovers to unsupported firms that the newly stimulated activities generate (see Bloom et al., 2013, Lychagin et al., 2016, and Zacchia, 2020 for recent evidence on the magnitude of, and mechanisms for, such spillovers).

Most importantly, however, the typically small amount of a subsidy relative to the size of the recipient, and the limited size of our sample, mean that we cannot rule out the possible existence of some impacts on economic performance, especially in the SMEs, albeit too small in magnitude to be measurable with the data at hand. The standard error on the estimated impact on sales is 0.1, which implies that the true effect would have to be greater than 0.165 to be detected at a 10% significance level (a t-value of 1.65). For a subsidised SME with average (median) sales, this would require an increase in sales by about 39 (24) million CZK. But, given that the average annual subsidy to SMEs supported in the ALFA programme is about 1 million CZK, this would require an annual rate of return to the additional R&D expenditures generated by the subsidies on the order of 100s of %. It is not realistic to expect rates of return of this magnitude.

Table 3. RD estimates for innovation output (dummy) and economic performance (logs)

	SMEs						Large firms					
	During the treatment			After the treatment			During the treatment			After the treatment		
	Coef.	St. err.	N	Coef.	St. err.	N	Coef.	St. err.	N	Coef.	St. err.	N
Patent (0/1)	-0.01	0.07	765	-0.05	0.09	526	-0.13	0.14	376	0.14	0.12	290
Employment	-0.03	0.05	754	0.06	0.11	511	-0.05	0.05	376	-0.10	0.12	290
Sales	-0.03	0.10	754	-0.04	0.17	511	0.00	0.09	376	-0.29	0.20	290
Labour productivity	-0.04	0.06	748	-0.12	0.10	508	-0.04	0.08	372	0.00	0.07	278

*Note: RD estimates for a bandwith of 5 points around the cut-off. Columns 2–7 report results for SMEs and Columns 8–13 for large firms. The effects are estimated during (d) and after (d+3) the period of receiving the subsidy, where d varies by project. All estimates include the pre-treatment logs of total R&D, R&D components by the source of funding and the type of expenditure, a patenting dummy, logs of employment, sales and labour productivity, age, dummies for foreign ownership, stockholding, Prague location, and co-operation with a research organisation, the number of project participants, and year and call fixed effects as controls. Standard errors are clustered at the firm level. N is the number of observations. * p<0.1, ** p<0.05, *** p<0.01.*

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TACR (2017).

Conclusion

This study provides comprehensive evidence of causal effects of the TA CR ALFA subsidy programme. The results of RD estimators, based on micro data for business sector participants near the cutoff, indicate that the programme had strong and persistent additionality effects on R&D inputs, but only in SMEs, and not in large firms. In addition, the results are inconclusive for additionality effects on R&D outputs and economic performance irrespective of the size of firms and either during or after the project.

The results raise a number of questions about the design of policy interventions in this area, which are of great importance for evidence-based decision making. First, the results indicate that similar programmes in the Czech Republic, including the follow-up programmes to ALFA, could become more efficient by reallocating money from funding large firms to SMEs. It is noteworthy that some of the most prominent programmes abroad, such as R&D subsidies in the Small Business Innovation Research (SBIR) program in the United States and the Small and Medium Enterprise Instrument (SMEI) of the European Commission, target not only small but specifically young innovative firms and start-ups, whereas their Czech counterparts support relatively established firms. It is striking that the median age of subsidy recipients in both programmes above is 5 years, whereas in ALFA, it is 19 years. Because small and young firms are also more likely to be cash and credit constrained, policymakers should seriously consider shifting the focus of the support to these groups of firms.

Second, if this type of subsidy continues to be small compared to the size of their recipients, and are thus relatively evenly spread across a large population of firms, we might never be able to find out whether the programmes deliver impacts on economic performance and competitiveness of the economy, on the grounds of which the subsidies are primarily justified. Admittedly, this should be acknowledged ex-ante when funding for these programmes is considered by the government.

Third, interestingly, the inputs additionality effect appears to be negatively associated with the extent of co-funding requirement by the recipient from non-public sources – the maximum proportion of eligible costs of the project that could be covered by the subsidy – because the latter was significantly higher in large firms than in SMEs, while the opposite holds for the former. In other words, large firms were required to co-fund a larger share of project costs but the subsidy actually turned out to have a smaller input-additionality effect on them. Hence, the co-funding requirement must not be confused with the additionality (or motivation) effect of the funding, as sometimes happens with stake holders and popular commentators.

Moreover, the devil is in the details. Our results show that understanding of the programme effects significantly deepens when analysis is done not only of the total R&D expenditure, which none of the previous RD studies on this topic has been able to do, but also on their detailed sub-categories by the source of R&D funding and the types of R&D costs. Studies that rely solely on indirect proxies of R&D inputs and/or measures of general economic performance to evaluate R&D subsidy programmes might miss the most salient part of the picture. For example, this study would not find any significant results in the absence of information on R&D expenditure. Studies of the effects of R&D subsidies should exploit the full advantage of data from R&D surveys, which is readily collected in fine detail in most advanced countries.

From a methodological perspective, the RD approach should be applied to other R&D subsidy programmes, whenever data and the underlying design of the instrument allows for it, and should become a standard in programme evaluation in the coming years. Admittedly, a major hindrance to this line of enquiry has been limited access to administrative microdata from evaluation of projects proposals from within the funding providers – the evaluation points and/or ranking of the proposals – which is necessary for RD analysis. In the Czech Republic, TA CR should be praised for beginning to provide this data on a regular basis, although other funders, most notably the Ministry of Industry and Trade, are yet to follow suit. Czech policymakers can derive important lessons from rigorous quantitative evaluations of these programmes to facilitate policy learning and future policy design.

A major limitation of this analysis that should be reiterated is that it only considers direct effects of subsidies on recipient firms. Assessments of subsidy programmes should also consider their spillover effects on unsupported firms. After all, the government should not subsidize business R&D with the narrow aim to help only that particular firm, but rather with an eye to maximize the desired social impacts, and to achieve positive externalities through wider knowledge spillovers. Until we manage to pin down the extent of knowledge spillovers from subsidised projects, which are indeed notoriously difficult to measure, the jury is still out on whether a subsidy programme contributed to the development of the economy as a whole.

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Appendix

Table A1: Variable definitions

R&D expenditure (millions CZK)	Total intramural R&D expenditure
Privately funded R&D expenditure (millions CZK)	Intramural R&D expenditure funded by private sources (business enterprise sector, incl. internal funds, private non-profit sector and higher education sector; all in Czechia and abroad) minus R&D tax deduction
Publicly-funded R&D expenditure (millions CZK)	Intramural R&D expenditure funded by public sources from Czechia, abroad and R&D tax deduction
Publicly-funded R&D exp. – national (millions CZK)	Intramural R&D expenditure funded directly by public sources from Czechia (incl. national programmes of direct R&D support)
Publicly-funded R&D exp. – international (millions CZK)	Intramural R&D expenditure funded directly by public sources from abroad (incl. the EU structural funds and framework programmes)
Publicly-funded R&D exp. – tax incentives (millions CZK)	Intramural R&D expenditure funded indirectly by R&D tax deduction
Current R&D expenditure (millions CZK)	Current intramural R&D expenditure (labour costs, materials, supplies, energy, equipment, etc.)
Capital R&D expenditure (millions CZK)	Capital intramural R&D expenditure (acquisition of tangible and intangible fixed assets)
Patent (1/0)	Dummy variable with value 1 if the firm filed a patent application in the Industrial Property Office of the Czech Republic
Employment (FTE)	Number of employees in full-time equivalent (FTE)
Sales (millions CZK)	Sales of products and services
Labour productivity (thousand CZK)	Value added per employment
Time since incorporation	Number of years since the firms was registered in the business register
Foreign-owned (1/0)	Dummy variable with value 1 if the firm belongs to a foreign controlled institutional subsector
Stockholding (1/0)	Dummy variable with value 1 if the legal form of the firm is stockholding company
Manufacturing (1/0)	Dummy variable with value 1 if the principal activity of the firm is manufacturing
Prague (1/0)	Dummy variable with value 1 if the seat of the firm is registered in Prague
Number of project participants	Number of project participants in the project proposal consortium
Co-operation with a research organisation (1/0)	Dummy variable with value 1 if the project proposal consortium included a research organization

Note: R&D data is based on the harmonized methodology of Frascati manual (OECD 2015). Higher education sector is classified as a private source of funding for the purpose of this study, because similarly to private entities, higher education institutions make business-like decisions on this funding independently of the government and its support programmes.

Source: Based on micro data from CZSO (2021) and TACR (2017).

Table A2. Descriptive statistics

	SME						Large					
	N	Mean	P50	SD	Min	Max	N	Mean	P50	SD	Min	Max
R&D expenditure (millions CZK)	4601	24.0	10.6	35.9	0.0	368.0	1810	70.7	24.5	172.9	0.0	2606.0
Privately funded R&D exp. (millions CZK)	4601	16.3	5.4	29.3	0.0	368.0	1810	59.5	17.7	167.9	0.0	2553.4
Publicly-funded R&D expenditure (millions CZK)	4601	7.7	3.6	11.3	0.0	138.4	1810	11.2	6.0	15.8	0.0	153.8
Publicly-funded R&D exp. – national (millions CZK)	4601	6.4	2.7	9.9	0.0	78.7	1810	7.1	3.7	9.6	0.0	55.3
Publicly-funded R&D exp. – international (millions CZK)	4601	0.9	0.0	4.2	0.0	115.5	1810	1.2	0.0	6.4	0.0	133.1
Publicly-funded R&D exp. – tax incentives (millions CZK)	4601	0.4	0.0	1.2	0.0	17.2	1810	2.9	0.3	9.7	0.0	111.9
Current R&D exp. (millions CZK)	4601	22.0	9.7	33.3	0.0	288.9	1810	62.4	22.2	142.0	0.0	2032.1
Investment R&D exp. (millions CZK)	4601	2.0	0.0	7.9	0.0	225.3	1810	8.3	0.0	51.7	0.0	1209.8
Patent filed (1/0)	4601	0.2	0.0	0.4	0.0	1.0	1810	0.3	0.0	0.5	0.0	1.0
Employment (FTE)	4494	101	80	78	0	428	1806	1023	641	1166	54	10192
Sales (millions CZK)	4450	216	130	296	0	5206	1788	3105	1436	6419	22	72904
Labour productivity (thousands CZK / worker)	4406	783	707	406	0	4098	1768	806	723	453	53	4954
Time since incorporation	4601	18.3	19.0	5.5	0.0	31.0	1810	18.2	19.0	6.5	1.0	31.0
Foreign-owned (1/0)	4601	0.22	0.00	0.41	0.00	1.00	1810	0.39	0.00	0.49	0.00	1.00
Stockholding (1/0)	4601	0.43	0.00	0.49	0.00	1.00	1810	0.79	1.00	0.41	0.00	1.00
Manufacturing (1/0)	4601	0.56	1.00	0.50	0.00	1.00	1810	0.93	1.00	0.25	0.00	1.00
Prague (1/0)	4601	0.20	0.00	0.40	0.00	1.00	1810	0.09	0.00	0.29	0.00	1.00
Number of project participants	5357	3.0	3.0	1.2	1.0	8.0	1936	3.0	3.0	1.4	1.0	10.0
Co-operation with a research organisation (1/0)	5357	0.97	1.00	0.16	0.00	1.00	1936	0.97	1.00	0.17	0.00	1.00

Note: N is the number of observations.
Source: Based on micro data from CZSO (2022) and TACR (2017).

Table A3 RD estimates before the treatment (t-3 to t)

	SME			Large		
	Coef.	St. err.	N	Coef.	St. err.	N
R&D expenditure (log)	-0.16	0.39	797	-0.46	0.34	370
Privately funded R&D expenditure (log)	-0.24	0.41	797	-0.55	0.36	370
Publicly-funded R&D expenditure (log)	0.05	0.37	797	-0.11	0.45	370
Publicly-funded R&D exp. – national (log)	-0.05	0.40	797	0.14	0.60	370
Publicly-funded R&D exp. – international (log)	0.15	0.17	797	0.20	0.41	370
Publicly-funded R&D exp. – tax incentives (log)	-0.61	0.44	797	-0.92	1.03	370
Current R&D exp. (log)	-0.24	0.31	797	-0.29	0.33	370
Investment R&D exp. (log)	-0.31	0.37	797	-0.37	0.80	370
Patents (1/0)	-0.01	0.08	797	-0.12	0.22	370
Employment (FTE)	-0.25	0.27	785	0.20	0.47	369
Sales (log)	-0.39	0.33	766	0.28	0.63	356
Labour productivity (log)	-0.14	0.15	754	-0.18	0.19	356
Time since incorporation	-0.99	1.49	797	-2.16	3.36	370
Foreign-owned (1/0)	0.20*	0.12	797	-0.49**	0.23	370
Stockholding (1/0)	-0.28*	0.16	797	0.61**	0.25	370
Manufacturing (1/0)	0.09	0.17	797	0.03	0.08	370
Prague (1/0)	-0.12	0.15	797	0.06	0.10	370
Number of project participants	-0.11	0.43	880	0.14	0.72	392
Co-operation with a research organisation (1/0)	0.04	0.03	880	0.05	0.09	392

*Note: All estimates include the year and call fixed effects as controls. Standard errors are clustered at the firm level. N is the number of observations left (untreated) or right (treated) of the cutoff. * p<0.05, ** p<0.01, *** p<0.001.*

Source: Based on micro data from CZSO (2022) and TACR (2017).

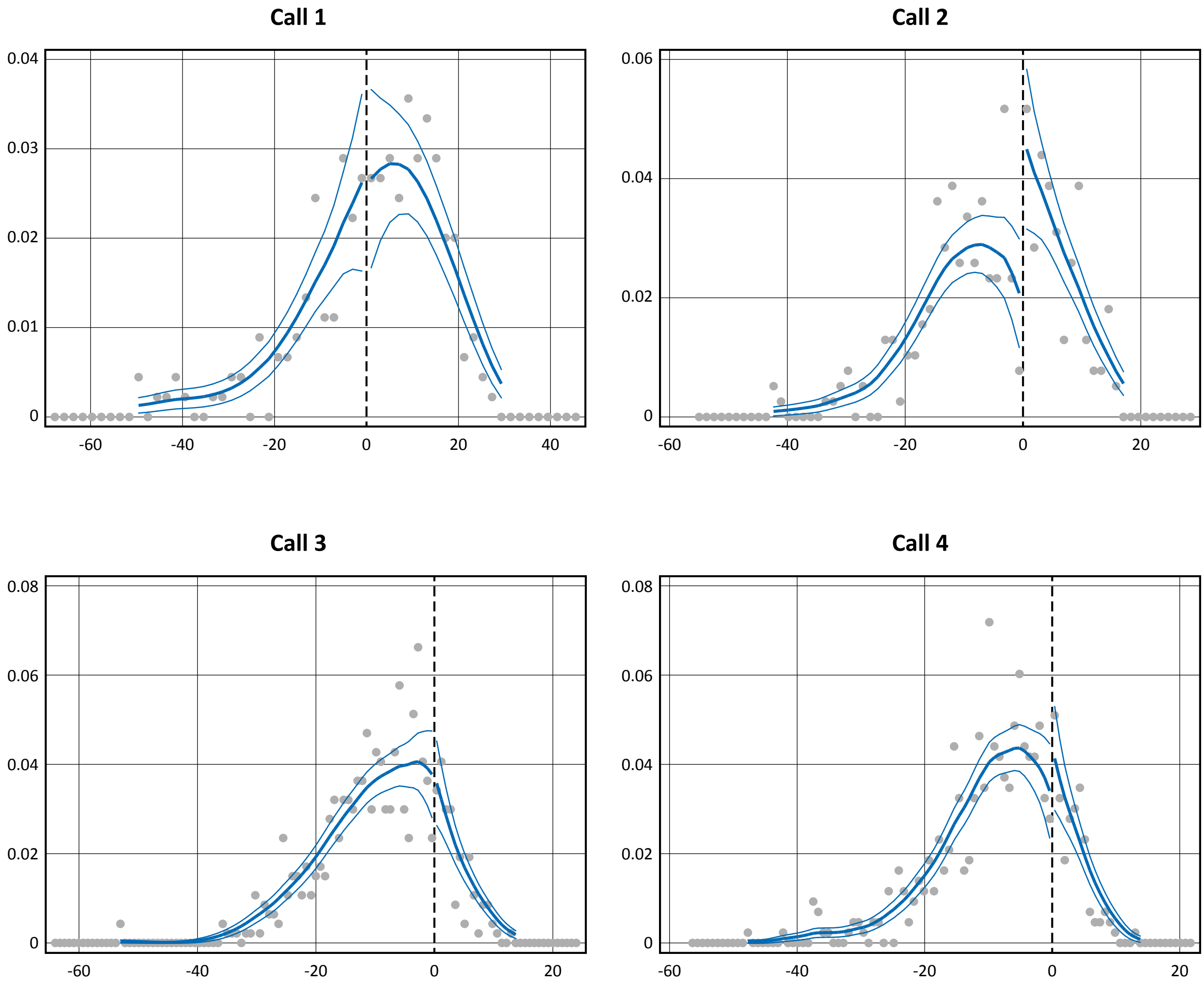
Table A4. RD estimates for R&D expenditure by year

	SMEs			Large firms		
	Coef.	St. err.	N	Coef.	St. err.	N
Before the subsidy						
t-3	0.27	0.26	179	0.10	0.39	87
t-2	-0.02	0.25	187	-0.30	0.28	91
t-1	0.04	0.14	211	0.09	0.17	94
t (year before the start o the project)	0	0	220	0	0	98
During and after the subsidy						
t+1	0.33	0.21	204	-0.02	0.23	97
t+2	0.29	0.24	195	-0.09	0.18	97
t+3	0.62***	0.21	194	0.07	0.19	96
t+4	0.60***	0.23	190	-0.41**	0.18	95
t+5	0.63**	0.3	177	0.01	0.32	95
t+6	0.88***	0.29	170	-0.27	0.38	95
t+7	0.65**	0.32	161	-0.02	0.36	91

*Note: RD estimates for a bandwith of 5 points around the cutoff. Columns 2–4 report results for SMEs and Columns 5–7 for large firms. All estimates include the pre-treatment logs of total R&D, R&D components by the source of funding and the type of expenditure, a patenting dummy, logs of employment, sales and labour productivity, age, dummies for foreign ownership, stockholding, Prague location and co-operation with a research organisation, the number of project participants, and year and call fixed effects as controls. Standard errors are clustered at the firm level. N is the number of observations. * p<0.1, ** p<0.05, *** p<0.01.*

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TA CR (2017).

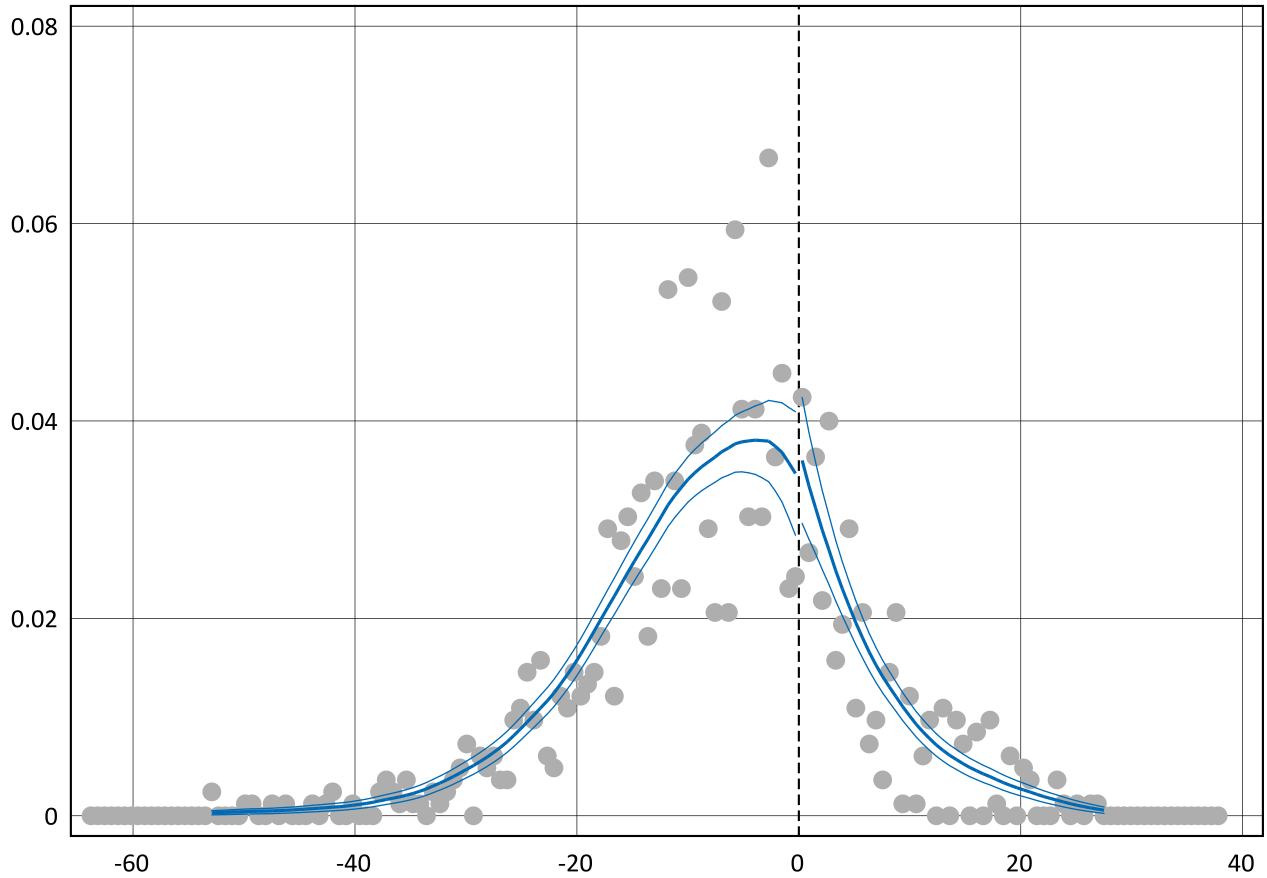
Figure A1: Density of project scores around the cut-off by call



Note: For each call of the Alfa programme, the figures plot the density of project proposals along the scores received, relative to the cut-off.

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TACR (2017).

Figure A2: Density of project scores around the cut-off for calls used in the analysis



Note: The figures plot the density of project proposals along the scores received, relative to the cut-off, for projects in calls 1, 3, and 4.

Source: Based on micro data from CZSO (2022), ISVaV (2022) and TACR (2017).

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