The effect of public subsidies on corporate R&D investment: An application of the generalized propensity score

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A R T I C L E   I N F O

A B S T R A C T

This paper aims to investigate how the effect of public subsidies on corporate R&D investment varies with different levels of public subsidies. Based on the generalized propensity score methodology, we estimate a dose–response function, using a large sample of Chinese manufacturing firms. Our results suggest public subsidies follow an S-shaped relationship and inverted-U correlation with the firm's total R&D and private R&D investment, respectively. There is a saturation point beyond which a further increase in public subsidies does not yield an increase of firm's total R&D investment. A minimum threshold value of public subsidies is required to induce the firm's private R&D spending. There are also critical values beyond which a further increase in public subsidies would partially or completely crowd out a firm's private R&D investment. Our conclusion implies the existence of an optimal interval of subsidy, and thus could help to improve the efficiency of public subsidies.

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1. Introduction

Evaluating the effect of public subsidies on a firm's R&D investment has been of interest to academic researchers and policy makers for many years. The rationale of public subsidies for R&D activities is rooted in the existence of market failures [2], which create a gap between private and social benefits. This gap makes firms' R&D investment turn out to be less than the socially optimum level. Although a great bulk of studies confirmed the worth of public subsidies, to the best of our knowledge, there is no attempt to evaluate the effect of varying degrees of public subsidies on corporate R&D investment.

The main concern of this paper is to assess the effectiveness of public subsidies in stimulating a firm's R&D spending, and subsequently analyzing whether the effects are different depending on the level of public subsidies. The generalized propensity score method employed in this paper allows us to set public subsidies as a continuous treatment. By estimating a dose–response function, we investigate the non-linear relationship between a firm's R&D investment and public subsidies. Our study contributes to the previous literature, since most studies only distinguish subsidized and non-subsidized firms, using public subsidy as a binary treated variable and comparing the R&D investment of subsidized and non-subsidized firms. The relationship between public subsidies and firms' R&D spending was treated as linear in the previous literature.

We also distinguish the effect of public subsidies on a firm's private R&D spending and a firm's total R&D expenditures. The detailed dataset we used in this paper provides the amount of a firm's R&D expenditures and public subsidies. It enables us to identify the source of a firm's R&D increase and the existence of a full crowding-out or a partial crowding-out effect. However, most of the previous studies only tested the

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presence or absence of full crowding-out effects. The increase of a firm's total R&D expenditures could benefit from private R&D effort or public subsidies themselves. A full crowding-out effect implies a complete substitution of firms' private R&D by public subsidies, and this means firms' total R&D investments keep constant with or without public subsidies. A partial crowding-out effect occurs when subsidized firms increase their total R&D expenditures, but the amount is smaller than the subsidies they received. Therefore, effective public subsidies should avoid both full and partial crowding-out effects.

Our research departs from the extant literature by focusing on the role of the amount rather than the type of public subsidies. The most recent works are generally concerning the type of subsidies (i.e. selective vs. automatic subsidies) or the specific goal (R&D-enhancing vs. other measures) for which a subsidy is implemented from a conceptual point of view. However, the role of the amount of pubic subsidies is still unexplored from a methodological point of view. We believe both the type and the amount are equally important when evaluating the effectiveness of public subsidies. While the most of the recent works have contributed to the former, in this work we contribute to the latter.

The reminder of this paper is organized as follows: Section 2 briefly reviews the literature on evaluating the effects of public subsidies on a firm's R&D investment. Section 3 describes the generalized propensity score method. Section 4 presents the data and definition of variables. Section 5 discusses the empirical results. Section 6 summarizes the conclusions.

2. Literature review

Parametric regression analyses and non-parametric matching methods are extensively used to investigate the issue of complementarity or substitutability between public subsidies and corporate R&D investment [4,6,21,24]. David and Hall [15] carried out a leading review, presenting a general structural model for explaining the effect of public funds on firm's R&D expenditures. Cerulli [7] provides a wide review on the principal econometric models used to measure the effects of public support for firm R&D investment.

The potential endogeneity and selection bias are core issues encountered in parametric regression analysis. Assuming the public subsidy as a strictly exogenous variable could be seriously misleading, since the allocation of R&D subsidies cannot be a random process. The allocation of public subsidies is the outcome both of the application decision made by a firm and of the approval or rejection decision made by the public agencies [3]. For example, if governments take a "picking the winner" strategy, firms with higher R&D activity are more likely to receive subsidies [5,32,37]. In this case, observing a positive relationship between public subsidies and firms' R&D expenditure can be caused by the specific strategy operated by the public agencies rather than the impact of public subsidies on the firm's R&D spending. To overcome this endogeneity problem, Lichtenberg [32] proposes a two-stage least squares (2SLS) estimation, using the "value of competitive contracts that were potentially awardable" to each firm as an instrumental variable. Wallsten [37] brought a full crowding out effect of subsidies using a simultaneous model with a sample of US firms. The selection models proposed by Heckman [22] were extensively applied to estimate the causal effect of public subsidies on a firm's R&D investment [4,9,36].

In the most recent studies, there is a widespread tendency to apply non-parametric matching methods, trying to answer how much the firm would have spent on R&D had it not received public subsidies [1,8,12,13,16]. By constructing a comparable control group, the matching approach is able to eliminate sample selection bias and potential endogeneity. Among these studies, Hussinger [25] obtained a positive effect of public support on a firm's R&D spending with a sample of German manufacturing firms. Koga [28] concluded a complementary relationship between public R&D subsidies and firms' R&D efforts based on Japanese high-tech start-ups. Gonzalez and Pazo [19] indicated the absence of crowding-out effect for Spanish manufacturing firms. Cerulli and Poti [9] applied various matching methods to evaluate the effect of public subsidies on firm's R&D activity. The results turned out to be sensitive to the specific method employed.

Another tendency of the extant literature is to distinguish the type of public subsidies and firms' heterogeneity when evaluating the effect of public subsidies. Subsidies awarded on a competitive basis are found to be more effective than those assigned through an automatic procedure [10]. Selective R&D subsidies outperform other typologies of schemes [20]. Governments co-financing and university seed funds play a similar role with public subsidies [11]. As regards to firms' heterogeneity, it covers firm size, technological competence, market competition, appropriability and so on [17,19,38]. For example, Lach [29], using a panel data of Israeli firms, found evidence suggesting that the R&D subsidies greatly stimulated private R&D investment for small firms but had a negative effect for large firms. Gelabert et al. [18], using data from the Spanish Community Innovation Survey, find that the effectiveness of public support depends on the degree of appropriability. Public support is less effective to stimulate private R&D investment in firms where appropriability mechanisms are effective. Lee [30] tested the differential effects of public R&D support using firm-level data for six countries. Complementarity effect of public support on private R&D occurs for firms with low technological competence, for firms in industries with high technological opportunities and for firms facing intense market competition. Czarnitzki and Lopes-Bento [14] analyzed how the observed effects of subsidies on R&D intensity vary over time, if a firm receives multiple public support programs, and if a firm gets support consecutively.

We follow the above line of research tendencies and, specifically, investigate how the effect of public subsidies on corporate R&D investment varies if firms get different levels of public subsidies. To the best of our knowledge, this issue has not yet been addressed in the existing literature. Instead of treating public subsidy as a binary variable, as in the previous literature, we employ the generalized propensity score method, which allows for a continuous treatment. It enables us to analyze the non-linear relationship between a firm's R&D investment and public subsidies. Moreover, it's possible to identify the optimal level of public subsidies. Thus, our paper not only contributes to the existing literature by providing a different lens through which the heterogeneous effect of public subsidies can be analyzed, but also sheds light on how public subsidies can be optimized.