R&D Tax Credit and Product Quality vs. Scope*

Pavel Chakraborty† Sankalp Mathur‡ Sujaya Sircar§ Rubina Verma¶

August 2026

Abstract

Do firms with heterogeneous in-house R&D capacities respond differently to innovation policy? Using India's 1998 R&D tax credit targeting firms with in-house R&D units, we find that R&D spending rose across firms, but product responses differed. Small and medium firms expanded product scope, whereas large firms improved product quality, especially among exporters and producers of differentiated goods. Our heterogeneous-firm model explains these patterns through optimization across scope, scale, and quality. A complementary welfare accounting exercise reports a 93% decline in the observed effective price index, suggesting substantial welfare gains during the policy period.

Keywords: R&D Tax Credit, In-house R&D Units, R&D Expenditure, Product Quality, Product Entry, Welfare Gains, Industrial Policy.

JEL Codes: O1, O31, O32, O33, O38.

*We like to thank the seminar participants at University of Bath; Cardiff University; Indian Institute of Management, Bangalore; and conference participants at 7th Annual Economics Conference, Ahmedabad University, 2026; Indian Institute of Management Calcutta Economics Research Conference 2026; 2025 Economics of Firm Workshop, Siv Nadar University; 2025 Annual Conference on Economic Growth and Development (ACEGD), Indian Statistical Institute, New Delhi; 2025 Research Seminar, Development Economics Trade and International Integration, World Bank, Washington D.C.; 2024 Southern Economics Association, Washington D.C.; 2023 Washington Area Development Economics Symposium (WADES); 2023 University of Southern California (USC) Alumni Conference. All errors are our own.

†Department of Economics, University of Bath, BA2 7AY, UK; E-mail: pc2037@bath.ac.uk

‡Centre for Advanced Financial Research and Learning (CAFRAL), Reserve Bank of India (RBI), Mumbai, India; Email: sankalp.mathur@cafral.org.in

§Department of Economic Sciences, Indian Institute of Technology, Kanpur, India; E-mail: ssircar@iitk.ac.in

¶School of Foreign Service, Georgetown University, Washington D.C., USA; Email: rv422@georgetown.edu

1 Introduction

Governments are increasingly adopting targeted industrial policy, such as R&D tax credits, to confront a range of economic challenges, from climate transition and technological competition to upgrading firms' competitiveness. Such interventions are often justified by classic market failures—most notably knowledge spillovers and externalities—that cause private firms to underinvest in innovative activity. R&D tax incentives lower the effective cost of innovation and encourage firms to undertake projects with high fixed costs whose benefits may extend beyond the innovating firm through positive externalities. A parallel rationale underpins trade-related industrial policies that seek to strengthen domestic firms' ability to compete with foreign producers, particularly in sectors near the global technological frontier.

There is substantial evidence that R&D tax credits stimulate firm level innovation – R&D expenditures, patenting activity, entrepreneurship (Dechezleprêtre et al. (2023); Bloom et al. (2002); Rao (2016); Melnik (2024)) – much less is known about the form these innovation investments take in terms of product development. Specifically, it remains unclear whether firms predominantly invest these resources in expanding product variety (scope) or improving the quality of existing products. In addition, these strategic choices may also involve trade-offs. For multi-product firms, upgrading the quality of one product or introducing a new product can reallocate resources and shift demand across the firm's portfolio, with the magnitude and direction of these spillovers likely varying by firm size. Therefore, understanding whether (a) the type of R&D investments varies systematically with the size of the firm, and (b) such trade-offs are essential to design R&D incentive policies, that maximize both private and social returns to innovation, are of first order importance.

On the other hand, while there is a large literature that shows reductions in trade barriers can induce quality upgrading (Amiti & Khandelwal (2013); Khandelwal (2010); Bas & Strauss-Kahn (2015)) and product-scope expansion (Broda & Weinstein (2006); Goldberg et al. (2010); Atkin et al. (2018)), it remains less understood whether comparable gains in quality and scope can be generated through innovation-focused fiscal instruments such as R&D tax credits. We examine this question by studying whether targeted R&D tax incentives shape firms' quality upgrading and their expansion of product scope, thus clarifying an important but underexplored channel through which modern industrial policy can affect firm performance and aggregate welfare. To our knowledge, we are among the first to delve into such question.

We exploit a tax reform in India, proposed in the Union Budget of 1997–98, aimed to increase R&D tax credits for firms with in-house R&D units registered with the Ministry of Science & Technology, Govt. of India. The reform was initially introduced for drugs and pharmaceuticals, chemicals, electronic equipments, computers, telecommunication equipments in 1997–98 and later extended to helicopters and aircrafts in 2001 and automobiles and auto parts in 2004.[1] This R&D

[1] For details, please see Section 2.

tax credit policy partitioned firms based on a clearly defined eligibility criterion creating a set of eligible and non-eligible firms that are directly and not directly impacted by the reform, enabling us to causally estimate the relative effects of the reform both within and between industries.

We use this phased introduction of R&D tax incentive and combine with firm and firm-product level data from PROWESS (which provides detail information on R&D expenses of firms as well as sales value and quantity sold for each product produced by a firm) to estimate the effect of the R&D tax credit on product quality and probability of producing new products. We match our firm level data with a key information from the Department of Scientific & Industrial Research (DSIR), the research arm of the Ministry of Science and Technology that administer the R&D generation process in India. They provide a list of firms that have recognized in-house R&D facility and also classify the firms into three different categories based on their reported in-house R&D expenses: (a) firms with $<$ 10 million INR (small); (b) firms with 10–50 million INR (medium); and (c) firms with $>$ 50 million INR (large). We exploit this crucial classification in terms of the R&D expense distribution to estimate the differential effect of the R&D tax credit policy on R&D expenses, product entry, and product quality not only for eligible and ineligible firms, but also between different types of eligible firms.

The key point in exploiting this particular event of R&D tax credit policy for causal inference is that the policy design provides a plausible exogenous change in the dynamics of between as well as within industry; in our case for firms with recognized in-house R&D units in those industries for which the policy was implemented (representing the 'treatment' group) relative to the rest of the firms (representing the 'control' group). Using a difference-in-difference approach and detailed firm-product level information combined with data from firms' balance sheets and income statements from PROWESS, we find two important results.

(i) a remarkably persistent and economically meaningful positive effect of the R&D tax credit policy on the R&D expenses of all types of eligible firms, with a significantly higher effect for large firms. In particular, large firms, i.e. firms with $>$ 50 million INR of in-house R&D expenses recorded a 650% growth in R&D expenses as compared to 148% for firms with 10–50 million INR of R&D expenses and 12% for firms with $<$ 10 million INR;[2]

(ii) firms, depending on the size of their R&D expenses, invest their R&D resources differentially in response to the R&D tax credit policy. We find that large firms invest the R&D resources to significantly upgrade the quality of the range of products they produce – the quality index of their products as compared to the pre-policy quality index increases by about 140%. In particular, these firms improve the quality of the peripheral products and not the core product. On the other hand, small and medium-sized firms expand their product range or variety. In other words, they invest their R&D resources in product innovation. These patterns are particularly pronounced for firms that belong to industries that have high elasticity of substitution or higher *cannibalization* rate or

[2]Our results are consistently robust while controlling for several other simultaneous policy changes, such as trade reform, delicensing of industries, etc.

produce less differentiated products. We believe, we are among the first to show that firms with different sizes of R&D expenses behave disparately while investing their R&D resources. This is our key and primary contribution.

We also show that R&D leads to an increase in sales for all firms. Large firms maximize their sales value by increasing prices (as quality goes up), while small and medium-sized firms maximize through increase in the quantity of products sold (as the number of varieties increases). Large firms also use more capital, skilled labour, and imported raw materials and capital goods in the process of improving the quality of their range of products. All these resulted in higher gross value-added and exports.

To rationalize these new and rather unique empirical findings, we develop a nested CES model with multi-product firms, in the spirit of Hottman et al. (2016). The model allows substitution both across firms and within a firm across its products. Treating firms as single-product entities abstracts from within-firm interactions that are central in our setting.[3] When products within a firm are close substitutes, expanding either product scope or product quality can draw demand away from the firm's existing products. When within-firm substitution is low, these investments generate less within-firm reallocation and instead increase the firm's total demand.

A firm's choice between investing in quality and expanding scope depends on the extent to which each strategy reduces demand for its other products—what we refer to as *cannibalization*. We summarize this force using a *cannibalization elasticity* for quality and for scope in response to tax incentives, and we compare the two elasticities given the substitution parameters and market structure. Scope expansion generates cannibalization because each new product competes not only with other competing firms but also with the firm's own products. As product scope N increases, the number of within-firm substitution links rises roughly with the number of product pairs, $\binom{N}{2}$, so cannibalization from scope increases on the order of N^2. In contrast, quality upgrading is an intensive-margin change: improving one product mainly diverts demand from the rest of the firm's portfolio in a one-to-many way, implying cannibalization that increases only linearly with N. Therefore, for small N the marginal cannibalization cost of adding products is limited and firms tend to expand scope. Beyond a threshold N^*, the quadratic growth in scope-induced cannibalization makes further scope expansion relatively unattractive, and firms optimally tilt toward quality upgrading.

Further, to complement the causal estimates, we conduct a welfare-accounting exercise that separates the contributions of product quality, product scope, and unit prices. Using the nested two-tier utility framework and the exact price-index decomposition of Sheu (2014), we compare the observed product sets in cohort-specific pre-policy periods (three years before treatment) with those in post-policy periods (three years after treatment). The aggregate effective price index declines by 2.7 log points, corresponding to a 93.3% decline between the two reference periods.

[3] In PROWESS, the dataset we use for our empirical estimation, about 83% firms are multi-product (i.e., they produce more than 1 product).

Under the maintained CES demand assumptions, this decline represents an improvement in consumer welfare. The accounting decomposition attributes 62.5% of the observed log change to the product-variety component and 32.7% to the estimated-quality component.[4] Because this exercise compares observed pre- and post-policy outcomes without using the treatment-control research design to construct the evolution of the price index in the absence of the tax credit, the resulting welfare change should not be interpreted as the causal effect of the R&D tax credit.

Our paper makes a few important contributions. First, using novel firm-product level data with detailed information on product level sales and quantities, we provide the first evidence that R&D tax credit can have substantial effect on product development. And, this depends on the position of a firm in the R&D expenses distribution. Large firms invest in improving the quality of the products, while others invest in new products thereby quantifying the interdependence between R&D tax credit policy and entry of new product varieties, and product quality. More generally, our work informs how a government policy can have both direct and indirect effects of a specific program.

Second, this paper develops a theoretical framework to rationalize our central empirical result: following the introduction of R&D tax incentives, large firms respond by upgrading the quality of existing products, whereas smaller firms respond by expanding scope through new products. We argue that this result is driven by size-dependent within-firm demand reallocation. In particular, quality upgrading and scope expansion generate different degrees of cannibalization across a firm's product portfolio, and the degree of these cannibalization forces varies systematically with firm size and the number of products a firm supplies.

Although existing studies have investigated the impact of R&D incentives, these are typically conducted using empirical methods (e.g., Dechezleprêtre et al., 2023; Bloom et al., 2019) or dynamic general equilibrium frameworks that abstract from within-firm product heterogeneity (e.g., Akçigit & Kerr, 2018; Atkeson & Burstein, 2019). Our analysis builds on the two-tier CES demand system of Hottman et al. (2016), which allows for firm heterogeneity and accommodates elasticities of substitution across firms and within firms. A key object in Hottman et al. (2016)'s framework is the scope cannibalization elasticity—the reduction in demand for a firm's incumbent products induced by the launch of an additional product. We extend this environment by deriving the analogous quality cannibalization elasticity: the change in demand for a firm's other products when the firm raises the quality of one its products. This extension enables a comparison between scope- and quality-driven cannibalization and clarifies how the relative size of these two innovation margins changes with firm size and product scope.

Our combined empirical and theoretical results have two important implications: (i) we deviate from the literature and are among the first to show that interaction between R&D tax credit policy and the size of the R&D expenses of firms can produce new gains through increase in product variety and quality. And, industries with high cannibalization elasticity drives these findings;

[4]The remaining 4.8% is accounted for by changes in observed unit prices.

and (ii) R&D tax credit can increase competitiveness of those industries at the global level through increased exports. This is our primary contribution.

These results relate to a small but growing literature that examines the causal effect of R&D tax incentives on different types of innovation, such as (i) patents (Ivus et al., 2021); (ii) quality-adjusted patents (Dechezleprêtre et al., 2023); (iii) innovative search or new technologies (Balsmeier et al., 2025); (iv) product innovation (Czarnitzki et al. (2011); Labeaga et al. (2021); Pless (2025); Liu et al. (2025)); and (v) process innovation (Cappelen et al., 2012). We show how innovation investments depend on size heterogeneity.

Third, our results also contribute and complement the small, growing, and important literature on how industrial policies can affect firm performance.[5] Recently, several studies used the Global Trade Alert (GTA) project to study the relationship between industrial policies and different economic outcomes in both (a) cross-country setting (Criscuolo et al. (2019); Juh´asz et al. (2023); Barwick et al. (2024); Parente et al. (2025); Yueling et al. (2025)); and (b) country-specific case studies (Cherif & Hasanov (2019); Choi & Levchenko (2024)). Our paper is close to Lane (2025), who examines the effect of industrial policies on the industrial development of South Korea's heavy and chemical industries during 1973–79. He finds that those targeted policies promoted the expansion and comparative advantage of those industries. We complement this study to show that targeted industrial policies, in our case R&D tax credit, can also lead to both product variety expansion and upgrading of product quality, leading to new sources of gains from such policies.[6]

Lastly, we also contribute to the constantly growing literature on how R&D tax credit affects R&D expenses of firms in both developed (Czarnitzki et al. (2011); Cappelen et al. (2012); Guceri & Liu (2019); Dechezleprêtre et al. (2023)) and developing economies (Yang et al. (2012); Guo et al. (2016); Ivus et al. (2021)).

The rest of the paper is organized as follows. Section 2 briefly describes the R&D tax credit policy. Section 3 describes the data we use for our empirical specifications and presents a few stylized facts. Section 4 outlines our empirical strategy, including endogeneity checks. Section 5 presents our findings on the first order effects of the R&D tax credit. We present our benchmark finding in terms of product quality vs. variety in Section 6. Section 7 develops our our theoretical model to rationalize our empirical findings. We quantify the welfare gains from the R&D tax credit policy in Section 8. Section 9 provides some concluding remarks.

[5]Industrial policies are defined as "state actions aimed at transforming the structure of economic activity, typically by altering relative prices across sectors or directing resources toward specific industries or activities like exporting and R&D." (Parente et al., 2025)

[6]In addition, we also find that the export competitiveness of those industries improves significantly, supporting the findings of Lane (2025).

2 Institutional Background – The R&D Tax Credit Policy

In the Union budget of 1997–98, the Govt. of India introduced a fiscal incentive in the form of a tax-weighted deduction scheme for firms belonging to select industries that had in-house R&D units and were registered with the Department of Scientific and Industrial Research (DSIR), the nodal unit in the Ministry of Science & Technology, Govt. of India. These industries were: (1) drugs and pharmaceuticals, (2) chemicals, (3) electronic equipments, (4) computers, and (5) telecommunication equipments.[7] The scheme was further extended to helicopters and aircraft in 2001 and automobiles and auto parts in 2004. By 2009, this tax incentive was offered to all firms across all manufacturing industries, except a few listed in Schedule 11 of the Income Tax Act.[8]

Starting in 1998, firms with DSIR recognized in-house R&D facility in the five industries were offered a weighted tax deduction of 125% for any approved revenue or capital expenditure undertaken in their R&D facility. The tax-weighted deduction for those firms was increased to 150% in 2001.[9] However, the rest of the industries were not affected by the reform and continued to be eligible for the regular limit of 100% tax deductions on R&D spending.[10] Therefore, using the criterion of whether a firm has an in-house R&D, we can differentiate these firms from those that do not have an in-house R&D facility, thus identifying a group of firms within an industry that were not directly impacted by the reform. This enables us to estimate the effect of the R&D tax credit incentive not only between but also within industries.

Panel A of **Figure 1** plots the normalized R&D expenses for treated vs. control industries. The plot clearly shows that R&D expenses for firms in industries where the R&D tax credit was implemented increased significantly after the reform, relative to other industries, with only minor differences between the two groups before the reform. Similarly, **Panel B** juxtaposes the normalized R&D expenses for firms with recognized in-house R&D facility versus those without such a facility. The finding here is similar to that seen in **Panel A**, confirming the increase in R&D expenditure even within an industry after the tax credit.

[7]The DSIR releases annual reports to confer an overview of the R&D generation process across industries in India to disseminate information to government bodies, R&D institutions or anyone who may want to initiate interaction with the in-house R&D units in various sectors. While the reports from 1998 onward mention the tax deduction scheme, no information is provided on why some industries were eligible for the scheme, while others were not. In order to check whether differential trends exist between eligible or ineligible industries or firm characteristics or eligible firms lobbied for such type of policies, we run pre-trends and endogeneity checks and find that our results are robust to any unobserved selection into the treatment group. More on this in Section 5.

[8]These were tobacco, alcohol, cosmetics, confectionery, chocolate, etc.

[9]The DSIR approval requires that firms with in-house R&D units engage in R&D activities related to a firm's line of business, such as the development of new technologies, design and engineering, process and/or product design improvements, development of new methods of analysis and testing, research for increased efficiency in the use of resources, such as capital equipment, materials, and energy, pollution control, effluent treatment, and recycling of waste products. In addition, these firms were required to present the previous three years of annual reports, information on past, present, and future research projects, details on the scientific personnel and equipment working in the R&D unit, and photographs of the R&D facility. Once approved, firms were required to report their R&D activities each year and apply for renewal every three years.

[10]For further details on the discussed R&D tax credit policy, see Jain & Singh (2023).

3 Datasets and Stylized Facts

We exploit datasets from two different sources: (a) a well-known dataset at the firm level known as PROWESS, maintained by the Centre for Monitoring of the Indian Economy (CMIE); and (b) information on in-house R&D facilities of firms from the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology, Govt. of India.

3.1 PROWESS

PROWESS provides updated and detailed information on all listed firms and a larger set of unlisted firms covering all sectors of the economy, starting from the early 1990s until the present day, representing a panel dataset. For our purpose, we focus on 9,200+ firms that belong to the manufacturing sector during the 1992–2007 period. The database is compiled from audited annual reports of firms and information submitted to the Ministry of Corporate Affairs (MCA), Government of India.[11] These firms are predominantly private Indian firms or are affiliated to private business groups, with a small fraction of firms that are either government or foreign owned.[12] The dataset also provides information on a variety of firm level characteristics, including, but not limited to, total sales, exports, imports, raw materials expenses, capital employed, labour costs, gross value added, and assets, among others.

This dataset is unique in terms of its coverage —- especially since it provides data from the early 1990s in a panel format, both of which are crucial for our purpose. Below we list the other advantages:

1. To assess the first-order effects of the policy change, we exploit a key outcome variable – the R&D expenditure of a firm. Firms report information on R&D expenditure as per section 217 of the Companies Act. i.e., as per section 217(1)(e), the information shall be attached to every balance sheet laid before a firm in the Annual General Meeting, in a report by its board of directors. In addition, the dataset also provides information on expenses due to foreign technology transfer.

2. A unique feature of the PROWESS database is that it captures detailed information on quantity sold and value of sales of each product manufactured by a firm. The 1956 Companies Act requires firms to report detailed production data for all products they manufacture. The products in our data set, therefore, should be viewed as narrowly defined categories within industries rather than a specific product variety, such as barcode scanner datasets. There

[11] The coverage of the PROWESS database is quite extensive in terms of economic activities in the organized industrial sector. These firms are also responsible for more than 70% of all the output produced, 75% (95%) of corporate (excise duty) taxes collected by the Govt. of India. In terms of the sectoral composition of firms, about 19% firms belong to the chemical, followed by 13% in food products, 11% in textiles, 11% in basic metals, 6.5% in machinery & equipment, and 5.8% in rubber & plastic sector.

[12] About 92% firms in our sample are domestic private, with 5% beng foreign-owned, and the rest 3% are govt.-owned.

are over 4000 unique products in our sample. These product codes were then mapped on to the NIC 2004 4-digit level industries. We also use information to calculate the quality of each product produced by a firm, following the methodology of Amiti & Khandelwal (2013) and utilizing the elasticity of substitution coefficient at the industry level (2-digit) from Fujiy et al. (2023).

3.2 DSIR

One of the key ingredients of the R&D tax credit change was that the policy applied only to firms that had an in-house R&D unit. We exploit this information to understand whether a firm that had in-house R&D was differentially affected compared to firms that did not have such facilities.

The DSIR provides the directory of the recognized in-house R&D units of firms for each year.[13] The information provided in these directories includes firm names, address, the year in which the in-house R&D facility is recognized, and the year until which this recognition is valid.[14] In addition, these reports enlist three different cut-offs to classify firms in terms of their in-house R&D expenditure : (i) firms with in-house R&D of $<$ 10 million INR; (ii) firms with in-house R&D of 10–50 million INR; and (iii) firms with in-house R&D of $>$ 50 million INR. We extract all this information from the annual reports and match these with PROWESS firms based on the names of the firms using a combination of fuzzy and manual hand coding.

Using these reports, we first create the eligibility status of firms that availed the benefits of the weighted tax deduction scheme. In particular, a firm is coded as eligible if that firm was registered with DSIR, and had an in-house R&D facility any time between 1992 and 2007. Next, we use the above-specified cut-offs to segregate firms into three different sets based on their capacity of in-house R&D expenses, which serves as our key treatment variable. However, for our estimation purpose, we use the pre-policy registration year of the in-house R&D unit of a firm.

3.3 Stylized Facts

Stylized fact #1: A small set of firms had in-house R&D facility

On average, about 8.3% of the firms in our sample had in-house R&D units over the time period. Of this, approximately 58% of the firms had in-house R&D expenditure less than 10 million (the lowest category), 32% had in-house R&D expenditure in the range of 10–50 million INR (the

[13] See the DSIR Directory

[14] The DSIR registration process involves submitting an online application via the DSIR website followed by mailing a signed physical copy. It requires detailed documentation of R&D projects, infrastructure (minimum 1,000 sq. ft.), dedicated personnel, and firm incorporation documents. The process includes screening, a potential interview, and certification, usually valid for three years. It is free of cost and usually takes 2–3 months from the from the date of application submission to final certification.

medium category), and the remaining 10% of the firms had in-house R&D expenditure of more than 50 million INR (the highest category).

Stylized fact #2: R&D expenses and product quality were significantly higher for firms in the highest category.

Table 1 presents some simple statistics. An average firm in the highest category spent 168.5 million towards R&D, which was about 9.5 times higher than firms in the medium category and about 85 times higher than firms in the lowest category (column (1)).

In terms of quality, a firm in the highest category produces an average product whose quality is about 5.5 times higher than the average product of firms that belonged to the medium category and 32 times higher than firms from the lowest category (column (2)). However, while estimating the average probability of introducing a new product (column (3)), we find that firms of the lowest category of R&D expenses had the highest probability of introducing a new product, while the same is about 10% less for firms of the highest category.

4 Empirical Strategy

Our main goal is to estimate the differential impact of the R&D tax credit policy on key firm and firm-product level outcomes. We do so by differentiating firms into three categories of in-house R&D expenditure and use the following simple differences-in-differences framework:

$$\begin{aligned} x_{it} = \beta_1 Treated_{jt} &+ \beta_2 (Treated_{jt} \times R\&D\ Unit_{i,<10Million}) \\ &+\beta_3 (Treated_{jt} \times R\&D\ Unit_{i,10-50Million}) \\ &+\beta_4 (Treated_{jt} \times R\&D\ Unit_{i,>50Million}) \\ &+X_{it} + \eta_i + \phi_t + \theta_j^t + \epsilon_{it} \end{aligned} \tag{1}$$

x_{it} represents our outcome variable of interest for firm i at time t. x assumes the following outcomes (i) at the firm level – amount of R&D expenditure and establishment of new R&D unit; and (ii) at the firm-product level – product entry, product quality, product level sales, product level quantity sold, and product level price (unit).

Our key variable of interest is $Treated_{jt}$. This is an interaction of two terms – (i) $R\&D\ Reform_t$, a year dummy variable that takes a value of 1 in the post R&D tax credit policy period, i.e., for the period 1998–2007 for chemicals, pharmaceuticals, computer, electrical equipments, telecommunications and 2002–2007 for aircraft and 2004–2007 for automobiles and autoparts, and 0 otherwise; (ii) $Treated\ Industry_j$. This also takes a value 1 for the following industries: chemicals (2004 NIC 4-digit – 2411, 2412, 2413, 2421, 2422, 2424, 2429, and 2430), pharmaceuticals (2004 NIC 4-digit – 2423), computer and computer parts (2004 NIC 4-digit – 3000), electrical equipments (2004 NIC 4-digit – 3110, 3120, 3130, 3140, 3150, and 3190), telecommunication equipments (2004 NIC 4-digit

– 3220), aircraft (2004 NIC 4-digit – 3530), and automobiles and Autoparts (2004 NIC 4-digit – 3410, 3420, and 3430). Therefore, these twenty one industries (at the 4-digit level) will serve as our treated group, while the rest will serve as the control group.

We then interact $Treated_{jt}$ with three dummies to indicate which category of in-house R&D unit does a firm belong to: (i) $R\&D\ Unit_{i,<10Million}$ – takes a value of 1 if the firm has in-house R&D expenses of less than 10 million INR; (ii) $R\&D\ Unit_{i,10-50Million}$ – takes a value of 1 if the firm has in-house R&D expenses of more than 10 million but less than 50 million INR; and (iii) $R\&D\ Unit_{i,>50Million}$ – takes a value of 1 if the firm has in-house R&D expenses of more than 50 million INR. All these triple differences would then depict the differential effects of firms that belong to the specified intervals of R&D expenses. So, our coefficients of interest are β_2, β_3, and β_4.

Now, this eligibility status variable is highly endogenous as R&D activities in the post-policy period can significantly influence it – e.g., if a firm increases its R&D expenditure, due to reasons other than the new incentive (e.g. the R&D team gets a million-dollar idea which the board and investors agree to fund), this may switch the eligibility status variable on, creating reverse causality. In addition, the size categories are also endogenous if determined by current R&D expenditure in the post-policy period. In order to avoid such biases affecting our estimation, we use the eligibility criteria of a firm in its initial period, i.e., when it first registers it's in-house R&D facility with the DSIR.

X_{it} is a vector of firm controls which includes the gross value added of a firm (indicator of size), age, and age squared of a firm. η_i are firm fixed effects (controlling for firm level unobservables) and ϕ_t are year fixed effects. We also control for interactions of industry fixed effects (at 4-digit) with year-specific trends, θ_j^t, to control for major time-varying changes at the industry level due to various industrial policies, such as delicensing, trade policy changes such as drop in tariffs (input and output), demand and/or technology shocks, etc.[15] We cluster our standard errors at the 4-digit NIC 2004 level – the same level at which our treatment variable varies.

4.1 Pre-trends and Endogeneity Checks

Our basic estimates may still provide inconclusive evidence of the causal effect of the R&D tax credit policy for the following reasons: (a) differential time trends between the industries which have been targeted by the R&D tax credit and others; and (b) reverse causality. In the following, we will consider each of them separately and show that our results are robust to both.

We start by comparing three key outcome variables of interest to show that firms in the treated group of industries were not different from firms in the control (or other) industries during the pre-policy period of 1992–1997. These variables are: (a) R&D expenses, (b) product entry (c) product

[15]We also check our results by interacting industry fixed effects (at 2-digit level) with year fixed effects – the results remain the same.

quality. **Table 2** presents estimates using data from the prior policy period that reveal that there were no differences in time trends in these outcomes between the two groups.

Column (1) uses Equation (1) and regresses R&D expenses on the interaction terms of $Treated\ Industry_j \times R\&D\ Reform_t$, except that we use t = 1992, 1993, 1994, 1995, 1995, 1996, and 1997 (rather than years following $R\&D\ Reform_t$), controlling for firm characteristics, firm and year fixed effects and interactions of industry year trends. The estimates in column (1) suggest that there is no differential time trend in the R&D expenses for firms in industries for which the R&D tax credit policy was implemented relative to other manufacturing firms. Interpreting it differently, the idea here is to introduce any counterfactual R&D tax credit policy to see if it had any impact on the R&D expenses of firms. Our estimates from this exercise indicate that there is limited evidence of a consistent impact of such counterfactual policy changes.

Columns (2) and (3) replace firm level R&D expenses with firm-product level outcomes – product entry and product quality, respectively, and also replace firm fixed effects with firm-product fixed effects. The results show that the estimated coefficients on the interaction terms – year fixed effects with $Treated\ Industry_j$ dummy – are practically zero. Additionally, some of the interaction terms in columns (2) and (3) are positive and others are negative, lacking any consistent pattern. Therefore, we cannot reject the hypothesis that all the interaction terms are jointly equal to zero, and we conclude that firms in both groups followed a similar time trend with respect to key outcome variables in the pre-policy years.

Next, we check whether any key firm characteristics play a crucial role in the execution of the R&D tax credit policy for the industries mentioned above before the first policy was announced in 1998. In other words, we check if there has been a lobbying effort by certain firms toward the implementation of the policy using data for the years 1992–1997. For example, if firms that belong to the highest category of R&D expenses lobby to receive a tax credit, they can use the money to invest in improving their product quality, thereby reaping additional gains from such a policy change. In effect, we run the following specification:

$$Treated\ Industry_j = \pi\ X_{it-1} + \theta_{jt} + \epsilon_{ijt} \tag{2}$$

$Treated\ Industry_j$ is as defined before – it takes a value 1 for all industries for which the R&D tax credit policy was announced. X is a vector of firm level characteristics – R&D expenditure, gross value-added (representing size of a firm), $R\&D\ Unit_{i,<10Million}$, $R\&D\ Unit_{i,10-50Million}$, and $R\&D\ Unit_{i,>50Million}$. θ_{jt} are industry (2-digit)–year fixed effects. We cluster our estimates at the 4-digit industry level.

We present our results in **Table 3**. Columns (1) – (5) regress our treated variable, $Treated_j$, on lagged R&D expenses, lagged gross value-added, and different indicators of firms that belong to the three categories of in-house R&D expenditure. The coefficients indicate no statistical correlation between our treatment variable and the independent variables. Combining all the above observations, we can conclude that the R&D tax credit policy was exogenous to the prevailing conditions of the firms' previous R&D and their size.[16]

5 First Order Effects: R&D Expenses

5.1 Intensive Margin

The primary purpose of the R&D tax credit was to encourage and promote domestic R&D activities. Therefore, we start by checking the first order effects of the policy. **Table 4** presents the result of the effect of the R&D tax credit policy on R&D expenses of firms.

Column (1) regresses R&D expenses of firms on $Treated_{jt}$ controlling for firm and year fixed effects. We find that firms belonging to industries where the policy was implemented registered an increase of 11% in R&D expenses.[17] Column (2) introduces a triple interaction term in which we interact $Treated_{jt}$ with $R\&D\ Unit_i$. $R\&D\ Unit_i$ takes a value 1 for firms with in-house R&D unit. Our estimates show that the entire effect of the increase in R&D expenses is driven by firms with in-house R&D unit. Moreover, the effect jumps from 11 to 71%. Columns (3), (4), and (5) also introduce interactions of industry fixed effects (4-digit) with year trends, interactions of industry fixed effects (2-digit) with year fixed effects, and firm controls (age, age-squared and gross value-added). Our estimates remain positive and robustly significant. Overall, the effect of the increase in R&D expenses as a result of the R&D tax credit policy varies between 61–71%.

Next, we present our preferred empirical specification in columns (6) and (7) without and with firm controls, respectively. In particular, we introduce three indicators that show three different cut-off points regarding expenses of in-house R&D units of firms – $R\&D\ Unit_{i,<10Million}$, $R\&D\ Unit_{i,10-50Million}$, $R\&D\ Unit_{i,>50Million}$ – and their interaction with $Treated_{jt}$. We find that firms that had more than 50 million INR of in-house R&D expenses registered about 650% growth in R&D expenses, followed by firms with expenses on R&D between 10–50 million INR (148%) and firms with expenses on R&D below 10 million INR (12%). Lastly, in column (8) we use Callaway & Sant'Anna (2021) and present the average treatment effect estimates for R&D expenses. We find that similar to our OLS results, firms with $>$ 50 million INR of in-house R&D expenses had the highest increase followed by firms with 10–50 million INR of in-house R& expenses.[18]

Lastly, even though we use interactions of industry fixed effects at the most disaggregated

[16] We also perform balance tests for the years of pre-R&D tax credit policy change in **Table B.1**. We use a variety of firm characteristics (ranging from technology adoption, R&D expenses, firm inputs, and other outcomes) by dividing firms into two categories: firms with internal R&D unit vs. others.

[17] 11% is calculated using (exp(0.107) – 1) $\times$ 100. Other estimates are calculated accordingly.

[18] **Figure A.1** plots the R&D expenses of 4 different categories of firms using RD (regression discontinuity) design. The four different categories of firms are as follows: (i) 0 – firms with no in-house R&D unit; (ii) 1 – firms with in-house R&D unit of $<$ 10 million INR R&D expenses; (iii) 2 – firms with in-house R&D unit of 10–50 million INR of R&D expenses; and (iv) 3 – firms with in-house R&D unit of $>$ 50 million INR of R&D expenses. The figure clearly shows that firms with $>$ 50 million INR of R&D expenses and in-house R&D unit has 6–7 times more R&D expenses than its nearest counterpart (firms with 10–50 million INR of R&D expenses and in-house R&D unit).

level (4-digit) with year trends for all of our estimates to control for major concurrent policy changes, such as tariff reforms, delicensing of several industries, etc. we now explicitly use data on output and input tariffs at the 4-digit level to control for tariff reforms in **Table B.2**. Our results are remarkably robust across several specifications (both qualitatively and quantitatively) with no effect in case of tariff reforms.[19]

5.1.1 Event-Study Plots

A causal interpretation of our reduced form coefficients is subject to the assumption that R&D expenses for firms in R&D tax credit industries and others would have evolved comparably in the absence of the policy. Although the counterfactual cannot be directly tested, we exploit data prior to the policy change to estimate event-study specifications. In particular, we interact year fixed effects for five years prior to the policy announcement, and also seven years after, with $Treated_{ij}$. $Treated_{ij}$ assumes a value 1 if a firm i belongs to an industry for which the R&D tax credit policy was implemented.

As discussed earlier, the R&D tax credit policy was implemented in a staggered fashion. For chemicals, pharmaceuticals, computers, electrical equipment, and telecommunications it was implemented in 1998, while for aircraft it was in 2002 and for automobiles and auto parts it was in 2004. Therefore, in order to estimate the true event-study plot we follow Callaway & Sant'Anna (2021) and plot the coefficients for different years at the aggregate level (i.e., for all firms belonging to industries for which the R&D policy was implemented), for firms with in-house R&D unit, and for firms with in-house R&D unit and expenses of $>$ 50 million INR. We use the following regression equation:

$$ln(R\&D_{ijt}) = \left(\lambda_t \times Treated_{ij}\right) + \eta_i + \phi_t + \theta_j^t + \epsilon_{ijt} \tag{3}$$

where $Treated_{ij}$ assumes the value 1 for three different indicators – (i) when firm i belongs to industry j for which the R&D tax credit policy was implemented; (ii) when firm i belongs to industry j for which the R&D tax credit policy was implemented and has in-house R&D unit; and (iii) when firm i belongs to industry j for which the R&D tax credit policy was implemented and has in-house R&D unit with expenses exceeding 50 million INR.

Panels A, **B**, and **C** in **Figure 2** plot the evolution of the R&D expenses for firms belonging to the categories defined above, controlling for firm fixed effects, year fixed effects, and industry-year trends following equation (3). We compare the coefficients obtained from the regressions of our control group with those of the treated group (industries that did not get the R&D tax

[19] **Table B.3** reruns columns (1) – (7) of **Table 4** using firm expenses on foreign technology transfer as the outcome variable of interest. The idea is to check whether the R&D tax credit policy that significantly boosted domestic R&D, also simultaneously reduced firm's dependence on foreign technology transfer. We find limited evidence of such. Only firms that had in-house R&D expenses of less than 10 million INR lowered their dependence on foreign technology transfer, with no effect on other firms.

credit). The plots imply that the R&D expenses before the policy change were economically small and not statistically significant, indicating that there were no differential pre-policy trends in R&D expenses between firms in treated industries or between firms in any three categories of the control group.[20] This changed after the tax credit was implemented in 1998. The policy led to significant increase in the share of R&D expenses, especially by firms with in-house R&D units and firms with in-house R&D units and expenses of more than 50 million INR.[21,22,23]

5.2 Extensive Margin – New In-house R&D Unit

Having established that the R&D tax credit policy change positively impacted the amount of R&D expenses, especially by firms with more than 50 million INR of in-house R&D expenses, we now test whether there was a corresponding impact along the extensive margin of R&D units. Specifically, we examine whether the R&D tax credit policy led to the opening up of new in-house R&D units or not. Results are reported in **Table 5**.

DSIR reports a unique feature of the recognized in-house R&D dataset – the opening date of the in-house R&D unit. We use this aspect of the dataset to construct our outcome variable of interest. In particular, our dependent variable in this case takes a value of 1 if a firm opened up a new in-house R&D unit after the R&D tax credit policy was implemented. We find very limited evidence of the opening up of new in-house R&D units. Only firms that had R&D expenses between 10–50 million INR appeared to have opened new in-house R&D units after the policy reform.

6 Benchmark Results: Product Quality vs. Scope

6.1 Empirical Strategy

A key implication of our findings above could be how firms use these innovation investments. Firms, in reality, may face a trade-off between using innovation investments to develop

[20] The absence of pre-trends also negates the fact that other simultaneous reforms such as drop in tariffs due to the WTO membership in 1994 had any effect on R&D expenses and R&D tax credit policy was simply an amplification effect.

[21] Similarly, we also the plot the yearly coefficients of firms with in-house R&D units and expenses of less than 10 million INR (**Panel A**) and firms with in-house R&D units and expenses between 10–50 million INR (**Panel B**) in **Figure A.2**. Although the results show a significant increase in the post-policy period for firms in both groups, the pre-trends are not significantly clear.

[22] We also use OLS to plot the coefficients for all firms belonging to the treated industries vs. others (**Panel A**) and firms that have in-house R&D units and R&D expenditure exceeding 50 million INR (**Panel B**) in **Figure A.3**. The trends show similar outcomes as **Figure 2** – firms with in-house R&D units and expenses exceeding 50 million INR contribute immensely to our results.

[23] We also use binned scatter plots, but only for firms with $>$ 50 million INR of in-house R&D expenses in **Figure A.4**. The results remain the same – R&D expenses increase significantly after the policy is implemented, without much change around the implementation year. In other words, we do not find significant differences in the year pre- and after-policy.

new product varieties and upgrading the quality of the existing products to escape within-firm competition or the cannibalization effect. In other words, a firm producing multiple products can have low returns from investing in new products, as doing so may crowd out demand for its own products.

As mentioned above, a key feature of PROWESS is that it provides information on not only all the products produced by a firm but also sales and quantities of those products. We use this information to estimate the quality of the products produced by firms following the methodology developed by Amiti & Khandelwal (2013). The estimation is based on a utility function that computes the log of product quality for each firm-product-year observation. The product quality corresponds to the residual from an OLS estimation of the following equation:

$$ln(q_{ijkt}) + \sigma\, ln(p_{ijkt}) = \gamma_k + \alpha_{jt} + \eta_{ijkt} \tag{4}$$

where q is the amount of quantity sold by firm i belonging to industry j for product k at time t where p is the unit price charged. γ_k's denote product fixed effects as prices and quantities are not necessarily comparable across product categories, and α_{jt} controls for the demand and price index for each industry's (j) products. For our purpose, we use σ (2SLS) from Fujiy et al. (2023) for each 2-digit industry except leather and transport equipment. We estimate the quality of each product produced by a firm from the above equation and then standardize the estimate.

On the other hand, we create a dummy variable indicating whether a firm produces a new product or not. In other words, the dummy variable would take the value 1 if a firm introduces or produces a new product (p) in year (t), given that the firm has not produced the product in all years before it has been in operation. We use both of these variables as our outcome of interest in the equation below:

$$\begin{aligned} x_{ikt} = \beta_1 Treated_{jt} &+ \beta_2(Treated_{jt} \times R\&D\ Unit_{i,<10Million}) \\ &+\beta_3(Treated_{jt} \times R\&D\ Unit_{i,10-50Million}) \\ &+\beta_4(Treated_{jt} \times R\&D\ Unit_{i,>50Million}) \\ &+X_{it} + \eta_{ik} + \phi_t + \theta_j^t + \epsilon_{ikt} \end{aligned} \tag{5}$$

Two points worth mentioning regarding the above equation: (i) we now use firm-product-year level data rather than firm-year level data that we used to estimate Equation (1); and (ii) we replace firm fixed effects with pairwise firm-product fixed effects (η_{ik}) and cluster our standard errors two-way at the industry (4-digit) and product level. We present our results in **Table 6**.

6.2 Results

Panel A presents the results for product quality, while **Panel B** does the same for product entry. We start by estimating the effect for product quality in column (1) for all products of a firm. Our coefficients show that the R&D tax incentive significantly induces an increase in product quality, but the effect is concentrated only for firms that had in-house R&D units with R&D expenditure exceeding 50 million INR of expenses, i.e., $R\&D\ Unit_{i,>50Million}$. Given that the base (pre-policy) estimate of the quality of products produced by these firms is 0.043, the policy led to about 140% (= (0.061/0.043)*100) increase in the quality of products they produce.

Next, we divide the range of products produced by each firm into core and peripheral products in columns (2) and (3), respectively. This is to check whether $R\&D\ Unit_{i,>50Million}$ firms use the investments in R&D to imrpove the quality of only the core or the range of products they produce. The core product(s) of a firm is defined as a product(s) whose sales is greater than the 70% of total sales of a firm.[24] We find that while there is no differential effect for the core product for $R\&D\ Unit_{i,>50Million}$, there is a significant effect on the increase in product quality for peripheral products. This shows that the R&D tax credit led to an upgrade of the entire range of products produced by $R\&D\ Unit_{i,>50Million}$ firms.

Column (4) only looks at firms that belong to industries which are homogeneous or produce less differentiated products, i.e., have a high substitution elasticity. Flach & Irlacher (2018) show that firms producing multiple products in a homogeneous or less differentiated products industry invest more in process innovation rather than developing new products. To identify which industries are differentiated versus others, we follow the Rauch (1999) index which introduced a product classification scheme that has been widely used to empirically identify differentiated goods.[25] We find that our benchmark finding for $R\&D\ Unit_{i,>50Million}$ firms is overwhelmingly driven by firms that belong to less differentiated industries. The coefficient estimate increases by

[24] We have also used 60 and 65% criteria, the results remain the same.

[25] Rauch (1999) classifies SITC (Standard International Trade Classification) 4-digit product categories into three groups: homogeneous, reference price, and differentiated products. The first group comprises commodities that are traded on an organized exchange (e.g. steel, tea, or tobacco), while the second includes goods that are not sold on organized exchanges but have a benchmark price (e.g. chemicals with reference prices listed in industry guides). All remaining product categories are deemed differentiated. One problem that limits the use of Rauch (1999) index in our case is that there is no direct concordance of SITC codes with NIC (India's National Industrial Classification) codes. In order to solve this problem, we first match 4-digit NIC codes with 6-digit HS (Harmonized System) codes using Debroy & Santhanam (1993). Now, for each 4-digit NIC code, we have a number of 6-digit HS code. We then match those 6-digit HS codes with the SITC 4-digit codes using the UN classification system. At the end, each 4-digit NIC code comprises of a number of 6-digit HS codes, and these 6-digit HS codes reflect whether a good is differentiated or not. Since we do not know the exact 6-digit HS code product produced by an Indian firm, we can only identify the corresponding industry (4-digit) of a firm to be classified as a differentiated product industry or not, based on the classification of the 6-digit HS products belonging to that industry. However, there remains one problem in identifying a 4-digit industry to be differentiated or not. It is possible that within one 4-digit industry, some of the 6-digit HS codes follow the differentiated product category and some not. In this case, we classify that industry to be "less" differentiated if atleast 20% of the corresponding 6-digit HS codes are classified as either homogeneous or reference priced. Or else, if a 4-digit industry has 0 to $< 20\%$ of its products (6-digit HS codes) classified as non-differentiated, we classify that industry to be "highly" differentiated industry.

9 times. We do not find any effect for other firms.[26]

A string of studies in international trade using firm level data indicates that exporters generally sell higher-quality products than non-exporters (Hummels & Klenow (2005); Antoniades (2015); Manova & Zhang (2012)).[27] PROWESS provides information on the export status of a firm. We exploit this aspect and classify a firm as an exporter if the average exports of a firm before 1998 are greater than zero. We then estimate the effect for exporters in column (5). We find that $R\&D\ Unit_{i,>50Million}$ firms, which are exporters significantly improves the quality of their products. Additionally, we find that $R\&D\ Unit_{i,10-50Million}$ exporters also does the same, but the effect is one-fourth compared to $R\&D\ Unit_{i,>50Million}$ firms.

Figure 3 uses product quality as the outcome variable of interest for $R\&D\ Unit_{i,>50Million}$ firms which belong to homogeneous industries or industries where products have high cannibalization elasticity. We find significant increase in the quality estimates of firms with $R\&D\ Unit_{i,>50Million}$ in industries where the R&D tax credit was implemented and products are less differentiated.[28,29]

Next, in **Panel B** we replace product quality estimates with product entry as our outcome variable of interest in columns (6) – (10). Interestingly, our estimates show the effect to be opposite in terms of the R&D expenses distribution of firms. In particular, we find that $R\&D\ Unit_{i,>50Million}$ firms have no to very limited response of introducing a new product in response to the R&D tax incentive. On the other hand, firms with $R\&D\ Unit_{i,<10Million}$ and $R\&D\ Unit_{i,10-50Million}$ firms register similar and significant probability of introducing a new product. Likewise the results on product quality, the main finding is majorly driven by firms in those industries which have high cannibalization elasticity or high elasticity of substitution, i.e., less differentiated products.[30,31]

[26] We also use another measure of differentiated product industry in **Table B.4**. We use elasticity of substitution from Fujiy et al. (2023) at the 2-digit level to identify industries which have higher elasticity of substitution than the rest. In particular, industries which have higher than median elasticity of substitution for the entire manufacturing sector are classified as homogeneous or less differentiated industry. Column (1) of **Panel A** shows that our finding that $R\&D\ Unit_{i,>50Million}$ firms only upgrade the product quality of products continue to hold. We also check what happened to the firms in industries where products are highly differentiated in column (2) based on the Rauch (1999) index. We do not find any effect.

[27] This phenomenon could be driven by (i) quality sorting: most productive firms self-select themselves into the export markets and thereby have the capability to produce higher-quality goods; (ii) learning by exporting: entering foreign markets often forces firms to improve their manufacturing processes and product quality in order to compete with other international competitors; and (iii) high-quality products are necessary to overcome the fixed costs (such as tariffs) and demanding standards of international markets.

[28] We also check for the yearly plot of quality estimates for firms with $R\&D\ Unit_{i,<10Million}$ and $R\&D\ Unit_{i,10-50Million}$ using Callaway & Sant'Anna (2021) in **Figure A.5**. We do not find any significant change after the R&D tax credit policy was implemented.

[29] **Figure A.6** also checks whether R&D increased for those industries or not, using Callaway & Sant'Anna (2021). We find such to be true.

[30] **Panel B** of **Table B.4** checks for the robustness of product entry results using elasticity of substitution from Fujiy et al. (2023) as the measure for differentiation. Similar to product quality results, using other indicator does little to change the result. And, we do not find any effect for products which have low elasticity of substitution.

[31] **Table B.5** presents the ATT estimates of Callaway & Sant'Anna (2021) for product quality and product entry. We find those estimates echoing our OLS ones. In case of product quality (column (1)), firms with $>$ 50 million INR of in-house R&D expenses have the highest effect, while for product entry (column (2)) firms with $<$ 10 and 10–50 million of R&D expenses have significant effects.

Figure 4 plots the yearly coefficients employing Callaway & Sant'Anna (2021) and using product entry as the outcome variable. For this case, we put together firms with $R\&D\ Unit_{i,<10Million}$ and $R\&D\ Unit_{i,10-50Million}$ in industries which have high cannibalization elasticity. Our plots clearly show that while there was no difference in product entry for those firms in industries where the R&D tax credit was implemented before the policy, compared to others, it changed significantly afterward.[32]

6.2.1 Mechanisms

Did increase in product quality and scope, for the respective group of firms, led to any changes in production factors, such as higher-quality inputs, marketing, design, etc? Different uses of these factors may imply different changes to marginal versus fixed costs, and thus should generate heterogeneous effects across the margins of adjustment for product development. To investigate if such is the case, we use capital employed, managerial compensation, raw materials, import of production units (capital goods + raw materials), and promotional expenses (advertising + marketing + distribution) of a firm as the outcomes of interest in **Table 7**.

We find significant increase across all these production factors, but mainly for firms with $R\&D\ Unit_{i,>50Million}$. Our results show that while capital employed only increases for $R\&D\ Unit_{i,>50Million}$ firms, demand for skilled labour or managers went up for all firms. Interestingly, $R\&D\ Unit_{i,>50Million}$ firms only used imported and $R\&D\ Unit_{i,<10Million}$ firms only domestic inputs, respectively. But, $R\&D\ Unit_{i,10-50Million}$ firms used both with higher effect for domestic raw materials. Promotional expenses also increased for all types of firms; the increase is positively correlated with the size of in-house R&D unit.

6.3 What Happened to Sales, Quantity, and Price?

A quick follow–up question arises: What happened to the value of sales, the quantity sold, and the prices charged by these firms for the products produced during the period? The results are reported in **Table 8**. We find that firms in all three categories experienced an increase in sales value with results dominated by products having high substitution elasticity.

For firms belonging to $R\&D\ Unit_{i,<10Million}$, the increase in value of sales is driven by both the quantity sold and the increase in price, but largely by the increase in the former than the latter. For firms belonging to $R\&D\ Unit_{i,10-50Million}$ and $R\&D\ Unit_{i,>50Million}$, the increase in sales value is completely driven by the increase in the price of the products. This price increase reflects an improvement in product quality.[33]

[32] We also plot the yearly product entry estimates for firms with $R\&D\ Unit_{i,>50Million}$ in **Figure A.7**. Likewise our regression estimates, we do not find any effect.

[33] **Table ??** also checks what happened to gross value added (sales – raw material expenses), exports and domestic sales of a firm. Our estimates show an interesting result: R&D tax credit resulted in an increase in exports, especially for $R\&D\ Unit_{i,>50Million}$ and $R\&D\ Unit_{i,10-50Million}$ firms with a simultaneous drop in domestic sales. This implies that

Overall, our empirical results show an interesting finding and/or anomaly. Firms, based on where they are located in the distribution of R&D expenses, have differential responses to product development, product quality vs. scope, while using new R&D investments or in response to a R&D tax credit.[34] We now explain this empirical finding by using a theory model in a monopolistically competitive economy in the next section.

7 Theory

This section develops a theoretical framework to rationalize our central empirical result: following the introduction of R&D tax incentives, large firms respond by upgrading the quality of existing products, whereas smaller firms respond by expanding scope through new products.

7.1 Preferences and Demand

We assume that the utility is a Cobb-Douglas aggregate of real consumption, C_j, of a continuum of industries/sectors:

$$lnU = \int_{j\in\Omega^j} \psi_j ln\, C_j, \qquad \int_{j\in\Omega^j} \psi_j\, dj = 1 \tag{6}$$

where j denotes the industry group, ψ_j is the share of expenditure in the industry j, and Ω^j is the set of industries in the economy.

Within each industry, we assume two CES nests for firms and products. Each industry j is a CES aggregate of the i firms in that industry. Therefore, the consumption indexes for each industry C_j can be written as:

$$C_j = \left[\sum_{i\in\Omega^I_j} \left(\psi^j_i C^j_i\right)^{\frac{\sigma_I - 1}{\sigma_I}} \right]^{\frac{\sigma_I}{\sigma_I - 1}} \tag{7}$$

The real consumption of any industry j is a function of the consumption of each firm i's output C^j_i, weighted by the appeal of the firm's output $\psi^j_i > 0$, and adjusted by the substituability of the output of each firm $\sigma_I > 1$. The set of active firms in industry j is given by set Ω^I_j.

Further, consumption of each firm i is a CES aggregate of the consumption of each of its products k.

firms exported higher-quality products as a result of the R&D tax incentive.

[34]We find that all our findings are driven by domestic and not foreign firms. (Results available of request)

$$C_i^j = \left[\sum_{k \in \Omega_{ij}^K} \left(\psi_{ki}^j C_{ki}^j \right)^{\frac{\sigma_K - 1}{\sigma_K}} \right]^{\frac{\sigma_K}{\sigma_K - 1}} \tag{8}$$

The subutility from consumption of a firm's output within an industry, C_i^j is a function of consumption of each of its products C_{ki}^j, multiplied by the product quality or appeal of the product given by ψ_{ki}^j, and adjusted by the substituability between the various products supplied by the firm σ_K. The set of the products produced by firm i in industry j is given by Ω_{ij}^K.

We further assume that the substituability across products within a firm is larger than across firms, $\sigma_K \geq \sigma_I$. When they are equal, the system collapses into a single tier CES system.

The corresponding exact price indices for consumption are:

$$P_j = \left[\sum_{i \in \Omega_j^I} \left(\frac{P_i^j}{\psi_i^j} \right)^{1-\sigma_I} \right]^{\frac{1}{1-\sigma_I}} \tag{9}$$

Further, the ideal price index for consumption of each firm is given as:

$$P_i^j = \left[\sum_{k \in \Omega_{ij}^K} \left(\frac{p_{ki}^j}{\psi_{ki}^j} \right)^{1-\sigma_K} \right]^{\frac{1}{1-\sigma_K}} \tag{10}$$

Using the properties of the CES demand structure, we can derive the expenditure (or market) share of each firm within an industry j, S_i^j as the elasticity of the industry price index P_j with respect to the firm-specific price index P_i^j. Therefore, the market share of firm i is given as:

$$S_i^j = \frac{\left(\frac{P_i^j}{\psi_i^j} \right)^{1-\sigma_I}}{\sum_{l \in \Omega_j^I} \left(\frac{P_l^j}{\psi_l^j} \right)^{1-\sigma_I}} = \frac{\partial P_j}{\partial P_i^j} \frac{P_i^j}{P_j} \tag{11}$$

Similarly, the market share of each product with a firm S_{ki}^j is the elasticity of firm price index P_i^j with respect to the product price index p_{ki}^j. Therefore:

$$S_{ki}^j = \frac{\left(\frac{p_{ki}^j}{\psi_{ki}^j} \right)^{1-\sigma_K}}{\sum_{m \in \Omega_{ij}^K} \left(\frac{p_{mi}^j}{\psi_{mi}^j} \right)^{1-\sigma_K}} = \frac{\partial P_i^j}{\partial p_{ki}^j} \frac{p_{ki}^j}{P_i^j} \tag{12}$$

Equation (11) and (12) make clear how to conceive of firm appeal and product quality in this setup. Holding prices fixed, a product with higher quality has a larger market share. Similarly, a firm with higher quality has a higher market share.

Maximizing the two-tier utility subject to standard budget constraints gives us the demand equation of a product k of any firm i in industry j as:

$$C^j_{ki} = \left(\psi^j_i\right)^{\sigma_I - 1}\left(\psi^j_{ki}\right)^{\sigma_K - 1} E_j \left(P_j\right)^{\sigma_I - 1}\left(P^j_i\right)^{\sigma_K - \sigma_I}\left(p^j_{ki}\right)^{-\sigma_K} \tag{13}$$

Here, E_j denotes the industry j expenditure in $j \in \Omega^J$. The equation (13) decomposes how each element determines the demand of any product: firm appeal, product quality, industry's expenditure share, price indices of industry, firm and the product itself.

7.2 Firms

We assume a flexible technology function for firms. To produce Y_{ki} units of product k by firm i, the firm incurs a cost $C(Y_{ki})$. In addition, firms faces a fixed cost of innovation: $H^j_i > 0$. This cost is incurred if the firm uses R&D resources to either upgrade quality of one of their products k (ψ^j_{ki}) or as the fixed cost of introducing a new product into the market, and hence increasing the scope.

Profit Maximization

Each firm chooses the price of its products under Bertrand Competition to maximize profits. Therefore, each firm i in industry j chooses its set of products $k \in \{k^j_{1i}, k^j_{2i}, ..., k^j_{Ni}\}$, and the product prices p^j_{ki} to maximize the profits, where the total number of products by firm i in industry j is N^j_i.

$$\max_{\{k^j_{1i}, k^j_{2i}, ..., k^j_{Ni}\}, \{p^j_{ki}\}} \Pi^j_i = \sum_{m=k^j_{1i}}^{k^j_{Ni}} [p^j_{ki} Y^j_{ki} - C^j_{ki}(Y^j_{ki})] - H^j_i(1 - \tau^j_i) \tag{14}$$

subject to the constraint that the output of each product is equal to its consumption demand, i.e., $C^j_{ki} = Y^j_{ki}$. Here, τ^j_i is the policy support in terms of innovation tax credits that the government may provide to lower firms cost of innovation. In the baseline, $\tau^j_i = 0$. When the government provides tax credits to selected industries j: $0 < \tau^j_i < 1$.

7.3 Tax Credits

R&D tax credits, denoted by τ^j_i, reduce the fixed cost of innovation faced by firms. In our framework, we assume that this fixed cost applies symmetrically to the two alternative innovations: enhancing the quality of an existing product and introducing a new product. An increase in the tax credit therefore lowers the effective cost of both quality upgrading and scope expansion, expanding the set of profitable innovation opportunities available to the firm.

In response to a reduction in the fixed cost of innovation, a firm may choose either to invest in improving the quality of one of its existing products, ψ^j_{ki}, or to expand its product scope by launching an additional variety. Both types of investment generate direct benefits. Quality upgrading raises the appeal of the improved product, increasing its demand and the firm's revenues from that variety. Scope expansion allows the firm to access a new segment of demand and earn profits from the newly introduced product.

At the same time, both these innovation margins give rise to cannibalization forces. Improving the quality of a single product reallocates demand away from the firm's other products, reducing their sales and profits. Similarly, introducing a new product increases internal competition within the firm's portfolio, drawing demand away from incumbent varieties. As a result, the net return to innovation depends not only on the direct gains from the new or improved product, but also on the magnitude of demand reallocation across the firm's existing products.

We show in **Appendix C.1** how the rate of cannibalization differs systematically across these two margins and depends on firm characteristics, in particular the number of products supplied by the firm, N_i^j, and its market share within the industry, S_i^j.[35] Consequently, tax credits induce heterogeneous innovation responses across firms: smaller firms i.e. firms with a lower number of products are more likely to expand scope, while larger firms with higher number of products direct R&D toward quality upgrading.

The firm's choice between investing in quality or expanding scope also hinges on the relative strength of these cannibalization effects. A firm chooses to invest in quality over scope if the marginal profits from quality are greater than the marginal profits from scope increase: $\frac{\partial \Pi_i^j}{\partial \psi_{ki}^j} \geq \frac{\partial \Pi_i^j}{\partial N_i^j}$. **Appendix C.2** shows that the marginal profits are inversely related to the cannibalization rates., i.e, higher the cannibalization rate lower is the marginal profits of the innovation.

7.4 Cannibalization Effects

7.4.1 Cannibalization from Quality Investments

We define the *quality-induced demand elasticity* as the aggregate elasticity of demand across all products supplied by firm i in industry j with respect to an increase in the quality of a single product k:

$$\eta^{\text{qual}} \equiv \sum_{m=1}^{N_i^j} \frac{\partial Y_{mi}^j}{\partial \psi_{ki}^j} \frac{\psi_{ki}^j}{Y_{mi}^j}. \tag{15}$$

This elasticity captures both the direct expansion in demand for the upgraded product and the indirect effects on the firm's remaining products through cannibalization.

To build intuition, consider first the partial elasticity of demand for product m with respect to

[35] **Table B.7** uses the number of products of a firm as a proxy for firm size as it strongly correlates with other measures of firm size, for e.g. firm's market share, their R&D expenses, etc. These firm characteristics determine how strongly innovation in one product affects demand for the rest of the firm's portfolio.

the quality of product k. When $m = k$, a quality upgrade raises demand for the upgraded product directly by

$$\frac{\partial Y^j_{ki}}{\partial \psi^j_{ki}} \frac{\psi^j_{ki}}{Y^j_{ki}} = \sigma_K - 1.$$

When $m \neq k$, the quality improvement affects demand only indirectly through changes in the firm level and industry level price indices.

$$\frac{\partial Y^j_{mi}}{\partial \psi^j_{ki}} \frac{\psi^j_{ki}}{Y^j_{mi}} = -(\sigma_K - 1)\, S^j_{ki}\, \varsigma_i$$

where S^j_{ki} denotes the within-firm expenditure share of the upgraded product, and ς_i is the *cannibalization rate* of firm i.

$$\varsigma_i = \left[\frac{\sigma_K - \sigma_I}{\sigma_K - 1} + \frac{S^j_i(\sigma_I - 1)}{\sigma_K - 1}\right] \tag{16}$$

where S^j_i is the market share of firm i within industry j.

The first term reflects the degree of substitution across products within the firm relative to substitution across firms. When products within the firm are more substitutable than products supplied by different firms ($\sigma_K > \sigma_I$), a quality upgrade induces stronger reallocation of demand across the firm's own product line. The second term captures general equilibrium effects operating through the industry price index: when a firm has a larger market share, reductions in its firm level price index have a larger impact on the industry price index, amplifying cannibalization.

Aggregating across all products supplied by the firm yields the total quality-induced reduction in the demand for other products. We define this as the *quality-induced cannibalization elasticity*, which takes the form:[36]

$$\epsilon^{\text{qual}} \equiv \sum_{m \neq k} -\frac{\partial Y^j_{mi}}{\partial \psi^j_{ki}} \frac{\psi^j_{ki}}{Y^j_{mi}} = \sum_{m \neq k} (\sigma_K - 1)\, S^j_{ki}\, \varsigma_i,$$

$$\implies \epsilon^{\text{qual}} \equiv (\sigma_K - 1)\left(S^j_{ki}\, \varsigma_i\, N^j_i\right). \tag{17}$$

This expression highlights three key determinants of cannibalization from quality investments. First, cannibalization increases linearly with the number of products N^j_i, reflecting intensified internal competition within broader product portfolios. Second, it is stronger when the

[36]The total quality-induced demand elasticity is the sum of the increase in demand of the upgraded product and the decrease in demand of all the other products, i.e., $\eta^{\text{qual}} \equiv (\sigma_u - 1) + \epsilon^{\text{qual}}$

upgraded product has a larger within-firm expenditure share S_{ki}^j. Third, the magnitude of cannibalization depends on the firm's market share and the relative substitutability parameters through ς_i.

At one extreme, when $S_i^j \to 0$ and $\sigma_K = \sigma_I$, the cannibalization rate collapses to zero, and quality upgrading generates no internal demand reallocation. At the other extreme, when within-firm substitution is very high ($\sigma_K \to \infty$), the cannibalization rate approaches one, and the gains from quality upgrading are largely offset by losses on the firm's remaining products. These forces play a central role in shaping firms' optimal R&D strategies across the quality and scope margins.

7.4.2 Quality Investments: Core vs Periphery Products

When investing in quality improvement, the firm also faces an internal allocation decision: whether to upgrade a *core* or a *periphery* product. This distinction is formalized using the within-firm expenditure share of a product, S_{ki}^j. A product is considered *core* when $S_{ki}^j \to 1$, indicating that it constitutes a large share of the firm's sales. Conversely, a product is classified as *periphery* when $S_{ki}^j \to 0$, implying it is marginal within the firm's portfolio.

This distinction is economically meaningful because the cannibalization effect from a quality upgrade depends directly on S_{ki}^j: the higher the share of the product being upgraded, the greater the internal competition it creates with the rest of the firm's products. As a result, the net gain from quality investment is typically higher when targeted toward peripheral products, where cannibalization losses are more limited.

We differentiate the quality-induced cannibalization elasticity with respect to the within-firm expenditure share of the product being upgraded, S_{ki}^j:

$$\frac{\partial \epsilon^{\text{qual}}}{\partial S_{ki}^j} = (\sigma_K - 1)\, \varsigma_i\, N_i^j > 0. \tag{18}$$

This derivative is strictly positive, which implies that the cannibalization effect (which is defined as a negative effect by definition) becomes more severe as the upgraded product accounts for a larger share of the firm's total sales. In other words, the more *core* the product is to the firm's portfolio, the greater the internal competition it generates when its quality is improved.

The intuition is as follows: increasing the quality of a high-share (core) product significantly reduces the firm-level price index P_i^j, which in turn reallocates demand away from the firm's remaining products. The result is a larger cannibalization loss from internal substitution. By contrast, upgrading a *periphery* product with a small expenditure share leads to smaller distortions in demand allocation within the firm, and thus a smaller cannibalization penalty.

This result formally supports the notion that firms should optimally target quality-enhancing R&D toward peripheral products, particularly when the cannibalization rate ς_i or the number of products N_i^j is large. As a result, firms optimally direct quality-enhancing investments toward peripheral products rather than core products. By doing so, they capture the direct demand expansion associated with higher quality while limiting cannibalization within their existing product portfolio. This mechanism provides a micro-foundation for the empirical pattern we observe in **Table 6** – quality upgrading occurs at the periphery rather than in their core products.

Consider the case where products within a firm are indexed in descending order of their expenditure shares, such that product 1 is the most central (core) and product N_i^j is the most peripheral. Given the form of the quality-induced cannibalization elasticity:

$$\epsilon^{\text{qual}}\Big|_{k=n} \equiv (\sigma_K - 1)\left(S_{Ni}^j \cdot \varsigma_i \cdot N_i^j\right), \tag{19}$$

It follows that the elasticity is minimized (i.e., least negative) when the firm upgrades the quality of its most peripheral product—product N_i^j with the lowest expenditure share S_{Ni}^j. Since cannibalization losses scale linearly with S_{ki}^j, targeting a product with minimal existing market weight ensures that the reduction in demand for the firm's other products is limited.

7.4.3 Cannibalization from Scope

In response to the R&D tax credits, firms may expand their product scope by introducing new varieties or products. The optimal number of products, N_i^j, is determined by balancing the incremental profit from launching a new product against the cannibalization losses across existing products, net of fixed entry costs. As in the case of quality improvements, scope expansion generates substitution effects within the firm's portfolio, reducing the sales of incumbent products.

We define the *scope-induced cannibalization elasticity* as the aggregate percentage reduction in demand for the firm's existing products when the number of products increases marginally:[37]

$$\epsilon^{\text{scope}} \equiv \sum_{m=1}^{N_i^j}\left(-\frac{\partial Y_{mi}^j}{\partial N_i^j}\cdot\frac{N_i^j}{Y_{mi}^j}\right). \tag{20}$$

This expression captures how adding a new product reallocates demand within the firm, crowding out sales of the existing varieties. We can express the cannibalization impact on each product as:

$$-\frac{\partial Y_{mi}^j}{\partial N_i^j}\cdot\frac{N_i^j}{Y_{mi}^j} = S_{Ni}^j \cdot \varsigma_i \cdot N_i^j, \tag{21}$$

where S_{Ni}^j is the within-firm expenditure share of the N^{th} product, and ς_i is the cannibalization rate defined in Equation (16). Summing over all existing products, we obtain the total

[37] Assuming N is a continuum of products.

scope-induced elasticity:

$$\epsilon^{\text{scope}} = S^j_{Ni} \cdot \varsigma_i \cdot \left(N^j_i\right)^2. \tag{22}$$

This expression highlights the structural forces driving cannibalization from scope expansion. First, the elasticity is increasing in the number of products N^j_i: as the firm's product line grows, each new product generates stronger internal competition. Second, it rises with S^j_{Ni}, the share of the N^{th} product within the firm's sales. Third, the elasticity is scaled by the cannibalization rate ς_i, which itself increases in the firm's market share S^j_i and in the degree of substitution across products within the firm (as captured by σ_K relative to σ_I). While taking this to the data, we show that in **Table B.8** that the probability of introducing a new product is negatively correlated with the market share of the N^{th} product, S^j_{Ni}, and the number of products N^j_i, empirically supporting the theoretical micro-foundations.

Together, these forces imply that the marginal benefit of adding a new product declines as the firm becomes larger or more internally substitutable. This sets up a natural trade-off: while scope expansion can increase profits, it also reduces the returns from additional variety due to intensified cannibalization within the product portfolio.

7.5 Quality versus Scope: Cannibalization Trade-offs

Firms face a fundamental trade-off when allocating R&D resources between improving the quality of existing products and expanding the scope of their product portfolio. Quality upgrading enhances the appeal of a specific variety, thereby increasing its demand, but it also intensifies internal competition by diverting demand away from other products within the firm. Similarly, scope expansion—through the introduction of new products—broadens market coverage and raises revenues, but comes at the cost of cannibalizing sales of the firm's incumbent products. In both cases, the core friction arises from internal substitution: each new or improved variety draws demand away from others in the portfolio.

A firm chooses to invest in expanding scope rather than upgrading product quality whenever the cannibalization associated with scope expansion is lower than that associated with quality improvement:

$$\sum_m -\frac{\partial Y^j_{mi}}{\partial \psi^j_{ki}} \frac{\psi^j_{ki}}{Y^j_{mi}} > \sum_m -\frac{\partial Y^j_{mi}}{\partial N^j_i} \frac{N^j_i}{Y^j_{mi}}. \tag{23}$$

Because substitution across products within a firm is governed by σ_K, the magnitude of these cannibalization elasticities depends on the size of the firm's product portfolio. As the number of products increases, scope expansion intensifies internal substitution, raising the scope-induced cannibalization elasticity. In contrast, quality improvements increase product appeal without directly increasing the number of competing products. As a result, there exists a threshold number of products N^* such that firms with $N_i^j < N^*$ optimally expand scope, while firms with $N_i^j > N^*$ optimally invest in quality upgrading.

In order to find the optimal N_i^j, we equate the cannibalization elasticities

$$\implies S_{Ni}^j \varsigma_i (N_i^j)^2 = (\sigma_K - 1)(S_{ki}^j \varsigma_i N_i^j)$$

$$\implies N^* = (\sigma_K - 1)\frac{S_{ki}^j}{S_{Ni}^j}$$

Given the structural parameters of the firm and the market, a firm invests in scope as long as $N < N^*$. When $N \geq N^*$, the firm invests in quality to minimize the cannibalization effect. If the firm is deciding between expanding scope and enhancing the quality of its N^{th} product, the optimal N^* reduces to $\sigma_K - 1$.

To illustrate, **Figure 5** shows the optimal N^* given the structural and market parameters. We assume an across-firm substitution elasticity, σ_I of 5, a within-firm substitution elasticity, σ_K of 7, and a firm market share, S_i of 20%. The firm then decides whether to upgrade the quality of one of its products, which has a within-firm market share, S_{ki} of 10%. **Figure 5** shows that when the firm has fewer than six products, scope cannibalization is lower, so the firm chooses to introduce a new product. In contrast, when the firm already has more than six products, quality cannibalization is lower, so the firm chooses to improve the quality of the existing product.

8 Welfare Accounting

To complement the causal estimates in the preceding sections, we provide a descriptive accounting exercise following Sheu (2014). Using the exact CES price-index decomposition, we compare the observed product sets in cohort-specific pre- and post-policy reference periods and decompose the change in the effective price index into unit-price, estimated-quality, and product-variety components. This exercise does not use the treatment-control research design to construct the evolution of the price index in the absence of the tax credit [38]. The exercise provides a quantitative benchmark for the welfare relevance of these margins during the policy period, while leaving the share of the aggregate welfare change attributable to the tax credit unidentified.

Upper-tier preferences are Cobb–Douglas across industries $j = 1, \ldots, J$ with weights $\psi_j > 0$, as in Equation (6). To tractably quantify the welfare change, we consider a CES aggregator for each industry j aggregated over various products (varieties) produced by multiple firms, i.e., within each group j, preferences are CES across individual varieties $k \in \Omega_{j,r}^K$ (where $r = (t+1, t)$) with elasticity of substitution $\sigma > 1$. We assume that within an industry j, substitution elasticity across

[38] Consequently, the resulting price-index change should not be interpreted as the causal welfare effect of the R&D tax credit.

firms and within-firms are equal, i.e., $\sigma_I = \sigma_K = \sigma_j$ and quality for a variety firm-product k in industry j at time r is $\Psi^j_{k,r}$.

$$C^j_r = \left[\sum_{k \in \Omega^K_{j,r}} \left(\Psi^j_{k,r} C^j_{k,r} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \tag{24}$$

We define the price index as a factor τ_{t+1} by which the prices of all goods in time period t would have to be multiplied in order to give the same utility as the set of goods available in $t+1$.

$$\tau_{t+1} = \frac{P_{t+1}}{P_t} = \frac{\prod_{j \in J} \left(\left(\sum_{k \in \Omega^K_{j,t+1}} \frac{p^j_{k,t+1}}{\Psi^j_{k,t+1}}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \right)^{\psi_j}}{\prod_{j \in J} \left(\left(\sum_{k \in \Omega^K_{j,t}} \frac{p^j_{k,t}}{\Psi^j_{k,t}}^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \right)^{\psi_j}} \tag{25}$$

If $\Psi^j_{k,t+1} \neq \Psi^j_{k,t}$ and Ω^K_j is the set of varieties that are available in both periods, i.e., $\Omega^K_j \subseteq (\Omega^K_{j,t+1} \cap \Omega^K_{j,t})$, we show (Appendix D) that the aggregate price index can be decomposed into:

$$\tau_{t+1} = \prod_{j=1}^{J} \Big[\underbrace{\prod_{k \in \Omega^K_j} \Big(\frac{p^j_{k,t+1}}{p^j_{k,t}} \Big)^{w_{k,t+1}(\Omega^K_j)}}_{UnitPrice} \cdot \underbrace{\prod_{k \in \Omega^K_j} \Big(\frac{\Psi^j_{k,t}}{\Psi^j_{k,t+1}} \Big)^{w_{k,t+1}(\Omega^K_j)}}_{Quality} \cdot \underbrace{\Big(\frac{\lambda^{\Omega^K_j}_{t+1}}{\lambda^{\Omega^K_j}_{t}} \Big)^{\frac{1}{\sigma-1}}}_{Variety} \Big]^{\psi_j} \tag{26}$$

where,

$$w_{k,t+1}(\Omega^K_j) = \frac{\left(\frac{S^j_{k,t+1}(\Omega^K_j) - S^j_{k,t}(\Omega^K_j)}{\ln S^j_{k,t+1}(\Omega^K_j) - \ln S^j_{k,t}(\Omega^K_j)} \right)}{\sum_{k \in \Omega^K_j} \left(\frac{S^j_{k,t+1}(\Omega^K_j) - S^j_{k,t}(\Omega^K_j)}{\ln S^j_{k,t+1}(\Omega^K_j) - \ln S^j_{k,t}(\Omega^K_j)} \right)} \tag{27}$$

$$S^j_{k,t+1}(\Omega^K_{j,t+1}) = \frac{p^j_{k,t+1}\, q^j_{k,t+1}}{\sum_{k \in \Omega^K_{j,t+1}} p^j_{k,t+1}\, q^j_{k,t+1}} = \frac{\left(\frac{p^j_k}{\Psi^j_k} \right)^{1-\sigma}}{\sum_{m \in \Omega^K_j} \left(\frac{p^j_m}{\Psi^j_m} \right)^{1-\sigma}} \tag{28}$$

and

$$\lambda^{\Omega^K_j}_r = \frac{\sum_{k \in \Omega^K_j} p^j_{k,r}\, q^j_{k,r}}{\sum_{k \in \Omega^K_{j,r}} p^j_{k,r}\, q^j_{k,r}} \quad r = (t+1, t) \tag{29}$$

Figure 6 presents the evolution of the price factor τ_{t+1}, computed using 1996 as the baseline year (t), while varying the post-period year ($t+1$) from 1996 to 2005, according to Equation (26). The figure reveals a steady decline in the price factor over time, with a pronounced drop after 1998, coinciding with the broader eligibility of industries for R&D tax credits. Notably, the price factor reached 0.115 in 2002, implying that 1996 prices would have to fall by 88.5% to make consumers as well off as they were in 2002, reflecting substantial welfare gains.

8.1 Gains from Quality and Variety

Next, we quantify the welfare gains from improvements in product quality and variety using the framework described above. We consider two time periods: a pre-policy period, t, defined as three years prior to an industry's treatment, and a post-policy period, $t+1$, defined as three years after treatment.[39] For each product k within industry j, the unit price $p^j_{k,r}$ is computed as the ratio of sales value to quantity. Following Amiti & Khandelwal (2013), we obtain quality estimates $\Psi^j_{k,r}$ for $r = (t, t+1)$.

The results in **Table 9** show that the aggregate effective price factor (τ_{t+1}) is 0.067. This implies that the effective price index in the selected post-period is 93.3% below its level in the corresponding pre-period, indicating a 2.7 log points decline, reflecting substantial welfare improvements[40]. Increases in variety or product scope explain 62.5% of the decline in the price index, while quality improvements explain about 32.7% of the price decline[41].

To further isolate the individual contributions of quality improvements and variety expansion, we sequentially hold each channel constant. Specifically, to assess the role of quality, we fix product quality in the post-policy period $t+1$ at its pre-policy level in period t and compute the resulting price factor. Similarly, to evaluate the contribution of increased variety, we eliminate the effect of the extensive margin on the price index by holding the set of available products constant across periods.

$$\tau^{\Psi}_{t+1} = \prod_{j=1}^{J}\Big[\underbrace{\prod_{k\in\Omega^K_j}\Big(\frac{p^j_{k,t+1}}{p^j_{k,t}}\Big)^{w_{k,t+1}(\Omega^K_j)}}_{UnitPrice} \cdot \underbrace{1}_{Quality} \cdot \underbrace{\Big(\frac{\lambda^{\Omega^K_j}_{t+1}}{\lambda^{\Omega^K_j}_{t}}\Big)^{\frac{1}{\sigma-1}}}_{Variety}\Big]^{\psi_j} \tag{30}$$

$$\tau^{\lambda}_{t+1} = \prod_{j=1}^{J}\Big[\underbrace{\prod_{k\in\Omega^K_j}\Big(\frac{p^j_{k,t+1}}{p^j_{k,t}}\Big)^{w_{k,t+1}(\Omega^K_j)}}_{UnitPrice} \cdot \underbrace{\prod_{k\in\Omega^K_j}\Big(\frac{\Psi^j_{k,t}}{\Psi^j_{k,t+1}}\Big)^{w_{k,t+1}(\Omega^P_j)}}_{Quality} \cdot \underbrace{1}_{Variety}\Big]^{\psi_j} \tag{31}$$

[39] For untreated industries, we take pre-period as 1997 and post period as 2003.

[40] These findings also align with Jain & Singh (2023), which studies the same policy's impact on firm-level product prices in treated industries and reports significant price declines, primarily due to reduced markups conditional on costs. Similarly, Sheu (2014) reports a price index factor of 0.084 for the printer industry over 1996–2005, corresponding to a 91.6% price reduction.

[41] Equation (26) in log terms can be written as $ln(\tau_{t+1}) = \sum_{j=1}^{J}\psi_j(lnp_j + ln\Psi_j + lnN_j) = \sum_{j=1}^{J}\psi_j lnp_j + \sum_{j=1}^{J}\psi_j ln\Psi_j + \sum_{j=1}^{J}\psi_j lnN_j$ and can be used to decompose the contribution of unit prices, quality and variety to explain the decline in the aggregate effective price index. This is an observed-equilibrium comparison under the maintained demand assumptions. It captures changes over a period that includes the expansion of tax-credit eligibility, but it may also reflect contemporaneous changes in prices, quality, variety, and market composition.

As shown in **Table 9**, if product quality in $t+1$ were held at t levels, the price index would have declined by only 83.8% (corresponding to a price factor of 0.162), suggesting that quality upgrades played a substantial role. Similarly, holding the number of varieties fixed implies a price index decline of just 63.7% (price factor of 0.363), highlighting the significant welfare gains attributable to increased product varieties, but substantially less than gains due to increase in product quality.

To convert the price index to consumer surplus, we calculate the additional expenditure that the consumers have to spend to obtain the utility at time $t+1$, if prices remained as in time t.

$$\Delta C = E(U_{t+1}, P_t) - E_{t+1} = \frac{E_{t+1}}{P_{t+1}} P_t - E_{t+1} = (\frac{1}{\tau_{t+1}} - 1) E_{t+1} \tag{32}$$

The results in **Table 9** show that the consumers will have to spend almost 31 times the expenditure in time t to get the same utility as in $t+1$ if the price remained as in t. To further disentangle the gains in consumer surplus from quality upgrades, we compute the consumer surplus with the price factor, τ^z, when there is no change in quality. The results indicate that the consumers will have to spend only 11.5 times the expenditure in time t if firms didn't invest in quality, but only in scope. Similarly, if the firms did not increase scope, and only invested in quality upgrades, consumers just have to spend 3.9 times the expenditure in time t to get the same utility. The analysis suggests that improvements in product quality and the expansion of variety are associated with substantial declines in the aggregate price index and increase in consumer surplus over the policy period.

9 Conclusion

Do firms with heterogeneous in-house R&D capacity respond discordantly in terms of product development to an industrial policy aimed at boosting the R&D expenditure? In this paper, we examine a weighted R&D tax credit scheme introduced by the Government of India for firms with in-house R&D units, across manufacturing industries during the late 1990s and early 2000s. We divide firms into three different categories – firms with <10 million INR of R&D, firms with 10–50 million INR of R&D, and firms with >50 million INR of R&D – and estimate the effect of the R&D tax credit policy on the R&D expenses and product choices of these firms.

We exploit PROWESS to source detailed information on R&D expenses and production data on all products produced by these firms to calculate the probability of entry of new products and the quality of products. We find that firms with in-house R&D units significantly increased their R&D spending in response to the policy. And this was largely driven by firms with incumbent in-house R&D units of >50 million INR of R&D.

Following, we find that firms with <10 million and $10-50$ million INR of R&D optimize the R&D investments by expanding their product range or scope, while firms with >50 million

INR of R&D optimize the same investments by increasing the quality of their product range. All these effects are magnified for firms that are present in industries with high elasticity of substitution. We rationalize our findings using a multi-industry framework featuring heterogeneous firms that produce multiple differentiated products where consumer utility is derived along three dimensions: product scope, scale of products, and the quality of the products offered. Our theoretical approach extends standard models of heterogeneous firms (Melitz, 2003) by incorporating endogenous product scope and quality choices. Lastly, we show how R&D tax credits not only stimulate firm level innovation but also translate into substantial consumer welfare gains through improved product quality and expanded variety as aggregate relative price index dropped by almost 93%.

Our theory and empirical results provide novel evidence that an industrial policy, in the form of R&D tax incentives, can result in different outcomes for firms at different levels of R&D distribution resulting in different types of gains from a single policy. Developing countries, like India, should actively promote such policies in order to increase not only the innovation expenses of firms or the country in question, but for the larger objective of welfare gains attached with such policies.

References

Akçigit, U. & Kerr, W. R. (2018). Growth through heterogeneous innovations. *Journal of Political Economy*, 126(4), 1374–1443.

Amiti, M. & Khandelwal, A. K. (2013). Import competition and quality upgrading. *The Review of Economics and Statistics*, 95(2), 476–490.

Antoniades, A. (2015). The quality of a firm's exports: Where you export to matters. *Journal of International Economics*, 82(2).

Atkeson, A. & Burstein, A. T. (2019). Aggregate implications of innovation policy. *Journal of Political Economy*, 127(6), 2625–2683.

Atkin, D., Faber, B., & Gonzalez-Navarro, M. (2018). Retail globalization and household welfare: Evidence from mexico. *Journal of Political Economy*, 126(1), 1–73.

Balsmeier, B., Fleming, L., Stiebale, J., & Veihl, M. (2025). The unintended impact of R&D tax credits on innovative search. *The Review of Economics and Statistics*, Forthcoming.

Barwick, P. J., Kwon, H.-S., Li, S., Wang, Y., & Zahur, N. B. (2024). Industrial policies and innovation: Evidence from the global automobile industry. *NBER Working Paper 33138*, NBER, Massachusetts.

Bas, M. & Strauss-Kahn, V. (2015). Input-trade liberalization, export prices and quality upgrading. *Journal of International Economics*, 95(2), 250–262.

Bloom, N., Griffith, R., & Van Reenen, J. (2002). Do R&D tax credits work? Evidence from a panel of countries 1979–1997. *Journal of Public Economics*, 85(1), 1–31.

Bloom, N., Van Reenen, J., & Williams, H. (2019). A toolkit of policies to promote innovation. *Journal of Economic Perspectives*, 33(3), 163–184.

Broda, C. & Weinstein, D. E. (2006). Globalization and the gains from variety. *The Quarterly Journal of Economics*, 121(2), 541–585.

Callaway, B. & Sant'Anna, P. H. (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics*, 225(2), 200–230.

Cappelen, , Raknerud, A., & Rybalka, M. (2012). The effects of R&D tax credits on patenting and innovations. *Research Policy*, 41(2), 334–345.

Cherif, R. & Hasanov, F. (2019). The return of the policy that shall not be named: Principles of industrial policy. *IMF Working Paper Number 074*, IMF.

Choi, J. & Levchenko, A. (2024). The long-term effects of industrial policy. *NBER Working Paper No. 29263*, NBER, Massachusetts.

Criscuolo, C., Martin, R., G. Overman, H., & Van Reenen, J. (2019). Some causal effects of an industrial policy. *American Economic Review*, 109(1), 48–85.

Czarnitzki, D., Hanel, P., & Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms. *Research Policy*, 40(2), 217–229.

Debroy, B. & Santhanam, A. T. (1993). Matching trade codes with industrial codes. *Foreign Trade Bulletin*, 14(1), 5–27.

Dechezleprêtre, A., Einiö, E., Martin, R., Nguyen, K.-T., & Van Reenen, J. (2023). Do tax incentives increase firm innovation? An RD design for R&D, patents, and spillovers. *American Economic Journal: Economic Policy*, 15(4), 486–521.

Flach, L. & Irlacher, M. (2018). Product versus process: Innovation strategies of multiproduct firms. *American Economic Journal: Microeconomics*, 10(1), 236–277.

Fujiy, B. C., Ghose, D., & Khanna, G. (2023). Production networks and firm-level elasticities of substitution. *Mimeo, The World Bank*.

Goldberg, P. K., Khandelwal, A. K., Pavcnik, N., & Topalova, P. (2010). Imported intermediate inputs and domestic product growth: Evidence from india. *The Quarterly Journal of Economics*, 125(4), 1727–1767.

Guceri, I. & Liu, L. (2019). Effectiveness of fiscal incentives for R&D: Quasi-experimental evidence. *American Economic Journal: Economic Policy*, 11(1), 266–291.

Guo, D., Guo, Y., & Jiang, K. (2016). Government-subsidized R&D and firm innovation: Evidence from China. *Research Policy*, 45(6), 1129–1144.

Hottman, C. J., Redding, S. J., & Weinstein, D. E. (2016). Quantifying the sources of firm heterogeneity. *The Quarterly Journal of Economics*, 131(3), 1291–1364.

Hummels, D. & Klenow, P. (2005). The variety and quality of a nation's exports. *American Economic Review*, 95(3), 704–723.

Imbens, G. & Wooldridge, J. M. (2008). Recent developments in the econometrics of program evaluation. *Journal of Economic Literature*, 47(1), 5–86.

Ivus, O., Jose, M., & Sharma, R. (2021). R&D tax credit and innovation: Evidence from private firms in India. *Research Policy*, 50, 104128.

Jain, T. & Singh, R. (2023). R&D tax credits and price competition: Evidence from India. *Mimeo, Ahmedabad University*.

Juh´asz, R., Lane, N., Oehlsen, E., & P´erez, V. C. (2023). The who, what, when, and how of industrial policy: A text-based approach. *Mimeo, University of British Columbia*.

Khandelwal, A. (2010). The long and short (of) quality ladders. *The Review of Economic Studies*, 77(4), 1450–1476.

Labeaga, J. M., Martínez-Ros, E., Sanchis, A., & A. Sanchis, J. (2021). Does persistence in using R&D tax credits help to achieve product innovations? *Technological Forecasting & Social Change*, 173, 121065.

Lane, N. (2025). Manufacturing revolutions: Industrial policy and industrialization in South Korea. *The Quarterly Journal of Economics*, 140(3), 1–59.

Liu, W., Cowling, M., & Zhang, N. (2025). The innovation impacts of R&D tax credits in the UK. *R&D Management*, Forthcoming.

Manova, K. & Zhang, Z. (2012). Export prices across firms and destinations. *The Quarterly Journal of Economics*, 127(1), 379–436.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6), 1695–1725.

Melnik, W. (2024). R&D tax credits and innovation. *Journal of Public Economics*, 232, 104995.

Parente, R. M., Baquie, S., Huang, Y., Jaumotte, F., Kim, J., & Pienknagura, S. (2025). Industrial policies and firm performance: A nuanced relationship. *IMF Working Paper Number 143*, IMF.

Pless, J. (2025). Are complementary policies substitutes? Evidence from R&D subsidies in the UK. *American Economic Journal: Economic Policy*, Forthcoming.

Rao, N. S. (2016). Do tax credits stimulate R&D spending? The effect of the R&D tax credit in its first decade. *Journal of Public Economics*, 140, 1–12.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of International Economics*, 48(1), 7–35.

Sheu, G. (2014). Price, quality, and variety: Measuring the gains from trade in differentiated products. *American Economic Journal: Applied Economics*, 6(4), 66–89.

Yang, C., Huang, C., & Hou, T. (2012). Tax incentives and R&D activity: Firm-level evidence from Taiwan. *Research Policy*, 41(9), 1578–1588.

Yueling, H., Baquie, S., Jaumotte, F., Kim, J., Lu, Y., Parente, R. M., & Pienknagura, S. (2025). Do industrial policies increase trade competitiveness. *IMF Working Paper Number 98*, IMF.

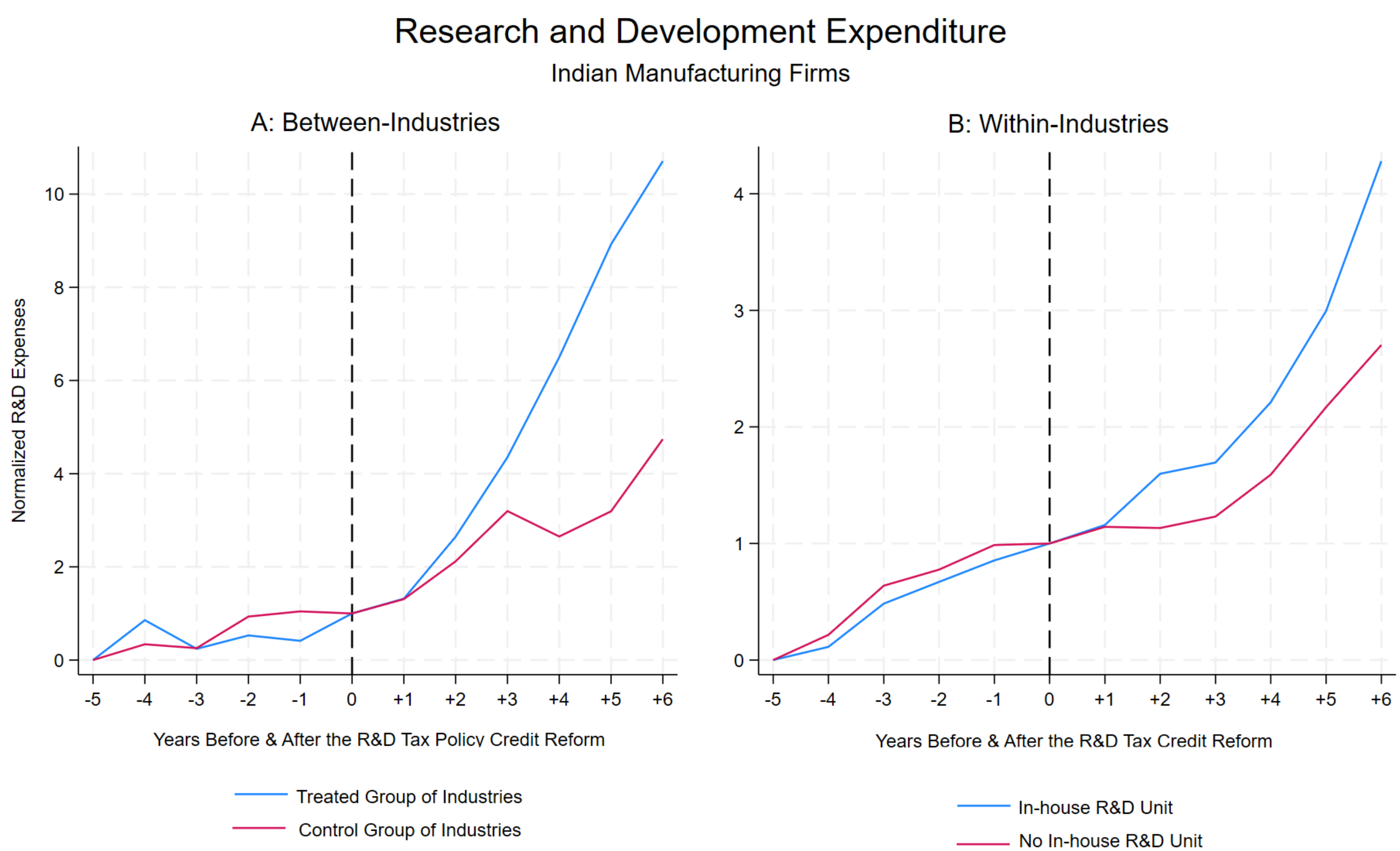

Figure 1: Research and Development Expenditure

Notes: Figure represents normalized Research and Development (R&D) Expenditure for Indian manufacturing firms. Panel A presents the values for treated (for whose the R&D tax credit policy was undertaken) and control group of industries. Panel B present the values for firms with recognized in-house R&D units versus firms with no in-house R&D units. The R&D tax credit policy was announced for the following industries: (1) chemicals, (2) drugs and pharmaceuticals, (3) electronic equipment, (4) computers, (5) telecommunication equipments, (6) aircrafts and helicopters, and (7) automobiles and auto parts.

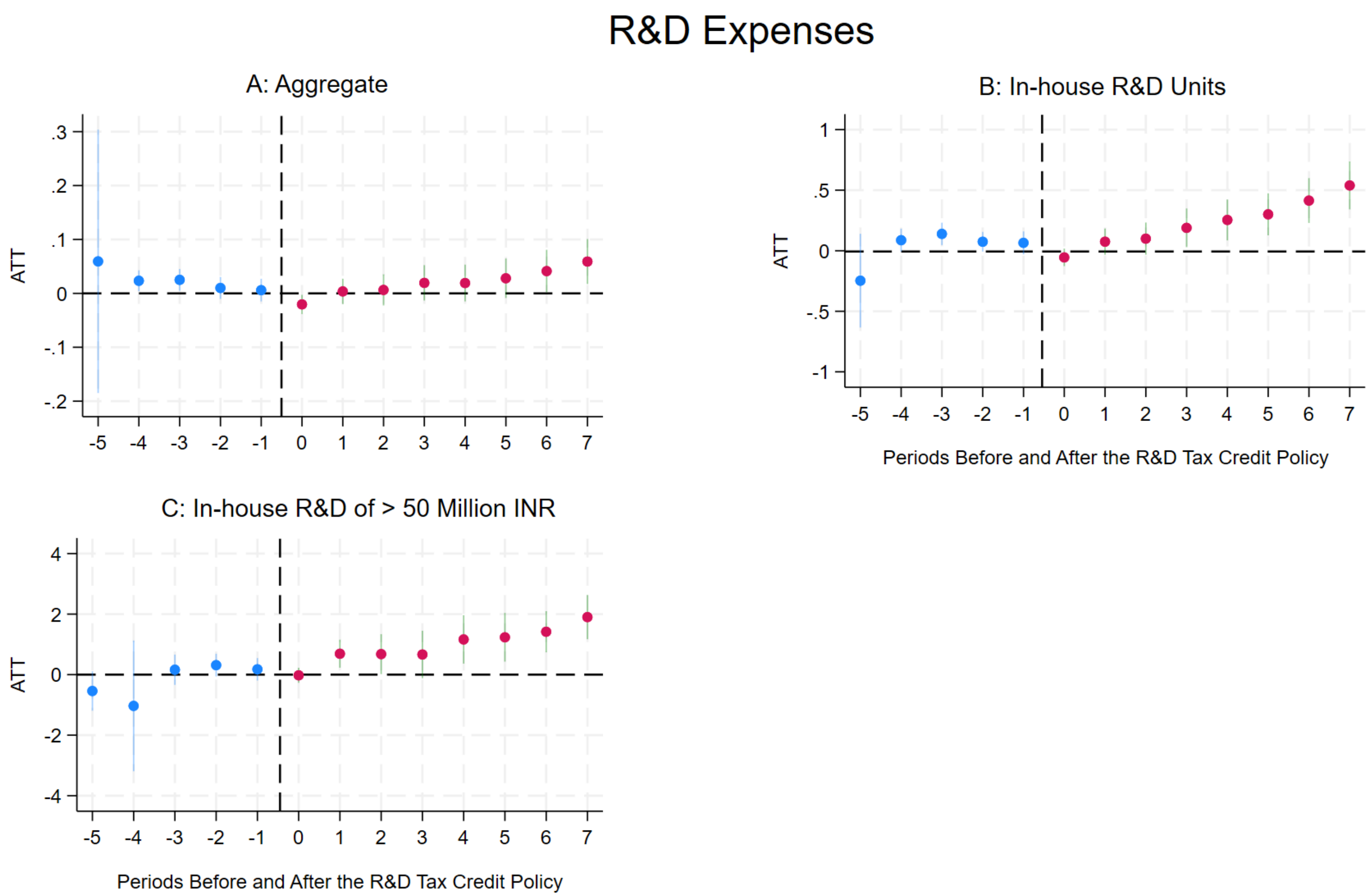

Figure 2: Effects of R&D Tax Credit on R&D Expenditure

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the R&D expenses for firms in treated and control group of industries at the aggregate (Panel A) and for firms with in-house R&D unit and no in-house R&D unit (Panel B) and for firms with in-house R&D unit and expenses of more than INR 50 Million (Panel C) in treated and control group of industries. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

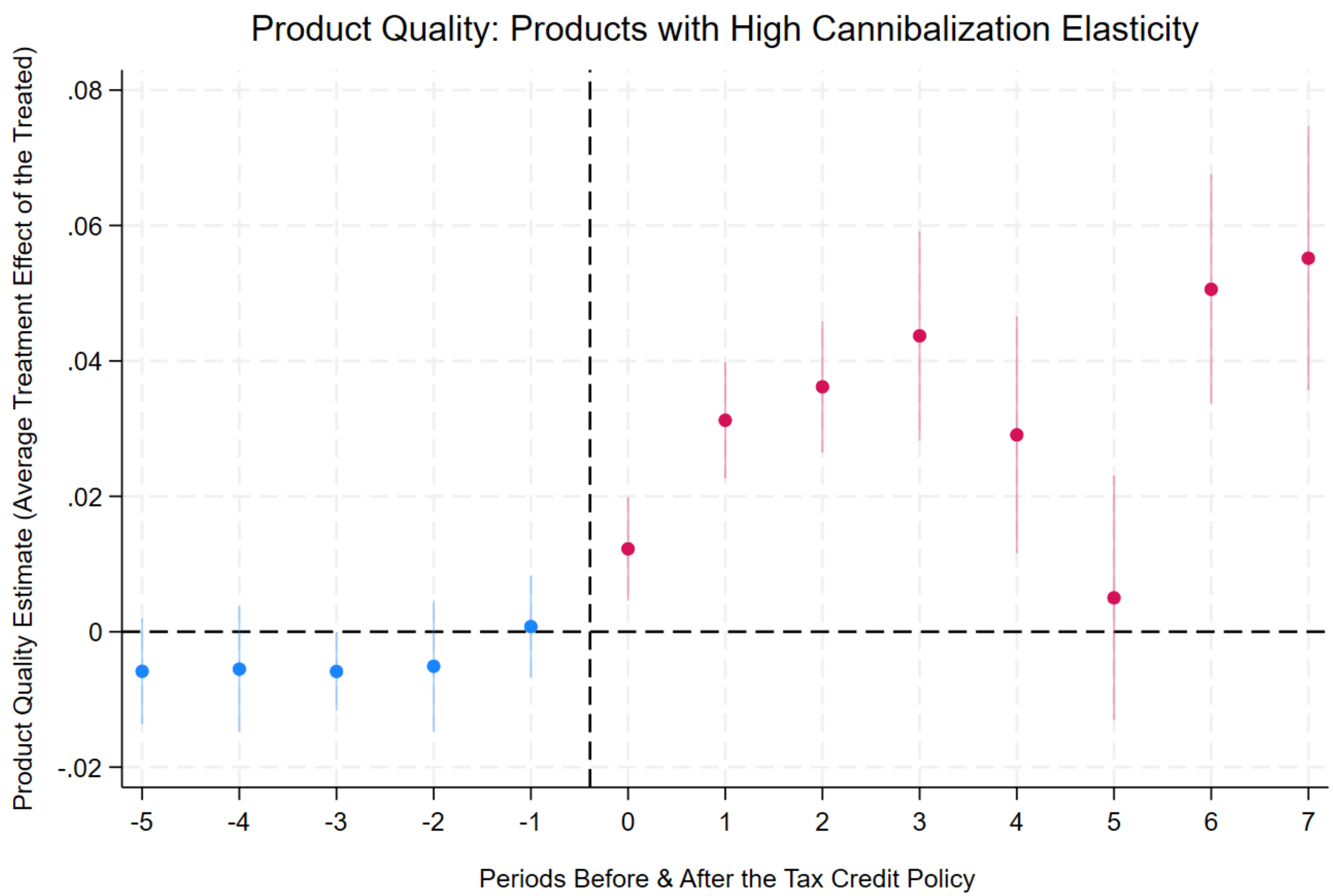

Figure 3: Effects of R&D Tax Credit on Product Quality – Firms with $>$ 50 million INR R&D and Producing Products with High Cannibalization Elasticity

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the product quality of firms with in-house R&D units and R&D expenses of more than 50 million INR which are in treated and control group of industries for products which have high elasticity of substitution or less differentiated. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm-product fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

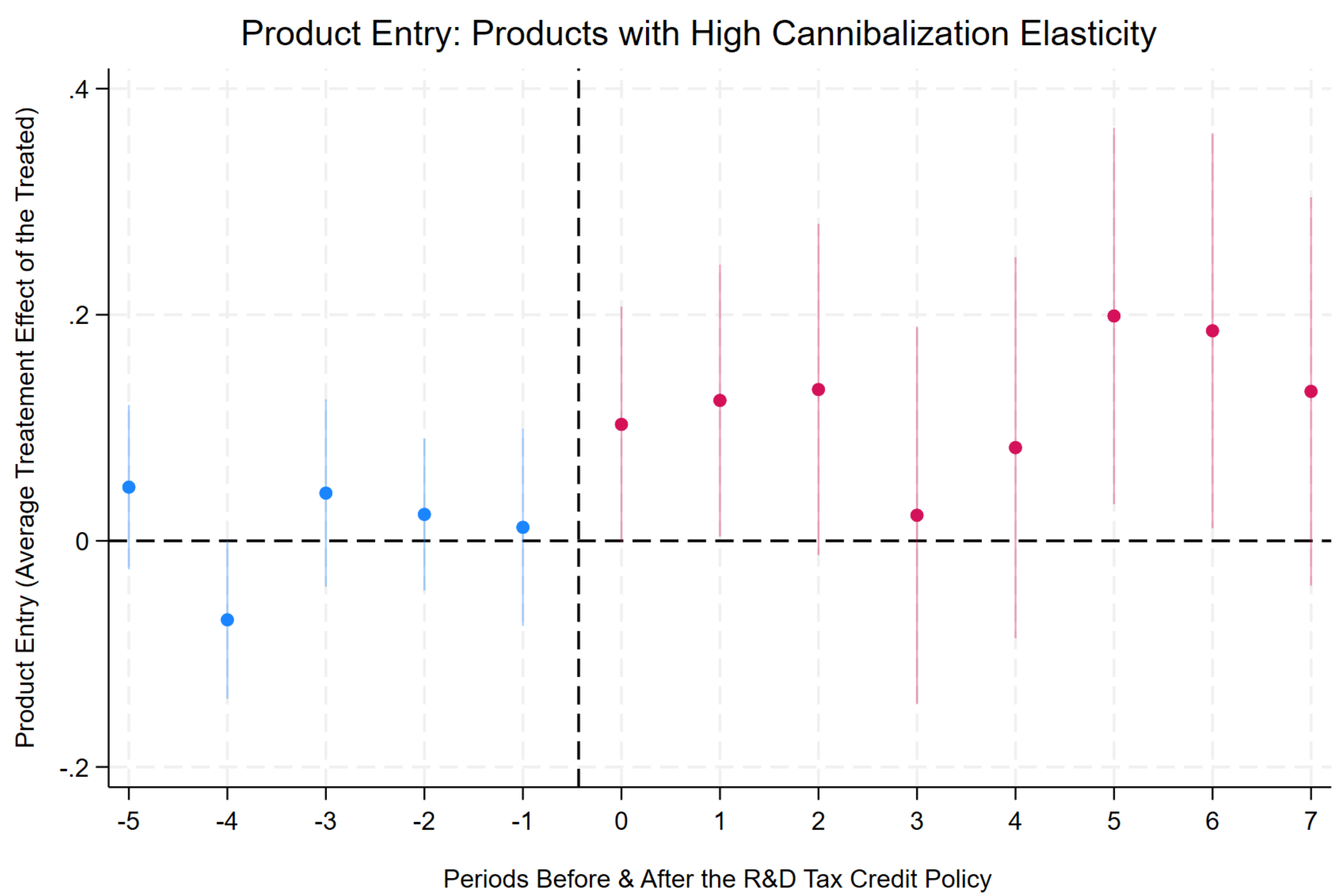

Figure 4: Effects of R&D Tax Credit on Product Scope – Firms with > 10 & 10–50 million INR R&D and In-house R&D Unit

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the probabilities of new product entry firms with in-house R&D units and R&D expenses of less than 10 million and 10–50 INR which are in treated and control group of industries for products which have high elasticity of substitution or less differentiated. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

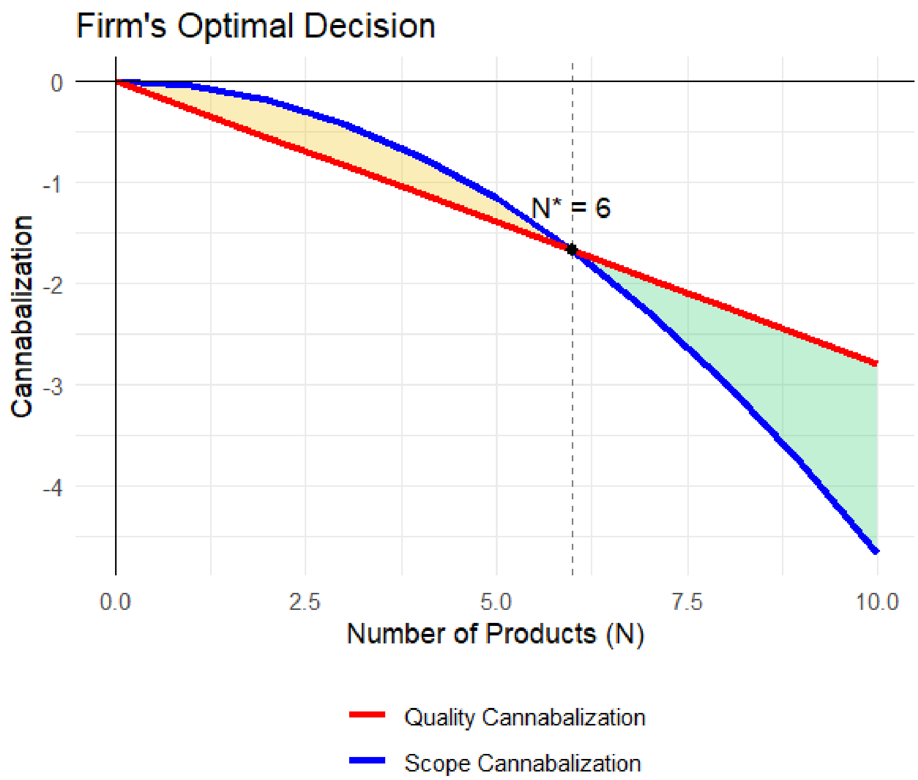

Figure 5: Quality vs Scope Induced Cannibalization Elasticity with Number of Products
Notes: The figure plots Equations (17) and (22) as a function of number of products N, under the assumption of across-firm substitution elasticity as 5, and the within-firm substitution elasticity as 7 for a firm with market share S_i^j of 0.2 and for a product with within-firm market share S_{ki}^j of 0.1.

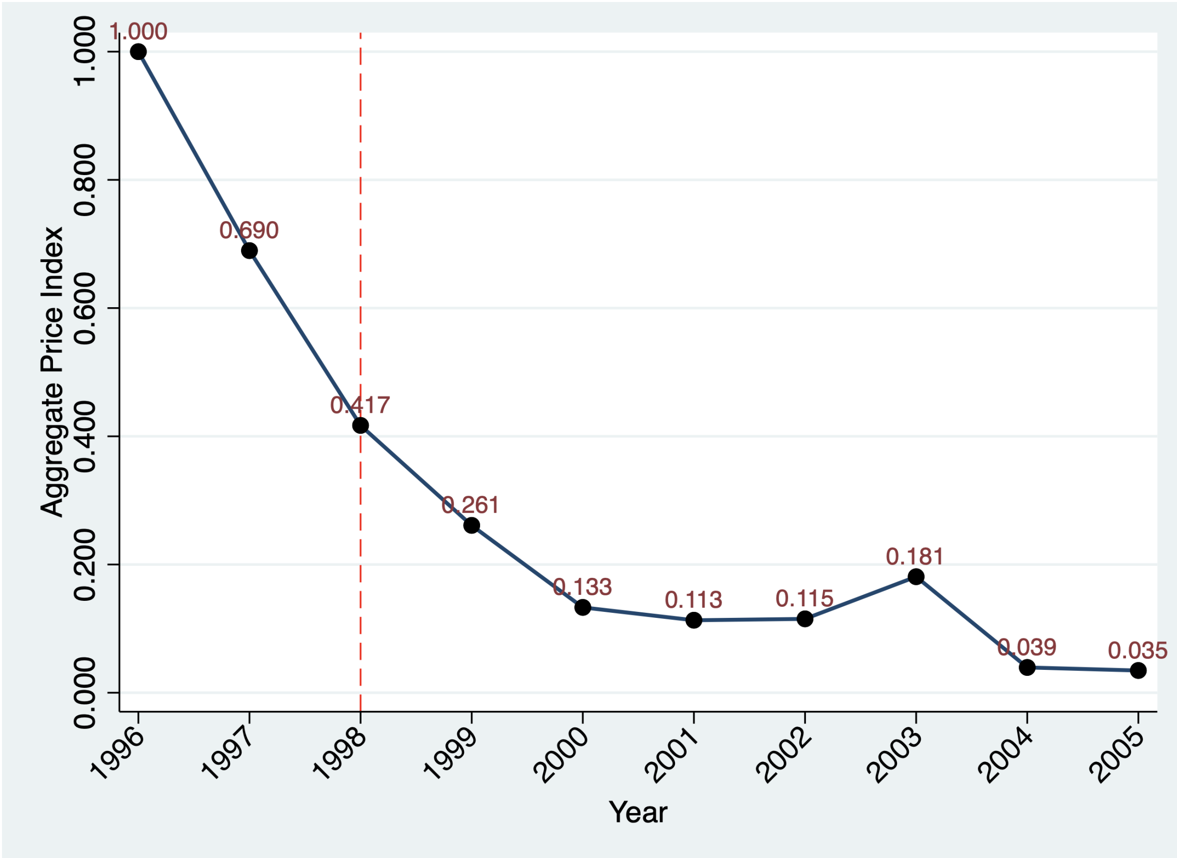

Figure 6: Price Index Factor over Time

Notes: Figure presents the evolution of τ_{t+1} as given in Equations (25) and (26). For every firm-product combination within an industry, we calculate yearly quality estimates (following Amiti & Khandelwal (2013)), infer unit prices (from sales/quantity), and estimate the share of entry and exit to capture variety (as in equation (29)) from the data. The price factor is calculated using 1996 as the pre-period (t) and subsequently changing the post-period ($t+1$) from 1996 to 2005. The values are based on the overall evolution of variables in the aggregate data. The vertical red line indicates the year when most industries were treated with R&D tax credits.

Table 1: Summary Statistics – R&D Expenditure, Product Entry, and Product Quality

	R&D Expenditure (1)	Product Quality (2)	Product Entry (3)
All Firms	2.528	3.27e-11	0.149
$R\&D\ Unit_{i,<10\ Million}$	2.247	0.001	0.146
$R\&D\ Unit_{i,10-50\ Million}$	18.379	0.006	0.135
$R\&D\ Unit_{i,>50\ Million}$	168.494	0.032	0.131

Notes: Numbers show the average value for a firm. Column (1) presents R&D Expenses of a firm in INR (Indian Rupees) Millions. Column (2) presents the probabilities of a new product being introduced by a firm. Column (3) presents the estimates of quality of an individual product produced by a firm. This is unit-free and standardized.

Table 2: Differences in Pre-Trends: Treated and Control Industries

	R&D Expenditure (1)	Product Quality (2)	Product Entry (3)
Treated Industry$_j$ × *Year*$_{1992}$	0.001	–0.240	–0.010
	(0.024)	(0.166)	(0.034)
Treated Industry$_j$ × *Year*$_{1993}$	0.009	–0.255	–0.021
	(0.024)	(0.209)	(0.034)
Treated Industry$_j$ × *Year*$_{1994}$	–0.016	–0.127	–0.027
	(0.019)	(0.225)	(0.032)
Treated Industry$_j$ × *Year*$_{1995}$	0.002	0.184	0.006
	(0.016)	(0.217)	(0.030)
Treated Industry$_j$ × *Year*$_{1996}$	0.009	0.073	0.017
	(0.008)	(0.289)	(0.018)
Treated Industry$_j$ × *Year*$_{1997}$	0.022	0.069	0.018
	(0.013)	(0.144)	(0.019)
R-Square	0.64	0.54	0.88
N	57,040	119,497	132,568
Firm Controls	✓	✓	✓
Firm FE	✓	X	X
Firm-Product FE	X	✓	✓
Year FE	✓	✓	✓
Industry FE (4-digit) × Year Trend	✓	✓	✓

Notes: All the regressions are run for the years 1992–1997. Columns (1), (2), and (3) use expenses on research and development, product entry, and product quality as the dependent variables, respectively. *Treated Industry*$_j$ is the treated dummy. It takes a value 1 for the industries (at 4-digit level) for which a tax deduction of 150% was announced for any in-house R&D capital and revenue expenditure incurred by firms. The industries which were listed in the R&D tax credit are the following: (1) drugs and pharmaceuticals, (2) electronic equipment, (3) computers, (4) telecommunications equipment, (5) chemicals, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. '*Year*$_{1992}$', '*Year*$_{1993}$', '*Year*$_{1994}$', '*Year*$_{1995}$', '*Year*$_{1996}$', '*Year*$_{1997}$' are year dummies. These dummies are equal to 1 for the respective years. Firm controls include the age of a firm and the age squared of a firm. Numbers in the parentheses are clustered standard errors at the industry (4-digit) level for columns (1) and (2). For columns (3) and (4), the standard errors are two-way clustered at the firm-product and industry (4-digit) level. Intercepts are not reported. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table 3: Endogeneity Checks: R&D Tax Credit Policy

	Treated Industry$_j$				
	(1)	(2)	(3)	(4)	(5)
R&D Expenses$_{it-1}$	0.002				
	(0.002)				
Gross Value-added$_{it-1}$		0.000			
		(0.000)			
$R\&D\ Unit_{i,<10Million}$			0.006		
			(0.004)		
$R\&D\ Unit_{i,10-50Million}$				0.015	
				(0.013)	
$R\&D\ Unit_{i,>50Million}$					0.010
					(0.014)
R-Square	0.98	0.98	0.98	0.98	0.98
N	62,805	61,841	71,771	71,771	71,771
Industry FE (2-digit) × Year FE	Yes	Yes	Yes	Yes	Yes

Notes: Columns (1) – (5) use $Treated\ Industry_j$ as the dependent variable. It takes a value 1 for the following industries: chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment, aircraft, and automobile parts. R&D Expenses is the R&D expenditure of a firm; Gross Value-added (= sales - raw material expenses) is the gross value-added of a firm; $R\&D\ Unit_{i,<10Million}$ takes a value 1 if a firm's in-house R&D unit has expenses less than 10 million INR; $R\&D\ Unit_{i,10-50Million}$ takes a value 1 if a firm's in-house R&D unit has expenses between 10–50 million INR; and $R\&D\ Unit_{i,>50Million}$ takes a value 1 if a firm's in-house R&D unit has expenses more than 50 million INR. Numbers in the parentheses are robust standard errors clustered at the 4-digit industry level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table 4: R&D Tax Credit and R&D Expenses – Intensive Margin

	R&D Expenditure							
	Aggregate					R&D Categories		ATE – C&S (2021)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Treated_{jt}$	0.107**	–0.032	–0.044**	–0.135*	–0.040*	–0.021	–0.011	
	(0.043)	(0.030)	(0.020)	(0.071)	(0.020)	(0.021)	(0.024)	
$Treated_{jt} \times R\&D\ Unit_i$		0.539***	0.539***	0.535***	0.478***			
		(0.062)	(0.063)	(0.063)	(0.050)			
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$						0.193***	0.113***	0.026
						(0.041)	(0.034)	(0.065)
$Treated_{jt} \times R\&D\ Unit_{i,<10-50\ Million}$						1.014***	0.908***	0.375***
						(0.078)	(0.085)	(0.141)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$						2.181***	2.012***	1.033***
						(0.300)	(0.225)	(0.282)
R-square	0.59	0.61	0.61	0.62	0.65	0.62	0.65	–
N	162,342	162,342	162,342	162,342	133,180	162,342	133,180	133,180
Firm Controls	X	X	X	X	✓	X	✓	✓
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	X	✓	✓	✓	✓
Industry FE (4-digit) × Year Trend	X	X	✓	X	✓	✓	✓	✓
Industry FE (2-digit) × Year FE	X	X	X	✓	X	X	✓	X

Notes: Columns (1) – (8) use research and development expenses (current plus capital) by a firm as the dependent variable, respectively. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_i$ takes a value 1 for firm i that has a registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research). $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered R&D unit has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Column (8) presents average treatment effects (ATE) for the treated following Callaway & Sant'Anna (2021). Firm controls include age of a firm, age squared, and real gross value-added of a firm. Standard errors are clustered at 4-digit industry level. Intercepts are not reported. *,**,*** denotes 10%, 5%, and 1% level of significance, respectively.

Table 5: R&D Tax Credit and R&D Expenses – Extensive Margin

	New R&D Unit $= 1$ *if year* > 1997			
	(1)	(2)	(3)	(4)
$Treated_{jt}$	0.004			
	(0.004)			
$Treated_{jt} \times R\&D\ Unit_i$		0.038*		
		(0.023)		
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$			–0.028	–0.010
			(0.022)	(0.028)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$			0.039	0.079**
			(0.037)	(0.037)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$			0.042	0.033
			(0.040)	(0.034)
R-Square	0.05	0.05	0.05	0.19
N	13,302	13,302	13,302	12,205
Firm Controls	X	X	X	✓
Year FE	✓	✓	✓	✓
Industry FE (4-digit) × Year Trend	✓	✓	✓	✓

Notes: All the regressions are for the years 1992–2007. Columns (1) – (4) use a dummy variable as the dependent variable. It takes a value 1 if a firm registers a new R&D unit with DSIR (Department of Scientific and Industrial Research) after the Govt. of India announced the tax rebate for certain industries (chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment, aircraft, and auto parts). $R\&D\ Unit_i$ takes a value 1 for firm i that has a registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research). $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered R&D unit has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include the age of a firm, age squared, and the real gross value-added of a firm. Standard errors are clustered at 4-digit industry level. Intercepts are not reported. *,**,*** denotes 10%, 5%, and 1% level of significance, respectively.

Table 6: R&D Tax Credit and Firm Product Choice – Quality vs. Scope

	All Products	Core Products	Peripheral Products	Less Differen. Products	Exporting Firms
	Panel A: Product Quality				
	(1)	(2)	(3)	(4)	(5)
$Treated_{jt}$	0.011	0.131***	0.013	0.012	0.022*
	(0.012)	(0.016)	(0.013)	(0.039)	(0.013)
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$	0.004	–0.004	0.001	0.072	0.002
	(0.005)	(0.007)	(0.005)	(0.088)	(0.006)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$	0.016	0.010	0.008	–0.052	0.014**
	(0.016)	(0.012)	(0.006)	(0.093)	(0.007)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$	0.061***	0.007	0.064***	0.549***	0.056***
	(0.012)	(0.015)	(0.011)	(0.083)	(0.012)
R-Square	0.22	0.83	0.27	0.23	0.18
N	248,757	47,241	200,821	96,988	205,398
	Panel B: Product Entry				
	(6)	(7)	(8)	(9)	(10)
$Treated_{jt}$	–0.023**	–0.026**	–0.020***	–0.029***	–0.018***
	(0.006)	(0.012)	(0.006)	(0.007)	(0.006)
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$	0.053***	0.041**	0.057***	0.059***	0.039***
	(0.008)	(0.020)	(0.009)	(0.010)	(0.008)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$	0.063***	0.059**	0.065***	0.087***	0.047***
	(0.007)	(0.023)	(0.008)	(0.009)	(0.007)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$	0.022	0.053	0.021*	0.017	0.008
	(0.020)	(0.035)	(0.012)	(0.015)	(0.010)
R-Square	0.37	0.46	0.37	0.37	0.38
N	283,065	54,420	227,740	249,340	227,910
Firm Controls	✓	✓	✓	✓	✓
Firm-Product FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
Industry FE (4-digit) X Year Trend	✓	✓	✓	✓	✓

Notes: All the regressions are for the years 1992–2007 and employ firm-product-year level data. Columns (1) – (5) use product quality and columns (6) – (10) uses a new product entry of a firm as the dependent variable, respectively. We use Amiti & Khandelwal (2013) to estimate the product quality. For estimation of product quality, we use the elasticities of substitution at the HS2 industry level from Fujiy et al. (2023) using the 2SLS method. In case of product entry, it takes a value 1 when a new product appears in the sample given that it hasn't in any year of that firm's operational years. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research) has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include the age of a firm, age squared, and the real gross value-added of a firm. Numbers in the parentheses are two-way clustered standard errors at industry and product level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table 7: R&D Tax Credit and Production Factors: Mechanisms

	Capital Employed (1)	Skilled Labour Compensation (2)	Raw Materials (3)	Import of Production Units (4)	Promotional Expenses (5)
$Treated_{jt}$	–0.007	–0.018	–0.059	0.001	–0.031
	(0.032)	(0.022)	(0.054)	(0.052)	(0.024)
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$	0.045	0.203***	0.204**	0.094	0.209***
	(0.074)	(0.039)	(0.089)	(0.107)	(0.048)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$	0.143	0.316***	0.755***	0.479***	0.582***
	(0.115)	(0.062)	(0.154)	(0.105)	(0.087)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$	0.142**	1.181***	0.564**	0.721**	0.927***
	(0.067)	(0.295)	(0.230)	(0.293)	(0.113)
R-Square	0.91	0.64	0.84	0.77	0.81
N	131,436	133,180	133,178	133,180	133,180
Firm Controls	✓	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓
Industry FE (4-digit) X Year Trend	✓	✓	✓	✓	✓

Notes: All the regressions are for the years 1992–2007 and employ firm-year level data. Column (1) use capital employed; column (2) use skilled labour or managerial compensation; column (3) use raw materials expenditure; column (4) use import of production units (raw materials plus capital goods); column (5) use promotional expenses (advertising + marketing + distribution) of a firm as the dependent variable, respectively. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research) has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include age of a firm, age squared, and real gross value-added of a firm. Standard errors are clustered at 4-digit industry level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table 8: R&D Tax Credit and Firm-Product Sales

	Product Sales		Product Quantity		Product Price (Unit)	
	All	Less Differen. Products	All	Less Differen. Products	All	Less Differen. Products
	(1)	(2)	(3)	(4)	(5)	(6)
$Treated_{jt}$	–0.068*	0.227	–0.086	–0.190	–0.119***	–0.209
	(0.038)	(0.144)	(0.058)	(0.142)	(0.037)	(0.169)
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$	0.193***	0.146*	0.280***	0.306***	0.122***	0.136
	(0.068)	(0.078)	(0.095)	(0.110)	(0.036)	(0.107)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$	0.200***	0.238***	0.105	–0.005	0.163***	0.231*
	(0.068)	(0.080)	(0.096)	(0.101)	(0.036)	(0.120)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$	0.475***	0.632***	0.062	0.119	0.273***	0.461***
	(0.139)	(0.163)	(0.137)	(0.163)	(0.064)	(0.159)
R-Square	0.34	0.36	0.38	0.36	0.57	0.49
N	285,201	59,834	285,192	59,831	180,578	36,392
Firm Controls	✓	✓	✓	✓	✓	✓
Firm-Product FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Industry FE (4-digit) X Year Trend	✓	✓	✓	✓	✓	✓

Notes: All the regressions are for the years 1992–2007 and employ firm-product-year level data. Columns (1) – (2) use product level sales; columns (3) – (4) use quantity of product sold; columns (5) – (6) use unit price (value/quantity) of a firm as the dependent variable, respectively. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research) has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include the age of a firm, age squared, and the real gross value-added of a firm. Numbers in the parentheses are two-way clustered standard errors at the industry and product level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table 9: Descriptive Decomposition of Effective Price Changes

	Aggregate	**Quality**	**Variety**	**Unit Price**
Panel A. Decomposition of the observed aggregate effective-price change				
Effective price factor, τ	0.067			
Log change, $\ln \tau$	-2.703	-0.880	-1.690	-0.130
Share of total log change		32.7%	62.5%	4.8%
Panel B. Partial price-index calculations and expenditure-equivalent gains				
	Aggregate	**Quality held fixed**	**Variety held fixed**	**Unit price held fixed**
Effective price factor, τ	0.067	0.162	0.363	0.076
Effective-price reduction, $100 \times (1 - \tau)$	93.3	83.8	63.7	92.4
Expenditure-equivalent gain, ΔC	$31.03\, E_t$	$11.5\, E_t$	$3.9\, E_t$	$27\, E_t$

Notes. Panel A provides a descriptive decomposition of the aggregate effective-price change between the cohort-specific pre- and post-policy reference periods. The aggregate effective price factor, τ, is defined in Equation (26). The log change is decomposed into the contributions of estimated quality, product variety, and unit prices. The component log changes sum to the aggregate log change up to rounding, and the reported shares measure each component's contribution to the total log change.

Panel B reports partial price-index calculations obtained by holding, in turn, estimated quality, product variety, or unit prices fixed between the two reference periods while retaining the observed changes in the other components. The expenditure-equivalent gain is calculated as $\frac{\Delta C}{E_t} = \left(\frac{1}{\tau} - 1\right) \frac{E_{t+1}}{E_t}$, and is reported in units of period-t expenditure, E_t.

Online Appendix for

R&D Tax Credit and Product Quality vs. Scope

Pavel Chakraborty
University of Bath

Sankalp Mathur
CAFRAL, RBI

Sujaya Sircar
IIT Kanpur

Rubina Verma
Georgetown University

A Graphs

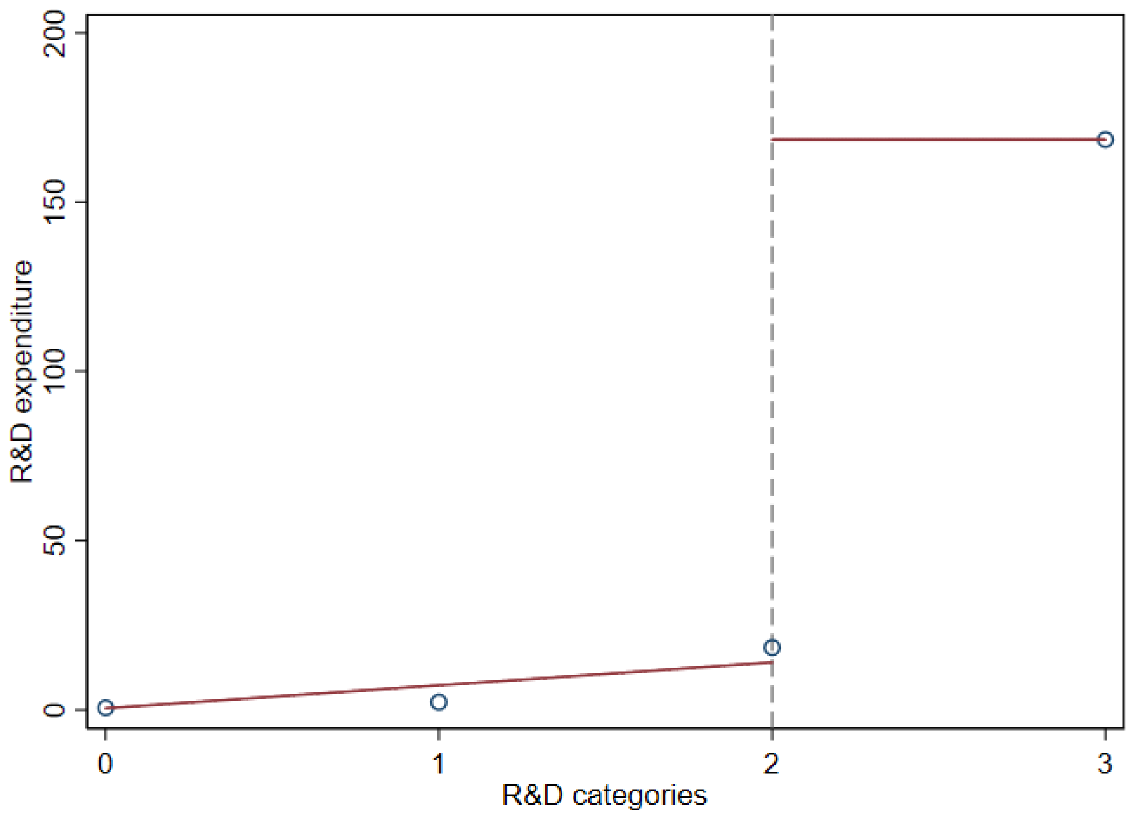

Figure A.1: R&D Expenses of Different R&D Categories

Notes: Figure presents the RDD (Regression Discontinuity Design) estimate of R&D Expenses for 4 different categories of firms: (a) 0 – firms with no in-house R&D unit; (b) 1 – firms with in-house R&D unit of $<$ 10 million INR R&D expenses; (c) 2 – firms with in-house R&D unit of 10–50 million INR of R&D expenses; and (d) 3 – firms with in-house R&D unit of $>$ 50 million INR of R&D expenses. Our coefficient estimates are controlled for firm fixed effects.

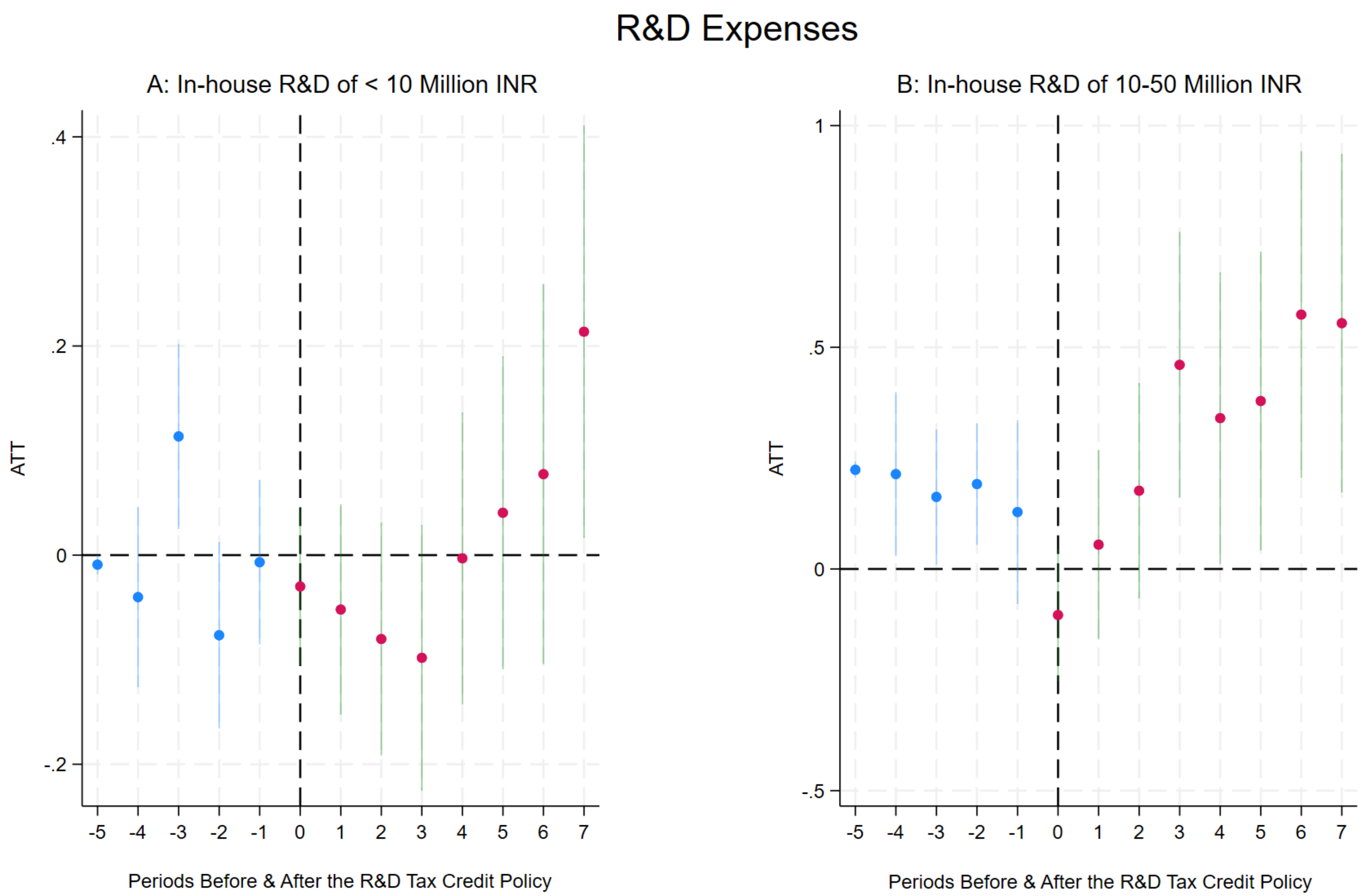

Figure A.2: Effect of R&D Tax Credit on R&D Expenditure – Other Firms

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the R&D expenses for firms with in-house R&D units and expenses of less than INR 10 Million (Panel A) in treated and control group of industries and for firms with in-house R&D units and expenses between INR 10–50 Million (Panel B) in treated and control group of industries. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

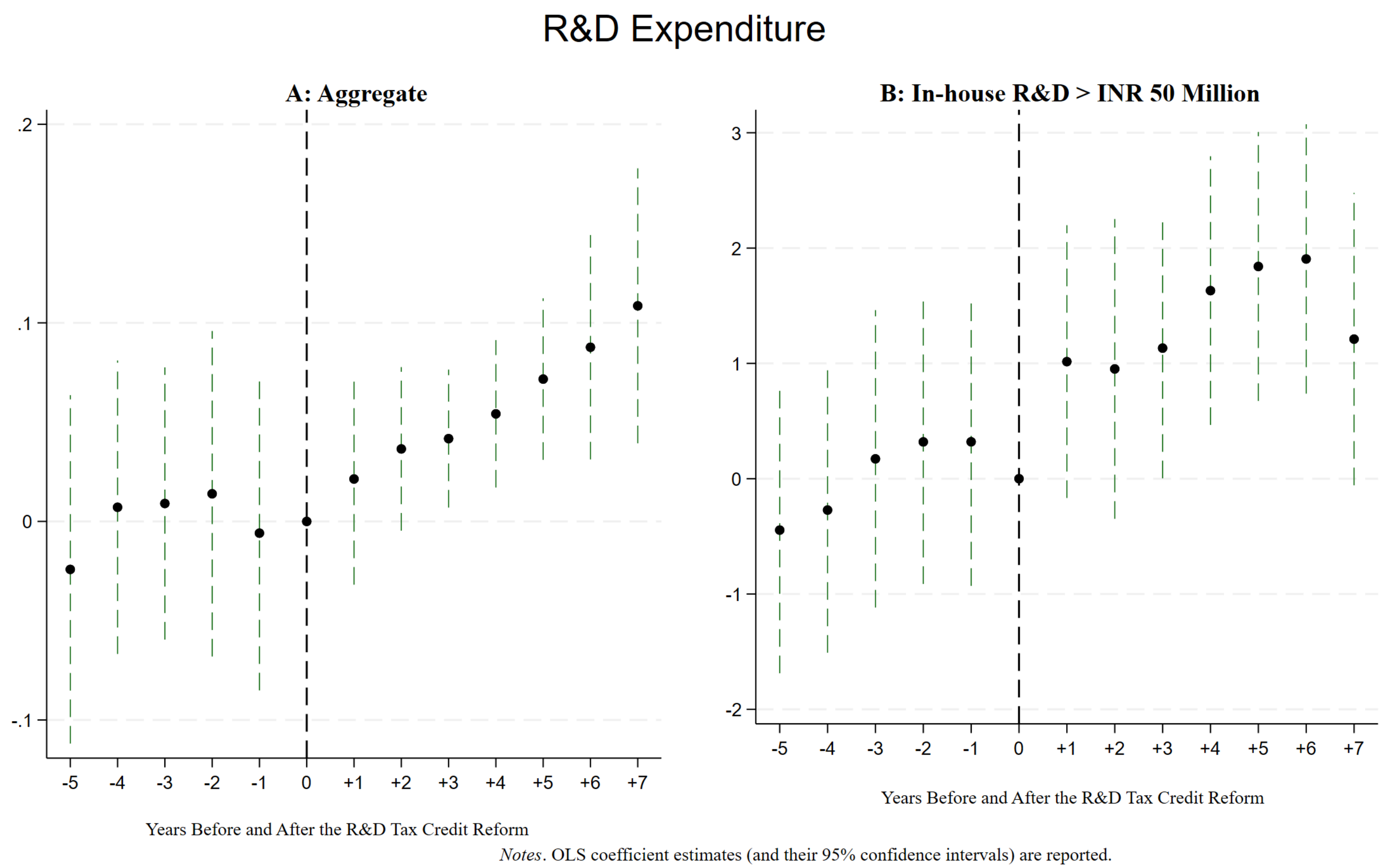

Figure A.3: Effect of R&D Tax Credit on R&D Expenditure – OLS

Notes: Figure presents the OLS coefficient estimates (and their 95% confidence intervals) of differences in the R&D expenses for firms in treated and control group of industries at the aggregate (Panel A) and for firms with in-house R&D expenses for more than INR 50 Million (Panel B) in treated and control group of industries. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) drugs and pharmaceuticals, (2) electronic equipment, (3) computers, (4) telecommunications equipment, (5) chemicals, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Regressions Standard errors clustered at the industry (4-digit) level.

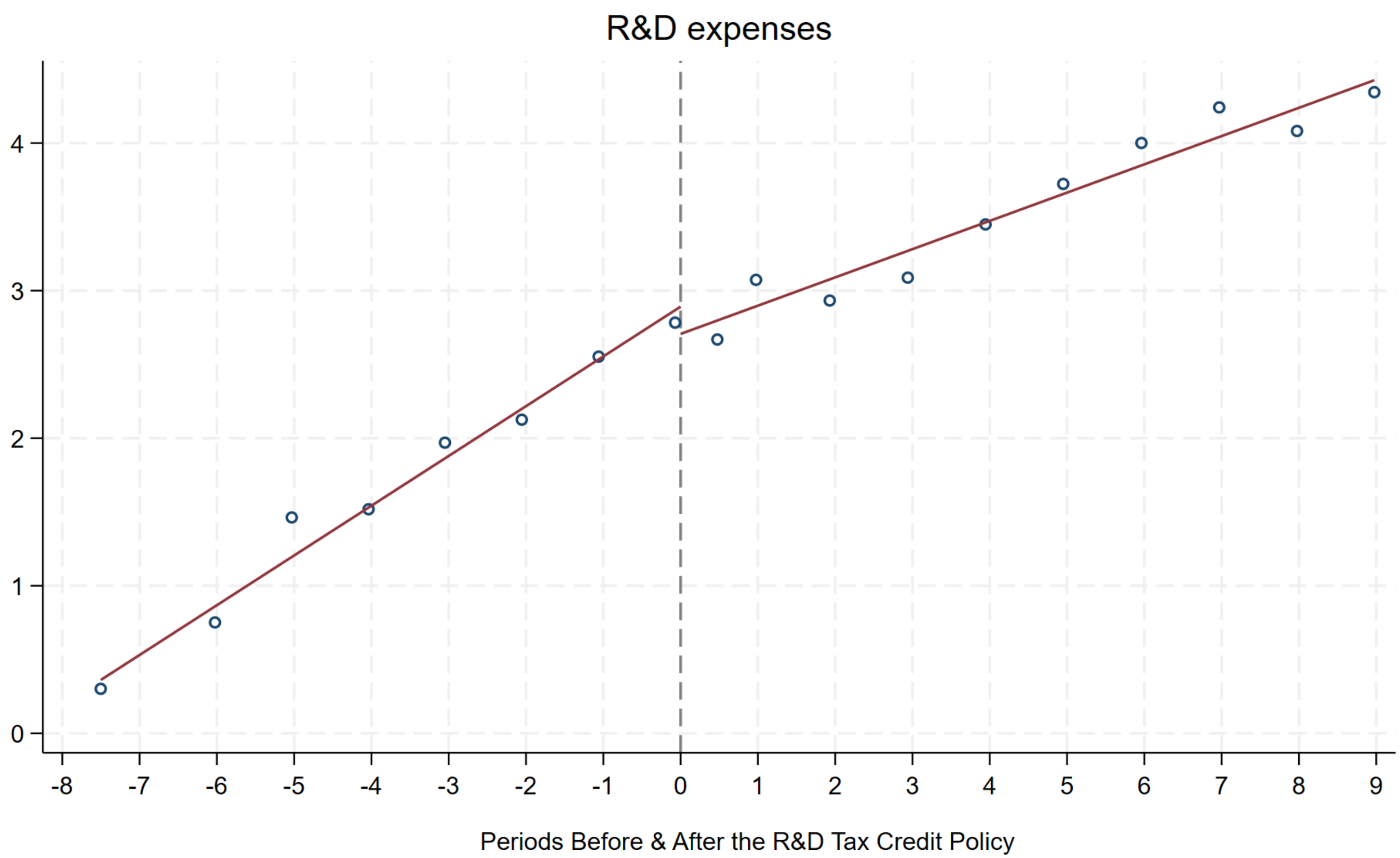

Figure A.4: Effect of the R&D Tax Credit Policy on R&D Expenditure of Firms with > 50 Million INR of R&D Expenses – Bin Scatter Plots

Notes: Figure presents the binned scatter plots for R&D Expenses only for firms with more than INR 50 Million of in-house R&D expenses. The sample consists of the following industries for which the R&D tax credit reform was undertaken by the Govt. of India: (1) drugs and pharmaceuticals, (2) electronic equipment, (3) computers, (4) telecommunications equipment, (5) chemicals, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Firm fixed effects are included.

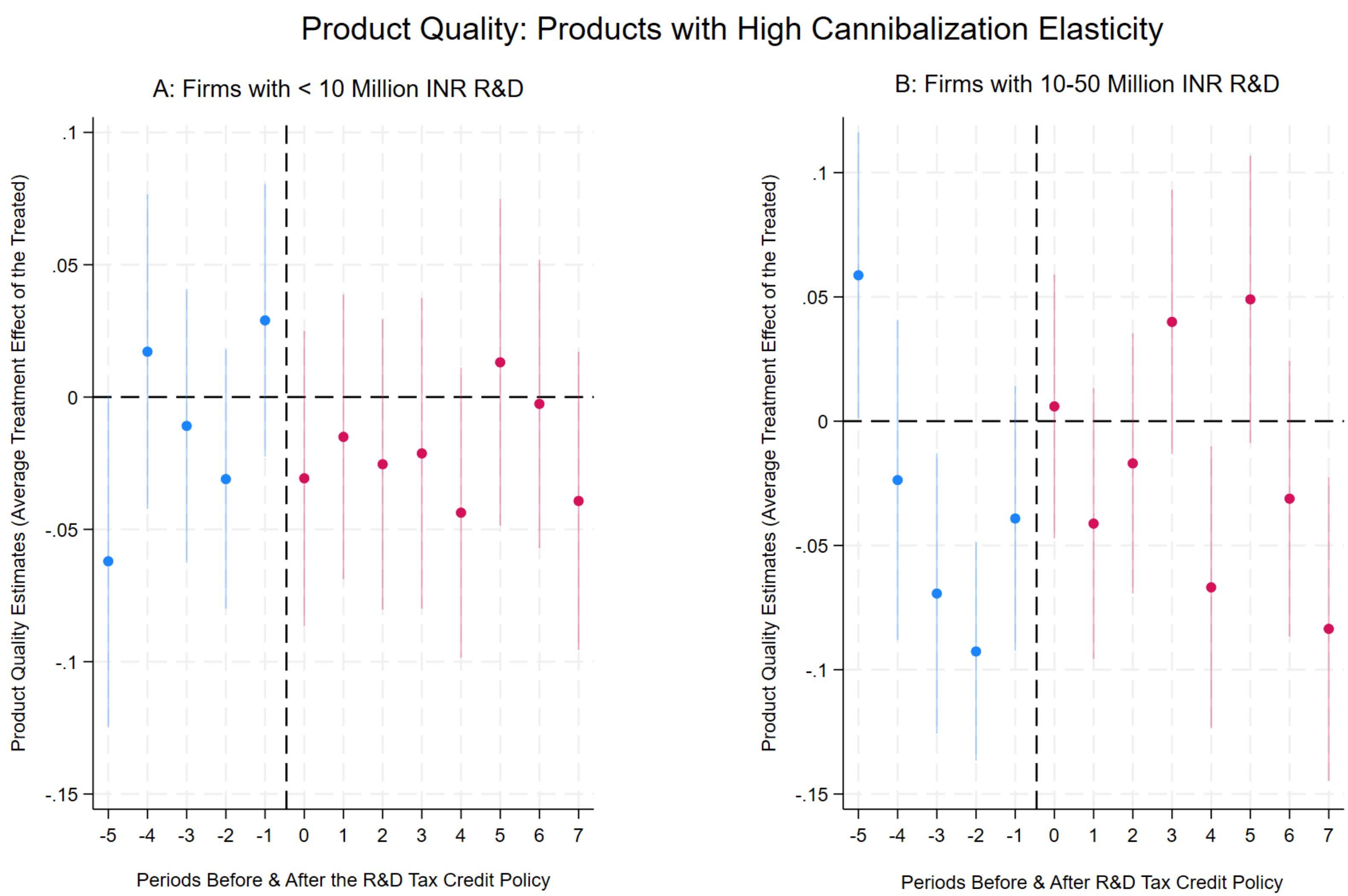

Figure A.5: Effects of R&D Tax Credit on Product Quality – Firms with $<$ 50 million INR R&D and have In-house R&D Unit

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the product quality of firms with in-house R&D units and R&D expenses of more than 50 million INR which in treated and control group of industries for products which have high elasticity of substitution or less differentiated. Panel A presents results for firms with less than 10 million INR R&D while Panel B does the same for 10-50 million of R&D expenses. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

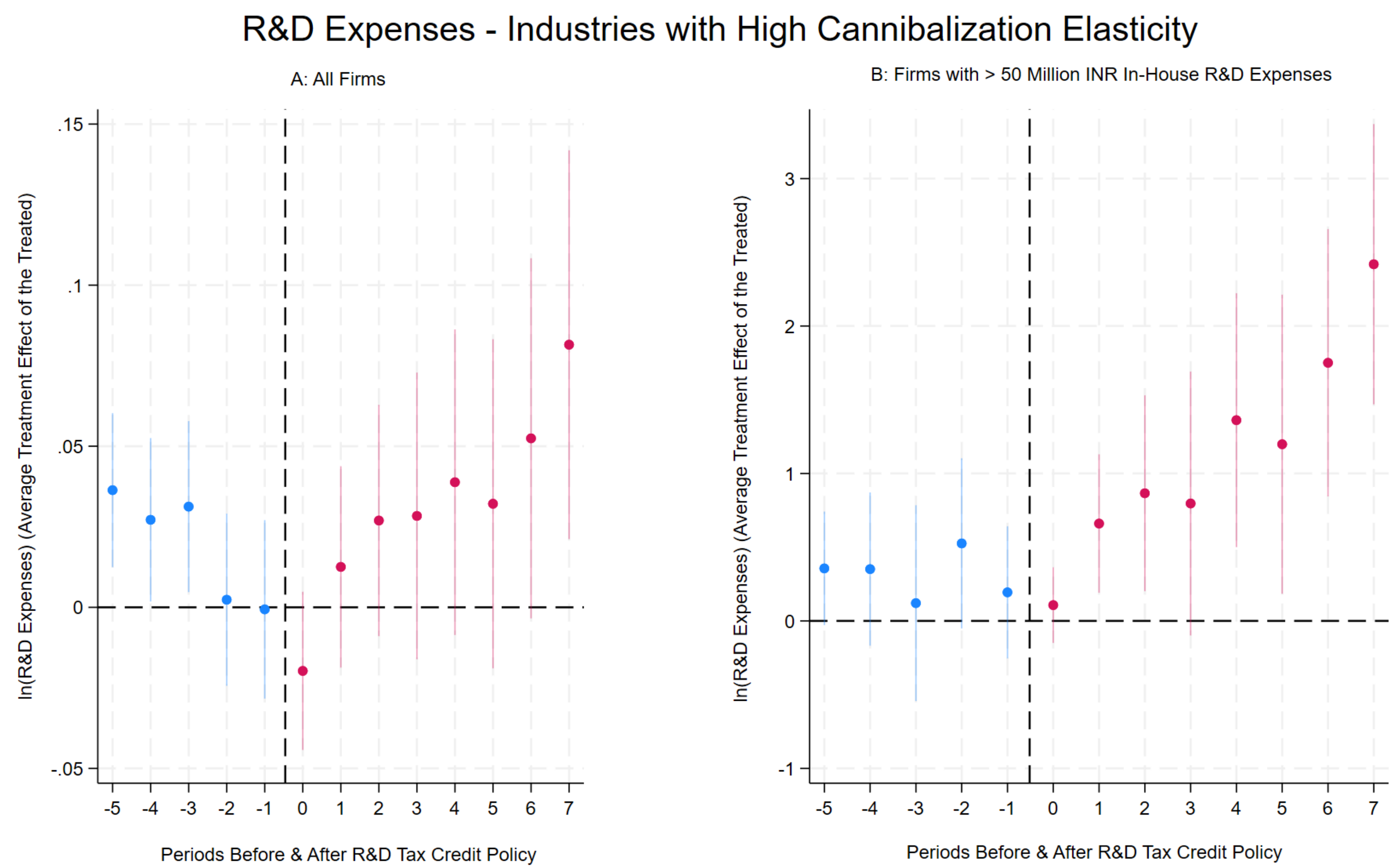

Figure A.6: Effects of R&D Tax Credit on R&D Expenditure – Firms with > 50 million INR R&D and In-house R&D Unit

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the R&D expenses of firms with in-house R&D units and R&D expenses of more than 50 million INR which in treated and control group of industries for the differentiated products (Panel A) and exporters (Panel B). The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

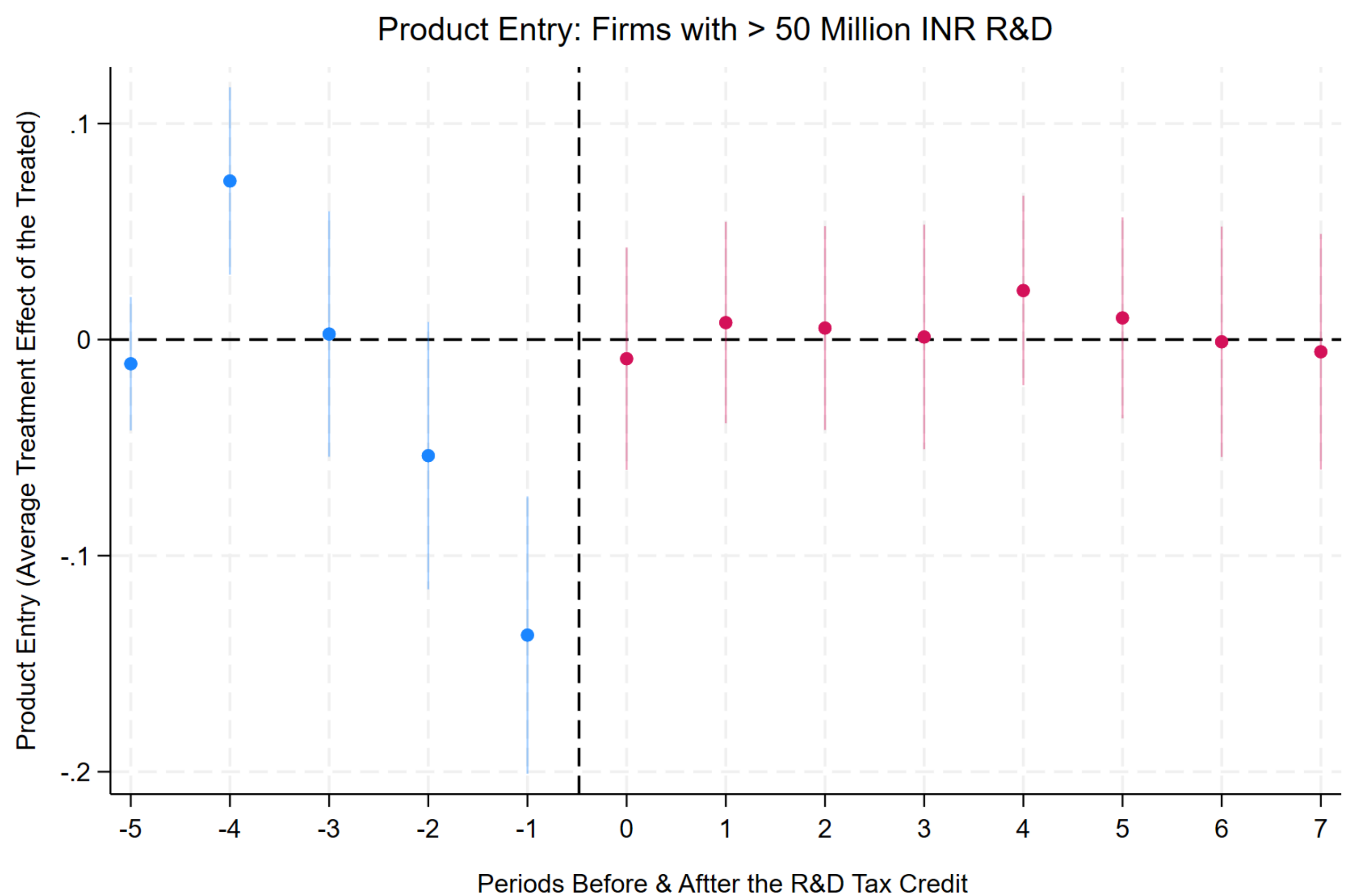

Figure A.7: Effects of R&D Tax Credit on Product Entry – Firms with > 50 million INR R&D and In-house R&D Unit

Notes: Figure presents the Callaway & Sant'Anna (2021) coefficient estimates (and their 95% confidence intervals) of differences in the probability of new product entry by firms with in-house R&D units and R&D expenses of more than 50 million INR which in treated and control group of products which have high elasticity of substitution or less differentiated. The treated group of industries are classified as industries for which the R&D tax credit reform was undertaken by the Govt. of India. The treated group of industries are: (1) chemicals, (2) pharmaceuticals, (3) electronic equipments, (4) computers, (5) telecommunications equipments, (6) manufacture of aircraft and helicopters, and (7) automobiles and auto parts. Our coefficient estimates are controlled for firm fixed effects, year fixed effects, and industry-year trends. Standard errors clustered at the industry (4-digit) level.

B Tables

Table B.1: Balancing Tests – Firms with Internal R&D Unit and Others

	Normalized Difference (1)
Panel A: Technology Adoption	
Total Technology Adoption	0.13
R&D Expenses	0.19
Technology Transfer	0.08
Panel B: Inputs	
Capital Employed	0.008
Managerial Compensation	–0.03
Raw Materials	0.21
Import of Production Units	0.008
Panel C: Other Characteristics	
Exports	0.006
Sales	0.24
Promotional Expenses	0.09

Notes: Table reports the normalized differences across several firm characteristics for firms having an internal R&D unit vs. others following Imbens & Wooldridge (2008). An absolute value above 0.25 would suggest an imbalance.

Table B.2: R&D Tax Credit and R&D Expenses – Controlling Explicitly for Trade Reform (Tariffs)

	R&D Expenses			
	(1)	(2)	(3)	(4)
		Internal R&D Unit	ATE	R&D Categories
$Treated_{jt}$	0.110**	–0.034*		–0.005
	(0.048)	(0.018)		(0.022)
$Treated_{jt} \times R\&D\ Unit_i$		0.483***	0.265***	
		(0.048)	(0.072)	
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$				0.115***
				(0.034)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$				0.909***
				(0.085)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$				2.059****
				(0.211)
$ln(Output\ Tariff)_{jt}$	0.028	0.022		0.021
	(0.043)	(0.037)		(0.038)
$ln(Input\ Tariff)_{jt}$	0.019	0.027		0.026
	(0.079)	(0.071)		(0.072)
R-square	0.64	0.65	–	0.65
N	133,180	133,180	132,170	133,180
Output Tariff	–	–	✓	–
Input Tariff	–	–	✓	–
Firm Controls	✓	✓	✓	✓
Firm FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Industry FE (4-digit) × Year Trend	✓	✓	✓	✓

Notes: Columns (1) – (4) use expenses made on account of foreign technology transfer by a firm as the dependent variable, respectively. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_i$ takes a value 1 for firm i that has a registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research). $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered R&D unit has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. $ln(Output\ Tariff)_{jt}$ and $ln(Input\ Tariff)_{jt}$ are output and input tariffs defined at the 4-digit industry level (j) at time t (t). Input tariffs are constructed by multiplying input-output coefficients with output tariffs. Firm controls include age of a firm, age squared, and real gross value-added of a firm. Standard errors are clustered at 4-digit industry level. Intercepts are not reported. *,**,*** denotes 10%, 5%, and 1% level of significance, respectively.

Table B.3: R&D Tax Credit and Expenses on Foreign Technology Transfer – Intensive Margin

	Foreign Technology Transfer							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Aggregate					R&D Categories		ATE – C&S (2021)
$Treated_{jt}$	–0.018	–0.025	–0.036	0.038	–0.022	–0.029	–0.015	
	(0.026)	(0.024)	(0.024)	(0.092)	(0.023)	(0.026)	(0.024)	
$Treated_{jt} \times R\&D\ Unit_i$		0.029	0.029	0.022	0.005			
		(0.025)	(0.025)	(0.025)	(0.024)			
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$						–0.052*	–0.060**	–0.034
						(0.029)	(0.025)	(0.030)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$						–0.055	–0.088	0.022
						(0.081)	(0.083)	(0.066)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$						0.415*	0.309	0.108
						(0.223)	(0.234)	(0.125)
R-square	0.56	0.56	0.56	0.57	0.61	0.56	0.61	–
N	162,341	162,341	162,341	162,341	133,179	162,341	133,179	132,271
Firm Controls	X	X	X	X	✓	X	✓	✓
Firm FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	X	✓	✓	✓	✓
Industry FE (4-digit) × Year Trend	X	X	✓	X	✓	✓	✓	✓
Industry FE (2-digit) × Year FE	X	X	X	✓	X	X	X	X

Notes: Columns (1) – (8) use expenses made on account of foreign technology transfer by a firm as the dependent variable, respectively. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_i$ takes a value 1 for firm i that has a registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research). $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered R&D unit has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include age of a firm, age squared, and real gross value-added of a firm. Standard errors are clustered at 4-digit industry level. Intercepts are not reported. *,**,*** denotes 10%, 5%, and 1% level of significance, respectively.

Table B.4: R&D Tax Credit and Firm Product Choice – Quality vs. Scope: Robustness Checks

	Other Differ. Measure	High Differen. Products
	Panel A: Product Quality	
	(1)	(2)
$Treated_{jt}$	0.024*	0.005
	(0.013)	(0.004)
$R\&D\ Unit_{i,<10\ Million}$	0.007	–0.008**
	(0.005)	(0.003)
$R\&D\ Unit_{i,10-50\ Million}$	0.020***	–0.004
	(0.006)	(0.004)
$R\&D\ Unit_{i,>50\ Million}$	0.038***	0.005
	(0.006)	(0.005)
R-Square	0.42	0.25
N	213,242	151,769
	Panel B: Product Entry	
	(3)	(4)
$Treated_{jt}$	–0.090***	0.008
	(0.014)	(0.019)
$R\&D\ Unit_{i,<10\ Million}$	0.034***	0.043
	(0.013)	(0.038)
$R\&D\ Unit_{i,10-50\ Million}$	0.053*	0.012
	(0.031)	(0.013)
$R\&D\ Unit_{i,>50\ Million}$	0.012	0.014
	(0.016)	(0.013)
R-Square	0.36	0.38
N	232,328	133,725
Firm Controls	✓	✓
Firm-Product FE	✓	✓
Year FE	✓	✓
Industry FE (4-digit) X Year Trend	✓	✓

Notes: All the regressions are for the years 1992–2007 and employ firm-product-year level data. Columns (1) – (2) use product quality and columns (3) – (4) uses a new product entry of a firm as the dependent variable, respectively. We use Amiti & Khandelwal (2013) to estimate the product quality. For estimation of product quality, we use the elasticities of substitution at the 2-digit industry level (NIC 2008 or ISIC Rev, 4) from Fujiy et al. (2023) using the 2SLS method. In case of product entry, it takes a value 1 when a new product appears in the sample given that it hasn't in any year of that firm's operational years. For columns (1) and (3), we use elasticity of substitution from Fujiy et al. (2023) as the other measure for differentiated goods. If the σ for a 2-digit industry is greater than the median σ for all the manufacturing sector, it is indicated as a less differentiated sector. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research) has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include the age of a firm, age squared, and the real gross value-added of a firm. Numbers in the parentheses are two-way clustered standard errors at industry and product level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table B.5: Callaway & Sant'Anna (2021) Estimates of R&D Tax Credit – Average Treatment Effects

	Product Quality (1)	Product Scope (2)
$R\&D\ Unit_{i,<10\ Million}$	–0.014	0.115**
	(0.012)	(0.048)
$R\&D\ Unit_{i,10-50\ Million}$	0.031***	0.072*
	(0.006)	(0.042)
$R\&D\ Unit_{i,>50\ Million}$	0.042***	0.129
	(0.009)	(0.084)

Notes: Numbers show the Average Treatment Effects (ATT) for a firm following Callaway & Sant'Anna (2021). Column (1) presents the estimates of product quality following Amiti & Khandelwal (2013). Column (2) presents the estimates on product scope of a firm.

Table B.6: R&D Tax Credit and Firm Performance

	Gross Value-added	Exports	Domestic Sales
	(1)	(2)	(3)
$Treated_{jt}$	–0.234**	–0.031	–0.005
	(0.108)	(0.050)	(0.030)
$Treated_{jt} \times R\&D\ Unit_{i,<10\ Million}$	–0.023	0.285***	–0.006
	(0.250)	(0.099)	(0.024)
$Treated_{jt} \times R\&D\ Unit_{i,10-50\ Million}$	0.676***	0.758***	–0.086***
	(0.207)	(0.119)	(0.031)
$Treated_{jt} \times R\&D\ Unit_{i,>50\ Million}$	1.382***	1.264***	–0.225*
	(0.497)	(0.273)	(0.122)
R-Square	0.63	0.75	0.97
N	133,180	133,180	132,423
Firm Controls	✓	✓	✓
Firm FE	✓	✓	✓
Year FE	✓	✓	✓
Industry FE (4-digit) X Year Trend	✓	✓	✓

Notes: All the regressions are for the years 1992–2007 and employ firm-year level data. Column (1) use gross value-added (sales – raw materials); column (2) use exports; and column (3) use domestic sales of a firm as the dependent variable, respectively. $Treated_{jt}$ takes a value 1 for all years since the Govt. of India announced the tax rebate for certain industries (at 4-digit level) and 0 otherwise. For example, it takes a value 1 for firms belonging to chemical, pharmaceuticals, electrical equipments, computers, telecommunication equipment industries after the year 1997. For aircraft, it takes value 1 after 2001 and for automobile parts after 2003. $R\&D\ Unit_{i,<10\ Million}$, $R\&D\ Unit_{i,10-50\ Million}$, and $R\&D\ Unit_{i,>50\ Million}$ takes value 1 for firms whose registered in-house R&D unit with DSIR (Department of Scientific and Industrial Research) has expenses less than 10 Million INR, between 10–50 Million INR, and greater than 50 Million INR, respectively. Firm controls include age of a firm, age squared, and real gross value-added of a firm. Standard errors are clustered at 4-digit industry level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

Table B.7: Correlations – Market Share, R&D, Product Quality, and Entry

	Coefficient	N	R-squared
	Panel A: ln(Market Share)		
	(1)	(2)	(3)
R&D Unit	0.024***	376,956	0.04
	(0.001)		
R&D Expenses	0.017***	376,956	0.04
	(0.000)		
Product Quality	0.025***	300,014	0.27
	(0.000)		
Product Scope	0.060***	376,956	0.10
	(0.001)		
	Panel B: ln(Product Scope)		
	(4)	(5)	(6)
R&D Unit	0.210***	376,957	0.25
	(0.002)		
R&D Expenses	0.117***	376,957	0.25
	(0.001)		
R&D Expenses/GVA	0.221***	376,805	0.23
	(0.030)		

Notes: Each row represents a separate regression where we regress natural logarithm of market share on the mentioned variables in each of the rows. First row uses a ordered variable indicating the if a firm has a recognized R&D unit by the DSIR, Ministry of Science & Technology, Govt. of India. It is an ordered variable from 0 to 3. 0 represents no recognized internal R&D unit; 1 represents a recognized internal R&D unit of a firm which spends less than 10 Million INR on R&D; 2 represents a recognized internal R&D unit of a firm which spends between 10–50 Million INR on R&D; 3 represents a recognized internal R&D unit of a firm which spends greater than 50 Million INR on R&D. R&D Expenses is the logarithm of total expenses by a firm on R&D. Product Quality is estimated using Amiti & Khandelwal (2013). Product Scope is the logarithm of total number of products produced by a firm. All the regressions control of industry (4-digit) and year fixed effects.

Table B.8: Correlations – Product Entry, Market Share of Products, and Product Scope

	Product Entry
	(1)
Sales $\text{Share}^{N-th\ Product}_{Pre-treatment}$	–0.088***
	(0.005)
ln(Product $\text{Scope})_{Pre-treatment}$	–0.013***
	(0.002)
N	88,506
R-squared	0.25
Year FE	✓
Industry FE (4-digit)	✓

Notes: The table uses product entry as the dependent variable. It takes a value 1 when a new product appears in the sample given that product hasn't been produced before. $Sales\ Share^{N-th\ Product}_{Pre-treatment}$ is the average sales share of the product which has the lowest sales share in the total sales of a firm before the treatment. $\ln(ProductScope)_{Pre-treatment}$ is the average number of products produced by a firm before the treatment. Numbers in the parentheses are two-way clustered standard errors at industry and product level. ***, **, * denotes statistical significance at 1%, 5%, and 10%.

C Model Derivations

C.1 Cannibalization Elasticity

We compare the elasticity of total sales Y^j_{mi} with respect to both appeal ψ^j_{ki} and scope N^j_i respectively.

First, for appeal, we utilize the following expression:

$$\frac{dY^j_{mi}}{d\psi^j_{ki}} = \underbrace{\frac{\partial Y^j_{mi}}{\partial \psi^j_{ki}}_{|m=k}}_{\text{First Order Effect}} + \underbrace{\frac{\partial Y^j_{mi}}{\partial P^j_i} \cdot \frac{\partial P^j_i}{\partial \psi^j_{ki}}}_{\text{Effect through price index}} + \underbrace{\frac{\partial Y^j_{mi}}{\partial P_j} \cdot \frac{\partial P_j}{\partial P^j_i} \cdot \frac{\partial P^j_i}{\partial \psi^j_{ki}}}_{\text{Effect through price index}}$$

$$\implies \frac{\partial Y^j_{mi}}{\partial \psi^k_{ki}}_{|m=k} + \frac{\partial P^j_i}{\partial \psi^j_{ki}} \left[\frac{\partial Y^j_{mi}}{\partial P^j_i} + \frac{\partial Y^j_{mi}}{\partial P_j} \cdot \frac{\partial P_j}{\partial P^j_i} \right]$$

Expanding the terms:

$$\implies \frac{(\sigma_K - 1)Y^j_{mi}}{\psi^j_{ki}}_{|m=k}$$

$$+ \left[\frac{-(1-\sigma_K)}{1-\sigma_K} \cdot \left(\frac{p^j_{ki}}{\psi^j_{ki}} \right)^{1-\sigma_K} \cdot \left(\frac{P_i^{j\sigma_K}}{\psi^j_{ki}} \right) \right] \left[(\sigma_K - \sigma_I) \frac{Y^j_{mi}}{P^j_i} + (\sigma_I - 1) \frac{Y^j_{mi}}{P_j} \cdot \frac{\partial P_j}{\partial P^j_i} \cdot \frac{P^j_i}{P_j} \cdot \frac{P_j}{P^j_i} \right]$$

$$\implies \frac{(\sigma_K - 1)Y^j_{mi}}{\psi^j_{ki}}_{|m=k} - \frac{S^j_{ki} \cdot Y^j_{mi}}{\psi^j_{ki}} \left[(\sigma_K - \sigma_I) + S^j_i(\sigma_I - 1) \right]$$

$$\implies \frac{dY^j_{mi}}{d\psi^j_{ki}} = \frac{(\sigma_K - 1)Y_{mi}}{\psi^j_{ki}} \left[1 - S^j_{ki} \underbrace{\left[\frac{\sigma_K - \sigma_I}{\sigma_K - 1} + \frac{S^j_i(\sigma_I - 1)}{\sigma_K - 1} \right]}_{\text{Cannibilisation Rate}} \right]$$

$$\implies \underbrace{\frac{dY^j_{mi}}{d\psi^j_{ki}} \frac{\psi^j_{ki}}{Y^j_{mi}}}_{\text{Elasticity}} = (\sigma_K - 1)_{|m=k} - (\sigma_K - 1)(S^j_{ki}\varsigma_i)$$

$$\implies \sum_{m=1}^{N^j_i} \frac{dY^j_{mi}}{d\psi^j_{ki}} \frac{\psi^j_{ki}}{Y^j_{mi}} = (\sigma_K - 1) - (\sigma_K - 1)(S^j_{ki}\varsigma_i) \sum_{m=1}^{N^j_i} 1$$

Finally, therefore:

$$\sum_{m=1}^{N_i^j} \frac{dY_{mi}^j}{d\psi_{ki}^j} \frac{\psi_{ki}^j}{Y_{mi}^j} = (\sigma_K - 1)(1 - S_{ki}^j \varsigma_i N_i^j) \tag{C.1}$$

For the elasticity with respect to scope, we follow the derivation in Redding 2016:

The partial elasticity of Y_{mi}^j with respect to N_i^j is given by:

$$\frac{dY_{mi}^j}{dN_i^j} = (\sigma_I - 1)\frac{Y_{mi}^j}{P_j}\frac{\partial P_j}{\partial N_i^j} + (\sigma_K - \sigma_I)\frac{Y_{mi}^j}{P_i^j}\frac{\partial P_i^j}{\partial N_i^j}$$

$$\implies (\sigma_I - 1)\frac{Y_{mi}^j}{P_j}\frac{\partial P_j}{\partial N_i^j}\frac{N_i^j}{N_i^j}\frac{P_i^j}{P_i^j}\frac{\partial P_i^j}{\partial P_i^j} + (\sigma_K - \sigma_I)\frac{Y_{mi}^j}{P_i^j}\frac{\partial P_i^j}{\partial N_i^j}\frac{N_i^j}{N_i^j}$$

$$\implies (\sigma_I - 1)\frac{Y_{mi}^j}{N_i^j}\left(\frac{\partial P_j}{\partial P_i^j}\frac{P_i^j}{P_j}\right)\left(\frac{\partial P_i^j}{\partial N_i^j}\frac{N_i^j}{P_i^j}\right) + (\sigma_K - \sigma_I)\frac{Y_{mi}^j}{N_i^j}\left(\frac{\partial P_i^j}{\partial N_i^j}\frac{N_i^j}{P_i^j}\right)$$

$$\frac{\partial P_i^j}{\partial N_i^j}\frac{N_i^j}{P_i^j} = \frac{\left(\frac{p_{ni}^j}{\psi_{ni}^j}\right)^{1-\sigma_K}}{P_i^{j\,1-\sigma_K}}\frac{N_i^j}{1-\sigma_K} = S_{ni}^j\frac{N_i^j}{1-\sigma_K}$$

$$\implies -\frac{dY_{mi}^j}{dN_i^j}\frac{N_i^j}{Y_{mi}^j} = -(\sigma_I - 1)S_i^j S_{ni}^j\frac{N_i^j}{1-\sigma_K} - (\sigma_K - \sigma_I)S_{ni}^j\frac{N_i^j}{1-\sigma_K}$$

$$\implies -\frac{dY_{mi}^j}{dN_i^j}\frac{N_i^j}{Y_{mi}^j} = S_{ni}^j N_i^j\left[\frac{\sigma_K - \sigma_I}{\sigma_K - 1} + \frac{S_i^j(\sigma_I - 1)}{\sigma_K - 1}\right]$$

$$\sum_{m=1}^{N_i^j} -\frac{dY_{mi}^j}{dN_i^j}\frac{N_i^j}{Y_{mi}^j} = S_{ni}^j \varsigma_i {N_i^j}^2 \tag{C.2}$$

C.2 Comparing Induced Profits

The firm faces a binary choice between quality improvement and scope expansion. We compare the profits generated from the quality improvement of the N^{th} good, and the profits generated from the scope expansion of the N^{th} good (noting that N is continuous and therefore $N + 1 \approx N$) , respectively.

1) With respect to appeal

$$\max_{\psi^j_{Ni}} \Pi^j_i = \sum_{m=k^j_{1i}}^{k^j_{Ni}} [p^j_{mi} Y^j_{mi} - A^j_{mi}(Y^j_{mi})]$$

subject to:

$$C^j_{mi} = Y^j_{mi} = \left(\psi^j_i\right)^{\sigma_I - 1} \left(\psi^j_{mi}\right)^{\sigma_K - 1} E_j \left(P_j\right)^{\sigma_I - 1} \left(P^j_i\right)^{\sigma_K - \sigma_I} \left(p^j_{mi}\right)^{-\sigma_K}$$

$$\frac{d\Pi^j_i}{d\psi^j_{Ni}} = \underbrace{\frac{d\Pi^j_{Ni}}{d\psi^j_{Ni}}}_{\textbf{Direct Effect}} + \underbrace{\sum_{m \neq N}^{N^j_i} \frac{d\Pi^j_{mi}}{d\psi^j_{Ni}}}_{\textbf{Indirect Effect}}$$

$$\implies \frac{\partial Y^j_{Ni}}{\partial \psi^j_{Ni}} \left(p^j_{Ni} - \gamma^j_{Ni}\right) + \sum_{m \neq N}^{N^j_i} \frac{\partial Y^j_{mi}}{\partial \psi^j_{Ni}} \left(p^j_{mi} - \gamma^j_{mi}\right)$$

$$\implies \frac{(\sigma_K - 1) Y^j_{Ni}}{\psi^j_{Ni}} \left(p^j_{Ni} - \gamma^j_{Ni}\right) \quad + \quad \sum_{m \neq N}^{N^j_i} -(\sigma_K - 1) S^j_{Ni} \varsigma_i \frac{Y^j_{mi} \left(p^j_{mi} - \gamma^j_{mi}\right)}{\psi^j_{Ni}}$$

given:

$$\epsilon^{\text{qual}} \equiv \sum_{m \neq N}^{N^j_i} -\frac{\partial Y^j_{mi}}{\partial \psi^j_{Ni}} \frac{\psi^j_{Ni}}{Y^j_{mi}} = \sum_{m \neq N}^{N^j_i} (\sigma_K - 1)\, S^j_{Ni}\, \varsigma_i,$$

We can rewrite the expression as:

$$\implies \frac{(\sigma_K - 1) Y^j_{Ni}}{\psi^j_{Ni}} \left(p^j_{Ni} - \gamma^j_{Ni}\right) \quad - \quad \epsilon^{\text{qual}} \cdot \frac{\sum_{m \neq N}^{N^j_i} Y^j_{mi} \left(p^j_{mi} - \gamma^j_{mi}\right)}{N^j_i \psi^j_{Ni}}$$

We can denote the marginal profit from N^j_i, $Y^j_{Ni}\left(p^j_{Ni} - \gamma^j_{Ni}\right)$ as π^j_{Ni} and similarly for other product m as π^j_{mi}, thus we simplify to get:

$$\implies \frac{(\sigma_K - 1) \pi^j_{Ni}}{\psi^j_{Ni}} \quad - \quad \epsilon^{\text{qual}} \cdot \frac{\sum_{m \neq N}^{N^j_i} \pi^j_{mi}}{N^j_i \psi^j_{Ni}}$$

The term $\frac{\sum_{m \neq N}^{N^j_i} \pi^j_{mi}}{N^j_i}$ simply is the average profit of all the other products, which we can denote as $\pi^{\text{av}}_{m \neq N}$ and hence,

$$\frac{d\Pi_i^j}{d\psi_{Ni}^j} = \frac{(\sigma_K - 1)\pi_{Ni}^j - \epsilon^{\text{qual}}\pi_{m\neq N}^{\text{av}}}{\psi_{Ni}^j} \tag{C.3}$$

2) With respect to Scope

$$\frac{d\Pi_i^j}{dN_i^j} = \left[p_{Ni}^j Y_{Ni}^j - A_{Ni}(Y_{Ni}^j)\right] + \sum_{m=1}^{N_i^j} \frac{\partial Y_{mi}^j}{\partial N_i^j}(p_{mi}^j - \gamma_{mi}^j)$$

$$\implies \left[p_{Ni}^j Y_{Ni}^j - A_{Ni}(Y_{Ni}^j)\right] \quad + \quad \sum_{m=1}^{N_i^j} -S_{Ni}^j \varsigma_i Y_{mi}^j (p_{mi}^j - \gamma_{mi}^j)$$

Given:

$$\epsilon^{\text{scope}} = \sum_{m=1}^{N_i^j} \left(-\frac{\partial Y_{mi}^j}{\partial N_i^j} \cdot \frac{N_i^j}{Y_{mi}^j} \right) = S_{Ni}^j \cdot \varsigma_i \cdot \left(N_i^j\right)^2.$$

$$\implies \left[p_{Ni}^j Y_{Ni}^j - A_{Ni}(Y_{Ni}^j)\right] \quad - \quad \frac{\epsilon^{\text{scope}}}{N_i^j} \cdot \frac{\sum_{m=1}^{N_i^j} Y_{mi}^j (p_{mi}^j - \gamma_{mi}^j)}{N_i^j}$$

The term $\frac{\sum_{m=1}^{N_i^j} Y_{mi}^j (p_{mi}^j - \gamma_{mi}^j)}{N_i^j}$ simply is the average profit of the existing portfolio, which we can denote as π_N^{av} and hence,

$$\frac{d\Pi_i^j}{dN_i^j} = \left[p_{Ni}^j Y_{Ni}^j - A_{Ni}(Y_{Ni}^j)\right] \quad - \quad \frac{\epsilon^{\text{scope}}\pi_N^{\text{av}}}{N_i^j} \tag{C.4}$$

A firm will stop expanding scope and start investing in quality when $\frac{d\Pi_i^j}{d\psi_{Ni}^j} > \frac{d\Pi_i^j}{dN_i^j}$. Therefore,

$$\frac{(\sigma_K - 1)\pi_{Ni}^j - \epsilon^{\text{qual}}\pi_{m\neq N}^{\text{av}}}{\psi_{Ni}^j} > \pi_{Ni}^j \quad - \quad \frac{\epsilon^{\text{scope}}\pi_N^{\text{av}}}{N_i^j}$$

Assuming that $\pi_{m\neq N}^{\text{av}} \approx \pi_N^{\text{av}} = \pi^{\text{av}}$ is the average profit of the existing portfolio, and rearranging the terms gives us:

$$\pi_{Ni}^j \left(\frac{\sigma_K - 1}{\psi_{Ni}^j} - 1 \right) \quad > \quad \pi^{\text{av}} \left(\frac{\epsilon^{\text{qual}}}{\psi_{Ni}^j} - \frac{\epsilon^{\text{scope}}}{N_i^j} \right)$$

Expanding the aggregate cannibalization terms, we get:

$$\pi^j_{Ni}\left(\frac{\sigma_K-1}{\psi^j_{Ni}}-1\right) \quad > \quad \pi^{\text{av}} S^j_{Ni}\varsigma_i N^j_i\left(\frac{\sigma_K-1}{\psi^j_{Ni}}-1\right)$$

Since $\pi^{\text{av}} = \frac{\sum_{m=1}^{N_i^j}\pi^j_{mi}}{N_i^j}$, we get the final condition:

$$\pi^j_{Ni} \quad > \quad S^j_{Ni}\varsigma_i \sum_{m=1}^{N_i^j}\pi^j_{mi} \tag{C.5}$$

The firm will invest in quality improvement when the marginal profit of the N^{th} good will exceed a fraction (defined by the product of the share of the N^{th} good and the firm cannibalization rate) of the aggregate profit of the portfolio.

D Price Index Decomposition

In order to prove (26), we need to focus only on the CES tier.

Given (28), we express the expenditure share on each variety as:

$$S^j_{k,r}(\Omega^K_{j,r}) = \frac{\left(\frac{p^j_k}{\Psi^j_k}\right)_r^{1-\sigma}}{\sum_{m\in\Omega^K_j}\left(\frac{p^j_m}{\Psi^j_m}\right)_r^{1-\sigma}}$$

$$\implies S^j_{k,r}(\Omega^K_{j,r}) = \frac{{p^j_{k,r}}^{1-\sigma}\cdot{\Psi^j_{k,r}}^{\sigma-1}}{{P_{j,r}}^{1-\sigma}}$$

$$\implies S^j_{k,r}(\Omega^K_{j,r})^{\frac{1}{\sigma-1}} = \Psi^j_{k,r}\cdot{p^j_{k,r}}^{-1}\cdot P_{j,r}$$

$$\implies P_{j,r} = S^j_{k,r}(\Omega^K_{j,r})^{\frac{1}{\sigma-1}}\cdot p^j_{k,r}\cdot{\Psi^j_{k,r}}^{-1} \tag{D.1}$$

Given (D.1), we write:

$$\tau^{CES}_{t+1} = \frac{P^{CES}_{t+1}}{P^{CES}_t} = \frac{S^j_{k,t+1}(\Omega^K_{j,t+1})^{\frac{1}{\sigma-1}}\cdot p^j_{k,t+1}\cdot{\Psi^j_{k,t+1}}^{-1}}{S^j_{k,t}(\Omega^K_{j,t})^{\frac{1}{\sigma-1}}\cdot p^j_{k,t}\cdot{\Psi^j_{k,t}}^{-1}} \tag{D.2}$$

The expenditure share on each variety at time r can be written as the product of expenditure share on each variety in the set of overlapping goods, Ω^K_j (28), and the variety change term, $\lambda_r^{\Omega^K_j}$ (29) as follows:

$$S^j_{k,r}(\Omega^K_{j,r}) = \frac{p^j_{k,r}\, q^j_{k,r}}{\sum_{k\in\Omega^K_{j,r}} p^j_{k,r}\, q^j_{k,r}} = \underbrace{\frac{p^j_{k,r}\, q^j_{k,r}}{\sum_{k\in\Omega^K_j} p^j_{k,r}\, q^j_{k,r}}}_{S^j_{k,r}(\Omega^K_j)} \cdot \underbrace{\frac{\sum_{k\in\Omega^K_j} p^j_{k,r}\, q^j_{k,r}}{\sum_{k\in\Omega^K_{j,r}} p^j_{k,r}\, q^j_{k,r}}}_{\lambda_r^{\Omega^K_j}}$$

We substitute this into (D.2), and get:

$$\tau^{CES}_{t+1} = \frac{S^j_{k,t+1}(\Omega^K_j)^{\frac{1}{\sigma-1}} \cdot \lambda_{t+1}^{\Omega^K_j \frac{1}{\sigma-1}} \cdot p^j_{k,t+1} \cdot \Psi^{j\ -1}_{k,t+1}}{S^j_{k,t}(\Omega^K_j)^{\frac{1}{\sigma-1}} \cdot \lambda_t^{\Omega^K_j \frac{1}{\sigma-1}} \cdot p^j_{k,t} \cdot \Psi^{j\ -1}_{k,t}}$$

Now, taking the geometric mean across varieties $k \in \Omega^K_j$, and utilizing weights as in (27), we get:

$$\implies \prod_{k\in\Omega^K_j} \Big(\frac{p^j_{k,t+1}}{p^j_{k,t}}\Big)^{w_{k,t+1}(\Omega^K_j)} \cdot \prod_{k\in\Omega^K_j} \Big(\frac{\Psi_{k,t}}{\Psi_{k,t+1}}\Big)^{w_{k,t+1}(\Omega^K_j)} \cdot \prod_{k\in\Omega^K_j} \Big(\frac{S_{k,t+1}(\Omega^K_j)}{S_{k,t}(\Omega^K_j)}\Big)^{\frac{w_{k,t+1}(\Omega^K_j)}{\sigma-1}} \cdot \Big(\frac{\lambda_{t+1}^{\Omega^K_j}}{\lambda_t^{\Omega^K_j}}\Big)^{\frac{1}{\sigma-1}}$$

Taking the natural log of the geometric mean of cost shares, it boils down to 0 as the total expenditure on overlapping goods Ω^K_j in both time periods is the same, hence the geometric mean is unity. This implies:

$$\tau^{CES}_{t+1} = \underbrace{\prod_{k\in\Omega^K_j} \Big(\frac{p^j_{k,t+1}}{p^j_{k,t}}\Big)^{w_{k,t+1}(\Omega^K_j)}}_{Price} \cdot \underbrace{\prod_{k\in\Omega^K_j} \Big(\frac{\Psi_{k,t}}{\Psi_{k,t+1}}\Big)^{w_{k,t+1}(\Omega^K_j)}}_{quality} \cdot \underbrace{\Big(\frac{\lambda_{t+1}^{\Omega^K_j}}{\lambda_t^{\Omega^K_j}}\Big)^{\frac{1}{\sigma-1}}}_{variety}$$

Taking the cobb-douglas weighted geometric mean of this gives us our Aggregate Price Index, as in (26).