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ABSTRACT

While the trade literature has tended to view export activity and innovation as complementary activities, we present evidence that financial constraints are a reason the two activities can act as substitutes for small exporters. In particular, we find that small exporters have lower expenditure on R&D than comparable non-exporters, and we find a corresponding pattern in the leverage ratio of the capital structure of small firms. A model that combines firm decisions regarding the amount of innovation, exporting, and endogenous financial capital structure is able to account for these empirical findings. The model implies that small firms are unable to fully reap the gains from exporting due to financial constraints, as they reduce R&D to finance the costs of export participation.

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A appendix is available at http://www.nber.org/data-appendix/w32904

1. Introduction

The international trade literature has tended to view exporting and innovation to be complementary activities, as access to larger markets expands the potential profits from investment in improved productivity. The literature has even viewed a rise in innovation as one of the benefits of policies promoting trade openness. See, for example, Lileeva and Trefler, 2010; Bustos, 2011; Maican et al., 2023. In particular, Maican et al. (2023) demonstrates that export market profits are a substantial source of the expected return to research and development (R&D), and that R&D spending has a larger impact on firm productivity in the export market than in the domestic market. For theoretical models studying the complementarity implied by the joint firm decision for exporting and innovation, see for example, Atkeson and Burstein (2010) and Costantini and Melitz (2007), Aghion et al. (2024), and Gorodnichenko and Schnitze (2010). [1]

This paper presents a more nuanced picture for heterogeneous firms: while exporting is complementary to innovation for larger firms, the opposite can be true for small exporters due to the presence of financial constraints. Since both activities may require financing, a limit on the supply of such financing to small firms can force a tradeoff.[2] In particular, we find evidence that small exporters have lower expenditure

[1] Bustos (2011) introduced joint decisions of technology and exporting choices in the model of trade with heterogeneous firms in Melitz (2003), and the study found that the increase in revenues produced by trade integration can induce exporters to upgrade technology. The paper found supportive evidence on entry in the export market and technology upgrading by Argentinian firms. Lileeva and Trefler (2010) showed in a model that the improved access to foreign markets raises productivity for some firms but not all firms since productivity responses are heterogeneous, and found empirical evidence that Canadian plants that were induced by the tariff cuts to start exporting or to export more, increased their labor productivity, engaged in more product innovation, and had higher adoption rates for advanced manufacturing technologies. Aghion et al. (2024) shows in a theoretical model with entry, exit, and innovation that adjustment of the extensive margin may limit the usefulness of firm level data to gauge the aggregate welfare implications of trade liberalization. Other related papers include Aghion et al., 2024; Maican et al., 2023; Peters et al., 2019; Akcigit and Melitz, 2022; etc. See the literature review in Appendix A for more details of the papers in this field.

[2] There is a large literature studying the intersection of financing and innovation, see for example: Hall and Lerner, 2010; Gorodnichenko and Schnitze, 2013; Acharya and Xu, 2017; Brown and Petersen, 2009; Comin and Nanda, 2019; Hsu, Tian, and Xu, 2014; Bernstein, 2015; Tadesse, 2006; Benfratello et al.,

on R&D than comparable non-exporters. A few papers in the literature have articulated related arguments. Aghion et al. (2024) shows innovation of French exporters depends on firm size, but does not discuss financial constraints. Gorodnichenko and Schnitze (2010) find that small firms, irrespective of exporting, are more sensitive to financial constraints on innovation.

A distinctive feature of our work is that we study R&D jointly with firm financing, in particular the adjustment of firm capital structure.[3] More precisely, we study data of public U.S. manufacturing firms regarding exporting, R&D expenditure, and firm financial leverage defined by the ratios of debt to firm total assets, where the last item distinguishes between long-term debt with maturities of greater than a year and shorter-term debt like working capital. First, we present a new stylized fact regarding R&D and exporting: while exporting has been associated with more R&D (Maican et al., 2023), we find that once controlling for sales, small exporters do less R&D than comparable non-exporters. This conclusion is based on a regression of R&D expenditure on sales, export status and the interaction of sales and export status. The indicator variable on exporter status has a negative coefficient, indicating that an exporter has lower R&D than a non-exporter controlling for sales, while the interaction term has a positive coefficient. Values indicate that for small exporters the net effect of exporting on R&D is negative, whereas for larger exporters the net effect of export status is positive.

2008; Howell, 2017; Lin, Liu, and Lai, 2018; etc. For other papers studying the intersection of trade and finance, see for example: Foley and Manova, 2015; Amiti and Weinstein, 2011; Paravisini et al., 2015; Manova, Wei and Zhang, 2015; Iacovone and Zavacka, 2019; Chaney, 2016; Manova, 2013; Kohn et al., 2016; Campa and Shaver, 2002; Greenaway et al., 2007; Xu, 2012; Baggs and Brander, 2006; Chen et al., 1997; Mittoo and Zhang, 2008; Bergin, Feng and Lin, 2018a; Chor and Manova, 2012; Feenstra, et al., 201. See appendix A for details.

[3] Although there are a very few papers that simultaneously consider the joint decisions of innovation and exports simultaneously under the presence of financial frictions (see Gorodnichenko and Schnitze, 2010; Altomonte et al., 2016; Egger et al., 2015; Föllmi et al., 2015; and etc.), none of these studies the joint adjustment of R&D, trade and innovation.

Second, we find a similar pattern when studying financial variables, when regressing the leverage ratio (LR) of firms on export status, R&D, and the interaction of export status and R&D. As with the R&D regression above, the indicator variable on exporter status has a negative coefficient, while the interaction term (on exporting and R&D) has a positive coefficient. Values indicate that for small exporters the net effect of exporting on LR is negative, whereas exporters with large amounts of R&D will have a higher LR. Additionally, our estimates indicate that while R&D is associated with higher levels of internal financing for non-exporting firms, the opposite is true for exporters, so that R&D is associated with higher levels of external financing.

Interpreting the implications of these facts for the relationship of R&D and firm financing requires help from a theoretical model drawing on the distinct literatures on R&D, export firm dynamics, and corporate finance. Accordingly, we develop a novel theoretical model characterizing the joint decisions of innovation, exporting, and firm capital structure. On the production side, firms can choose to make expenditure on R&D investment, which raises firm productivity.[4] In addition, firms face an export entry decision subject to a one-time sunk entry cost and a fixed per-period cost, where the latter is financed out of a short-term working capital. The novelty of the model lies in the interactions of innovation and export activity with firm financing. On the financial side, we use a model of endogenous capital structure from the corporate finance literature (as in Bergin et al., 2021; Jermann and Quadrini, 2012). It includes a standard short-term working capital constraint, where intra-temporal debt finances current fixed and variable production costs, a portion of R&D expenses and the fixed costs of exporting when a firm exports. Access to this working capital must be secured with collateral in the form of firm equity. Firms hence face a capital structure decision,

[4] Functional forms for the cost and benefit of R&D follow Aghion et al. (2024).

balancing the benefit of long-term debt financing in terms of tax shield advantages, versus the benefit of equity issuance which can be used as collateral to secure the short-term working capital loan.

Analytical results interpreting the first order conditions from the model show that the model's financial friction introduces a financial component to the cost of R&D investment, and for small exporters, this rise in the overall cost of R&D relative to the benefit can lead to a choice of lower R&D investment than a comparable non-exporter. A version of the model with parameters chosen to optimize fit of the model to the empirical regression results provides an explanation for the empirical findings, and for the role of financial frictions in accounting for the substitution between exporting and R&D. Parameter requirements include the need to finance with external working capital the fixed costs of exporting as well as a portion of the R&D costs for exporters.

In such a setting, small exporters adjust along multiple margins to balance the financial constraints on exporting and R&D. One margin is to adjust the capital structure toward equity to provide collateral to secure financing for working capital. However, the switch from cheaper long-term debt financing to more expensive equity financing lowers overall firm value, which may offset the rise in firm value from higher productivity due to innovation or larger market sales from exporting, and thereby reduce the ability of firms to pay the sunk entry cost of exporting. In order to still enter the export market, the small exporters must cut their innovation investments. Regressions on the simulated data characterizing the cross-section of firms in the steady state solution of the model reproduce the signs of all regression coefficients in our R&D and leverage ratio regressions in the empirical analysis. Results imply that small exporters are unable to reap the full benefits of exporting due to their inability to finance innovation along with the costs of export participation. In the calibrated model, the marginal exporter reduces R&D investment about 25% compared to a counterfactual case where R&D investment is not subject to financial constraint.

Related literature

Our paper contributes to the large literature studying the joint decisions of innovation and exports. We differ primarily in showing that this relationship is shaped by financial constraints and firm capital structure adjustments. The closest paper in this literature to us is Aghion et al. (2024), which demonstrate a related empirical finding among French firms: innovation of exporters rises in response to firms-specific export demand shocks, but primarily among larger firms rather than smaller firms whose innovations barely change. As a theoretical explanation, it proposes a model of export and innovation decisions, where new firm entry raises competition and discourages innovation among small firms. Our work differs, foremost, in proposing financial constraints as an explanation for the heterogeneous innovation behavior of small firms, rather than changes in the degree of competition, and that firms adjust capital structure in response to financial constraints on innovation and exporting. While our empirical finding is similar in flavor in that small exporters do less innovation than large exporters, it differs in showing that small exporters actually do less R&D than comparably sized non-exporters.

Only a small subset of the literature studies the three-way interaction of trade, innovation and firm financing. Within this literature, the closest work to us is the working paper of Gorodnichenko and Schnitze (2010), hereafter GS. They too show evidence that exporting and innovation can either be complements or substitutes, and that small firms are more sensitive to financial constraints on innovation. But our paper differs in several important respects. First, we focus on how innovation interacts with exporting across heterogeneous firms under the presence of firms' decisions about capital structure adjustment, whereas GS has a different focus, regarding how financial development affects macroeconomic outcomes like GDP growth and exports, and prevents poor countries from catching up through innovation. In fact, the published version of their paper removes all discussion of trade, and focuses just on the relationship of innovation and financial constraints. Second, we study the intensive margin, the varying degree of investment in innovation and exporting across heterogeneous firms, while GS study innovation and exports at the extensive margin, whether or not to innovate or to export. Third, we study how capital structure decision of firms affect the endogenous tightness of financial constraints, while GS takes the financial constraint as exogenous.

Altomonte et al. (2016) empirically find among European exporters that high productivity firms are less likely to be credit constrained, while better access to credit is associated with larger productivity and a higher probability of exporting. However, the paper finds no significant relation between investing in R&D and the probability to be credit constrained for exporters. This finding differs from us as well as GS. As with GS, the paper differs from us in only studying innovation and exporting at the extensive margin rather than the cross-sectional variation in innovation and exporting activities.

Another paper at this intersection is Egger and Keuschnigg (2015), which develops a theoretical model studying endogenous financing in relation to innovation, which distinguishes between financing of early-stage and late-stage innovation activities. They cite empirical evidence common in the finance literature that younger and smaller firms are more financially constrained in innovation activity. While the paper considers international trade, it shows that import protection can improve the financial strength of firms leading to more innovation activity, the paper does not study the export decision of firms or how firm export interacts with innovation, which is central to our empirical finding and model.

Similar to Egger and Keuschnigg (2015), Föllmi et al. (2015) also examined how trade liberalization affects firm investments in R&D. The paper first constructed a model where entrepreneurs differ in their wealth endowment, and the heterogeneous access to external funds causes the poor entrepreneurs to run smaller firms, be less likely to invest in R&D, and be more likely to exit the market. Tariff cuts worsen access to finance for small firms, exacerbating these effects. As in Egger and Keuschnigg (2015), the paper does not study the firm decision of whether to export, or compare exporting firms to non-exporting firms, which is a central distinction to our empirical result and theoretical explanation.

The next section of the paper presents empirical work supporting our stylized fact. Section 3 presents the benchmark theoretical model. Section 4 uses numerical solutions to demonstrate that the model can explain the key facts, along with sensitivity analyses to explore the mechanism. Section 5 concludes.

2. Empirical Motivation

We use a panel dataset from Compustat, which covers the financial data of public U.S. manufacturing firms from 1975 to 2014, to study the relationships of firm financing, innovation and exporting activities.[5] Since our interest focuses on firms' choice between debt and equity financing, the leverage ratio in the benchmark model is defined as book debt to total assets, where book debt is defined as total asset minus book equity. We also consider measures of debt with varying maturities: short-term

[5] The sample includes manufacturing firms (SIC: 2000-3999), where we drop firms that appear only once in the sample, have missing values for explanatory variables, and have negative values for the foreign income variable.

borrowing, long-term debt, debt in current liabilities, and book debt minus short-term borrowing.[6] We measure firm innovation with its expenses on R&D. See Table 1 for summary statistics.

2.1 Innovation

To investigate the relation between innovation and exporting decisions, we estimate panel regressions below:

$$RD_{it} = \alpha_0 + \alpha_1 size_{it} + \alpha_2 D\_exp_{it} + \alpha_3 size_{it} * D\_exp_{it} + F_i + \phi_t + \varepsilon_{it}$$

where RD_{it} is the log of R&D expenses of firm i, and $size_{it}$ is measured as the log of net sales of firm i. The regressor D_exp_{it} indicates if the firm is an exporter. To allow for the possibility that firm size has a distinct effect on the innovation investment of exporters and non-exporters, we introduce a term interacting the measure of firm size with the firm's export status. We also include a firm fixed effect F_i to control for the large set of firm-specific characteristics that may influence a firm's choice of R&D investment, such as industry and other firm characteristics that do not vary over time. A time fixed effect ϕ_t is included to help control for common trends and business cycle fluctuations.

Estimates are presented in Column (2) of Table 2, indicating that size is significantly and positively correlated with innovation expense ($\alpha_1 > 0$, significant at the 1% level). The estimate indicates that as the firm size doubles, the R&D expense increases about 0.478 percentage points on average. This is not a surprise, as a standard

[6] Short-term borrowing represents the approximate average aggregate short-term financing outstanding during the company's reporting year, which is usually in the form of lines of credit with banks. Long-term debt represents debt obligations due more than one year from the company's balance sheet date or due after the current operating cycle. Debt in current liabilities represents the total amount of short-term notes and the current portion of long-term debt that is due in one year.

finding in the innovation literature is that firm size raises innovation (see Gorodnichenko and Schnitze, 2010).

Regression results also indicate that innovation rises with firm size faster for exporters than for non-exporters ($\alpha_3 > 0$, significant at the 1% level). However, the coefficient on export status is negative and significant ($\alpha_2 < 0$, significant at the 1% level). This indicates that for small exporters, innovation is lower than for non-exporters with comparable size. But for sufficiently large exporters, innovation for exporters is higher than for comparable non-exporters.

The critical size at which an exporter will begin to have higher innovation is easily computed as $-\frac{\alpha_2}{\alpha_3}$. Regarding the level of innovation in Column (2), this critical size cutoff is 4.70; examination of average firm characteristics from Table 1 indicates that for an exporting firm with average size (6.617), its innovation is higher than if it were a non-exporter. We conclude that for an exporter of average size, its export status will make it do more innovation than if it were not an exporter. Further, this higher innovation of exporters can be attributed to the nonlinear effect of firm size on innovation for exporters.

2.2 Leverage

Next, we investigate the relation between capital structure, innovation and trade decisions by estimate the panel regressions below:

$$LEV_{it} = \alpha_0 + \alpha_1 RD_{it} + \alpha_2 size_{it} + \alpha_3 D\_exp_{it} + \alpha_4 RD_{it} * D\_exp_{it} + F_i + \phi_t + \varepsilon_{it}$$

where LEV_{it} is the leverage ratio of firm *i*. All other controls are the same as above. To allow for the possibility that R&D investment has a distinct effect on the capital structure of exporters and non-exporters, we also introduce a term interacting the measure of R&D investment with the firm's export status.

Estimates are presented in Column (1) of Table 3. Regression results indicate that the coefficient on R&D investment is negative and significant ($\alpha_1 < 0$, significant at the 1% level), showing that increased R&D is associated with falling long-term leverage ratios. This indicates that R&D investment is mainly financed by internal funding rather than external funding, supported in Column (3). However, the coefficient on the interaction term between export dummy and R&D investment is positive, suggesting that the reliance of R&D on external financing rises with a firm's exporting status, controlling for firm size. This indicates that for non-exporters, innovation is mainly financed through internal financing sources, while for exporters innovation may be primarily financed through external financing.

Similar to Bergin et al. (2021), there is a size effect in firm leverage ratio in that size is significantly and positively correlated with the leverage ratio ($\alpha_2 > 0$, significant at the 1% level). We also find that exporters have lower leverage ratios than their comparable non-exporter peers ($\alpha_3 < 0$, significant at the 1% level). However, the pattern is different when exporters raise their R&D investment, controlling for firm size, which increases their leverage ratio ($\alpha_4 > 0$, significant at the 1% level).[7]

The estimates in Table 3 indicate that firm leverage ratios are heterogeneous among firms, and in particular differ between large exporters and small non-exporters. This characterization resembles the empirical finding for the R&D regressions, showing that R&D expenditure differed between large and small exporters. We claim that the pattern in firm leverage is consistent with firms choosing capital structure to relax financial constraints on working capital associated with exporting and R&D activities.

[7] Estimates are little changed if we expand the regression to include an interaction term of size and exporter status.

In order to interpret the three-way interaction of trade, innovation and firm financing, we need a theoretical model describing how firms make the joint decisions of capital structure adjustment, innovation and exporting.

3. Benchmark Model

The model considers a small open economy, where the home country is in financial autarky, but trades goods with the rest of world. The analysis will focus on the steady state solution to the dynamic model defined below, in which aggregate variables do not change over time.

3.1 Goods market structure

The final good (Y_t) is produced under perfect competition using intermediate goods, both domestically produced and imported, with a CES production function $Y_t = \left[(Y_t^D)^{\frac{\sigma-1}{\sigma}} + \left(Y_t^{X^*}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$, where $Y_t^{X^*}$ represents foreign exports (home imports), which we treat as a standardized unit without varieties, and Y_t^D is a composite of all domestically produced varieties of intermediate goods, given by $Y_t^D = \left[\int_{i\in I_t^{nx}} (y_t^{nx}(\hat{z}_{it}))^{\frac{\sigma-1}{\sigma}} di + \int_{i\in I_t^{x}} \left(y_t^{xd}(\hat{z}_{it})\right)^{\frac{\sigma-1}{\sigma}} di\right]^{\frac{\sigma}{\sigma-1}}$. The subscript nx denotes the activity of a non-exporter, while xd denotes the domestic activity (d) of the exporter x.

We assume a one-to–one correspondence between a home intermediate variety and a firm producing it, indexed by i. Firms are heterogeneous in their initial productivity, z_{it}, and the productivity after R&D investment, $\hat{z}_{it}$. Let I_t^x represent the set of indexes of firms that export, and I_t^{nx} the set of firms that are non-exporters. For an exporting firm, $i \in I_t^x$, we denote the amount of production sold in the domestic market as $y_t^{xd}(\hat{z}_{it})$, and the amount for exports as $y_t^{xx}(\hat{z}_{it})$. Production of a non-exporting firm is $y_t^{nx}(z_i)$.

The corresponding price index (P_t) is:

$$P_t = \left[\int_{i \in I_t^{nx}} (p_t^{nx}(\hat{z}_{it}))^{1-\sigma} di + \int_{i \in I_t^{x}} \left(p_t^{xd}(\hat{z}_{it})\right)^{1-\sigma} + \left(P_t^{X^*}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{1}$$

and the implied relative demand functions for different products are:

$$y_t^{nx}(\hat{z}_{it}) = \left(\frac{p_t^{nx}(\hat{z}_{it})}{P_t}\right)^{-\sigma} Y_t \tag{2}$$

$$y_t^{xd}(\hat{z}_{it}) = \left(\frac{p_t^{xd}(\hat{z}_{it})}{P_t}\right)^{-\sigma} Y_t, \tag{3}$$

where $p_t^{nx}(\hat{z}_{it})$, $p_t^{xd}(\hat{z}_{it})$ and $P_t^{X^*}$ are the domestic market prices of the products produced by a home non-exporter, home exporter and foreign exporter, respectively.

The corresponding foreign market demand for domestic exports ($y_t^{xx}(\hat{z}_{it})$) is

$$y_t^{xx}(\hat{z}_{it}) = \left(\frac{p_t^{xx}(\hat{z}_{it})}{P_t^*}\right)^{-\sigma*} Y_t^* = \left(\frac{p_t^{xx}(\hat{z}_{it})}{P_t}\right)^{-\sigma*} \left(\frac{P_t}{P_t^*}\right)^{-\sigma*} Y_t^* \tag{4}$$

where $p_t^{xx}(\hat{z}_{it})$ is the foreign market price for home exporter with a productivity $\hat{z}_{it}$. P_t^* is the foreign price index, and Y_t^* is the foreign market size. The elasticity of demand facing firms in the world market (σ^*) may be distinct from that in the home market (σ).

3.2 Intermediate goods sector

3.2.1 Firm dynamics

Firms are assigned a random productivity level, z_i, from a common cumulative distribution function $G(z)$ before R&D investment.[8] Entrants have to pay a one-time sunk cost, K_t^E, if they decide to produce and sell in the domestic market. A potential exporter must pay a one-time sunk export entry cost, K_t^{EX} if they decide to sell in the foreign market. We view both of these sunk costs as including a mix of intangible and physical capital.

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[8] It is similar to Eaton and Kortum (2002) where the set of goods is exogenously given. For the numerical analysis firms' idiosyncratic productivity before R&D investment follows a Pareto distribution with a cumulative distribution function of G(z), where $G(z) = 1 - z^{-\theta}$.

Since our study is limited to the partial equilibrium in the steady-state case with no aggregate shocks and fixed assigned initial firm productivity, we follow Melitz (2003) in specifying endogenous firm exit only at the initial point of assigned productivity. The only reason for exit of a producing firm is if it is hit by an exogenous death shock. The entry decisions to domestic and export markets determine the cut-off productivity levels of the marginal domestic producers, z_{dt}, and the marginal exporters, z_{xt}, respectively.

Each period a firm must pay a fixed cost $w_t f_t^d$ to produce domestically, and an extra fixed cost $w_t f_t^x$ if it also chooses to export.[9] The cost of investment in R&D is quadratic as in Aghion et al (2024), given by $RD(k_{it}) = w_t \left(c_I k_{it} + \frac{1}{2} c_{I2} k_{it}^2\right)$, where c_I and c_{I2} are the parameters associated with the variable R&D investment (k_{it}). The direct benefit from the investment in R&D is to improve the productivity of firm i in the period, and we assume that $\hat{z}_{it} = \left(\frac{1}{z_{it}} - \varepsilon k_{it}\right)^{-1}$, where ε is the sensitivity of the productivity improvement to firm innovation. [10] This functional form is consistent with the finding in Maican et al. (2023) which find R&D spending has a larger impact on firm productivity in the export market than in the domestic market.

3.2.2 Firm enforcement constraint

[9] Since we only analyze a non-stochastic steady state of the model, the usual dynamic distinction between sunk and per-period fixed costs does not apply. The only operative distinction here between the two cost is how they are financed; the fixed cost must be financed by working capital loans each period by assumption, while the one-time sunk cost does not.

[10] Note, both the cost and the benefit of innovation are convex in R&D investment. For the costs, we have that R&D spending increases with firm innovation as $\frac{\partial RD(k_{it})}{\partial k_{it}} = w_t(c_I + c_{I2} k_{it}) > 0$, and the second-order derivative is positive as well with $\frac{\partial^2 RD(k_{it})}{\partial (k_{it})^2} = w_t c_{I2} > 0$. For the benefits, we have that the productivity rises with the R&D investment as $\frac{\partial \hat{z}_{it}}{\partial k_{it}} = \varepsilon \left(\frac{1}{z_{it}} - \varepsilon k_{it}\right)^{-2} > 0$, and the larger the initial productivity, the larger the marginal benefit of R&D investment on firm productivity as the second-order derivative is positive as well with $\frac{\partial^2 \hat{z}_{it}}{\partial (k_{it})^2} = 2(\varepsilon)^2 \left(\frac{1}{z_{it}} - \varepsilon k_{it}\right)^{-3} > 0$.

Following Jermann and Quadrini (2009, 2012), we assume that firm i uses debt ($b_t^j(\hat{z}_{it})$) and equity ($q_t^j(\hat{z}_{it})$), $j = nx, x$, to finance production, where debt is preferred to equity because of a tax-shield advantage. The subscript nx denotes the activity of a non-exporter, while x denotes the activity of an exporter. The effective gross interest rate for the debt is $R_t = 1 + r_t(1 - \tau)$, where τ is the tax rate on corporate income.

Firms must make factor payments, including variable and fixed production costs and innovation costs, at the beginning of each period before the realization of revenue. Therefore, in addition to the inter-temporal debt, a firm must borrow an intra-period loan to pay a certain portion of the production cost in advance. The intra-period loans for a non-exporter is given by:

$$loan_t^{nx}(\hat{z}_{it}) = \phi^d w_t[l_t^{nx}(\hat{z}_{it}) + f_t^d] + \phi^{RD,d} w_t\left[\left(c_I k_t^{nx}(\hat{z}_{it}) + \frac{1}{2}c_{I2}\left(k_t^{nx}(\hat{z}_{it})\right)^2\right)\right]$$

and for exporter is given by:

$$\begin{aligned} loan_t^x(\hat{z}_{it}) &= \phi^d w_t\left(l_t^{xd}(\hat{z}_{it}) + f_t^d\right) + \phi^x w_t\left(l_t^{xd}(\hat{z}_{it}) + f_t^d\right) \\ &\quad + \phi^{RD,x} w_t\left[\left(c_I k_t^x(\hat{z}_{it}) + \frac{1}{2}c_{I2}\left(k_t^{nx}(\hat{z}_{it})\right)^2\right)\right] \end{aligned}$$

where w_t is the level of real wage. $l_t^{xx}(\hat{z}_{it})$ and $l_t^{xd}(\hat{z}_{it})$ are the labor inputs by exporters for the production in the export and domestic markets, respectively. $l_t^{nx}(\hat{z}_{it})$ is the labor inputs by non-exporters.

For non-exporters, ϕ^d represents the externally financed fraction of production cost, and $\phi^{RD,d}$ represents the externally financed fraction of R&D cost. Similarly, for exporters, ϕ^x is the externally financed fraction of production cost, and $\phi^{RD,x}$ is the externally financed fraction of R&D cost. The intra-period loan is repaid at the end of each period with no interest. The empirical findings above suggest that exporters may more easily obtain external funds for financing innovation than non-exporters, and hence are able to borrow more to finance innovation, such that $\phi^{RD,x} > \phi^{RD,d}$.

Because firms may default on their debt repayments, their access to intra-temporal loans for use as working capital is restricted by an enforcement constraint. For non-exporters, this constraint is:

$$\xi_t E_t\left[m_{t+1}V_{t+1}^{nx}\left(b_t^{nx}(\hat{z}_{it})\right)\right] \geq \phi^d w_t[l_t^{nx}(\hat{z}_{it}) + f_t^d] + \phi^{RD,d} w_t\left[\left(c_I k_{it} + \frac{1}{2}c_I k_{it}^2\right)\right]$$

and for the exporters, the constraint is:

$$\xi_t E_t\left[m_{t+1}V_{t+1}^{x}\left(b_t^{x}(\hat{z}_{it})\right)\right] \geq \phi^d w_t\left(l_t^{xd}(\hat{z}_{it}) + f_t^d\right) + \phi^x w_t\left(l_t^{xd}(\hat{z}_{it}) + f_t^d\right)$$
$$+\phi^{RD,x} w_t\left[\left(c_I k_{it} + \tfrac{1}{2}c_I k_{it}^2\right)\right] \tag{5}$$

As in Bergin et al. (2018b), the collateral available to firms in securing their working capital is the end-of-period firm value, $E_t\left[m_{t+1}V_{t+1}^{j}\left(b_t^{j}(\hat{z}_{it})\right)\right]$, where $m_{t+1} = \frac{1}{1+r_{t+1}}$ is the discount factor. The firm's equity value $q_t^j(\hat{z}_{it})$ is the end-of-period firm value, $E_t\left[m_{t+1}V_{t+1}^{j}\left(b_t^{j}(\hat{z}_{it})\right)\right]$, where $j = nx, x$.

Although increasing the level of R&D can boost firms' productivity and equity value, the enforcement constraints, as shown in Eq. (5), reveal a trade-off between R&D investment and the costs of external funding. While increased R&D investment can enhance firms' productivity and production, it also raises production and R&D costs and may tighten firms' financial constraint. To relax the constraint, firms may raise their collateral equity value by reducing their debt issuance and switching from cheaper long-term debt financing to more expensive equity financing.

3.2.3 Firm production and pricing

Each firm produces a unique variety, requiring only one factor, labor. The production functions for different types of firms are thus given by

$$y_t^{nx}(\hat{z}_{it}) = A_t \hat{z}_{it} l_t^{nx}(\hat{z}_{it}) \tag{6}$$

$$y_t^{xd}(\hat{z}_{it}) = A_t \hat{z}_{it} l_t^{xd}(\hat{z}_{it}) \tag{7}$$

$$\frac{y_t^{xx}(\hat{z}_{it})}{1-\tau_x} = A_t \hat{z}_{it} l_t^{xx}(\hat{z}_{it}) \tag{8}$$

where A_t is the aggregate productivity common to all firms, τ_x is the iceberg cost for firms engaged in exports, $l_t^{xx}(\hat{z}_{it})$ and $l_t^{xd}(\hat{z}_{it})$ are the labor inputs by exporters for the production in the export and domestic markets, respectively. $l_t^{nx}(\hat{z}_{it})$ is the labor inputs by non-exporters.

Firm dividends for non-exporters are:

$$d_t^{nx}(\hat{z}_{it}) = \frac{p_t^{nx}(\hat{z}_{it}) y_t^{nx}(\hat{z}_{it})}{P_t} - w_t[l_t^{nx}(\hat{z}_{it}) + f_t^d] - \left[b_{t-1}^{nx}(\hat{z}_{it-1}) - \frac{b_t^{nx}(\hat{z}_{it})}{R_t}\right]$$
$$-w_t\left[\left(c_I k_t^{nx}(\hat{z}_{it}) + \frac{1}{2}c_{I2}\left(k_t^{nx}(\hat{z}_{it})\right)^2\right)\right] \tag{9}$$

and for exporters are

$$d_t^{x}(\hat{z}_{it}) = \frac{p_t^{xd}(\hat{z}_{it}) y_t^{xd}(\hat{z}_{it})}{P_t} + \frac{p_t^{xx}(\hat{z}_{it}) y_t^{xx}(\hat{z}_{it})}{P_t} - w_t[l_t^{xd}(\hat{z}_{it}) + l_t^{xx}(\hat{z}_{it})] - w_t[f_t^d +$$
$$f_t^x] - \left[b_{t-1}^{x}(\hat{z}_{it-1}) - \frac{b_t^{x}(\hat{z}_{it})}{R_t}\right] - w_t\left[\left(c_I k_t^{x}(\hat{z}_{it}) + \frac{1}{2}c_{I2}\left(k_t^{x}(\hat{z}_{it})\right)^2\right)\right]$$
$$\tag{10}$$

A firm with productivity z_{it} chooses pricing rule, $p_t^j(\hat{z}_{it})$, dividend payout, $d_t^j(\hat{z}_{it})$, new debt issuance, $b_t^j(\hat{z}_{it})$, and R&D investment $k_t^j(\hat{z}_{it})$ to maximize the beginning-of-period firm value ($V_t^j\left(b_t^j(\hat{z}_{it})\right)$) with productivity $\hat{z}_{it}$ after R&D investment:

$$V_t^j(\hat{z}_{it}) = \underbrace{max}_{p_t^j(\hat{z}_{it}), d_t^j(\hat{z}_{it}), b_t^j(\hat{z}_{it}), k_t^j(\hat{z}_{it})} \left[d_t^j(\hat{z}_{it}) + E_t\left[m_{t+1} V_{t+1}^j\left(b_t^j(\hat{z}_{it})\right)\right]\right], j = nx, x \tag{11}$$

subject to the enforcement constraint, (Eq. 5), market demand, (Eqs. 2-4), production technology (Eq. 6-8), and the cash flow, (Eqs. 9-10).

The first-order conditions for the non-exporters are:

$$\frac{p_t^{nx}(\hat{z}_{it})}{P_t} = \frac{\sigma}{\sigma-1}\left(1 + \phi^d \mu_t^{nx}(\hat{z}_{it})\right)\frac{w_t}{A_t \hat{z}_{it}} \tag{12}$$

$$\mu_t^{nx}(\hat{z}_{it}) = \frac{\frac{1}{R_t} - E_t[m_{t+1}]}{E_t[m_{t+1}]\xi_t} \tag{13}$$

$$\left[\frac{p_t^{nx}(\hat{z}_{it})}{P_t}\right]^{-\sigma} \frac{Y_t}{A_t} \varepsilon (1 + \mu_t^{nx}(\hat{z}_{it})\phi^d) = (c_I + c_{I2}k_{it})(1 + \mu_t^{nx}(\hat{z}_{it})\phi^{RD,d}) \tag{14}$$

The three equations define respectively for the pricing rule for goods price $\frac{p_t^{nx}(\hat{z}_{it})}{P_t}$, the Lagrange multiplier associated with the enforcement constraint $\mu_t^{nx}(\hat{z}_{it})$, and the innovation spending of non-exporters $k_t^{nx}(\hat{z}_{it})$.

The first-order conditions for the exporters are similar,

$$\frac{p_t^{xd}(\hat{z}_{it})}{P_t} = \frac{\sigma}{\sigma - 1}\left(1 + \phi^d \mu_t^x(\hat{z}_{it})\right)\frac{w_t}{A_t \hat{z}_{it}} \tag{15}$$

$$\frac{p_t^{xx}(\hat{z}_{it})}{P_t} = \frac{\sigma^*}{\sigma^* - 1}\frac{1}{1 - \tau_x}\left(1 + \phi^x \mu_t^x(\hat{z}_{it})\right)\frac{w_t}{A_t \hat{z}_{it}} \tag{16}$$

$$\mu_t^x(\hat{z}_{it}) = \frac{\frac{1}{R_t} - E_t[m_{t+1}]}{E_t[m_{t+1}]\xi_t} \tag{17}$$

In particular, the condition for the R&D investment of the exporters is given by:

$$\left\{\left[\frac{p_t^{xd}(\hat{z}_{it})}{P_t}\right]^{-\sigma} \frac{Y_t}{A_t}(1 + \mu_t^x(\hat{z}_{it})\phi^d) + \left[\frac{p_t^{xx}(\hat{z}_{it})}{P_t}\right]^{-\sigma*} \left(\frac{P_t}{P_t^*}\right)^{-\sigma*} \frac{Y_t^*}{A_t}(1 + \mu_t^x(\hat{z}_{it})\phi^x)\right\}\varepsilon$$
$$= (c_I + c_{I2}k_{it})(1 + \mu_t^x(\hat{z}_{it})\phi^{RD,x}) \tag{18}$$

3.2.4 The entry condition for the marginal firm

With the presence of domestic entry cost (K_t^E) , the entry conditions for the marginal entrant to domestic market is given by

$$\left\{\frac{p_t^{nx}(\hat{z}_{dt})y_t^{nx}(\hat{z}_{dt})}{P_t} - w_t[l_t^{nx}(\hat{z}_{dt}) + f_t^d] - w_t\left[f_t^{RD} + \left(c_I k_t^{nx}(\hat{z}_{dt}) + \frac{1}{2}c_{I2}\left(k_t^{nx}(\hat{z}_{dt})\right)^2\right)\right]\right\} + \frac{b_t^{nx}(\hat{z}_{dt})}{R_t} + q_t^{nx}(\hat{z}_{dt}) = K_t^E \tag{19}$$

The first bracket captures the operational profit from running in domestic market. The terms $q_t^{nx}(\hat{z}_{dt})$ and $\frac{b_t^{nx}(\hat{z}_{dt})}{R_t}$ are the end-of-period equity value and firm debt value respectively. Altogether, they represent the beginning-of-period firm value, whose relative size to the sunk entry cost, K_t^E, determines potential entrants' entry decisions to domestic market.

An additional one-time sunk export entry cost, K_t^{EX} implies a marginal exporter whose extra firm value from being an exporter than being a non-exporter must be sufficiently large to cover the sunk entry investment in the export market,

$$\frac{p_t^{xx}(\hat{z}_{xt})y_t^{xx}(\hat{z}_{xt})}{P_t} - w_t l_t^{xx}(\hat{z}_{xt}) - w_t f_t^x - w_t\left[\left(c_I k_t^x(\hat{z}_{xt}) + \frac{1}{2}c_{I2}\left(k_t^x(\hat{z}_{xt})\right)^2\right) - \left(c_I k_t^{nx}(\hat{z}_{xt}) + \frac{1}{2}c_{I2}\left(k_t^{nx}(\hat{z}_{xt})\right)^2\right)\right] + \frac{b_t^x(\hat{z}_{xt})}{R_t} - \frac{b_t^{nx}(\hat{z}_{xt})}{R_t} + q_t^x(\hat{z}_{xt}) - q_t^{nx}(\hat{z}_{xt}) = K_t^{EX} \qquad (20)$$

These entry conditions with the financial enforcement constraints together determine the cut-off productivity levels, z_{dt} and z_{xt}, for being a new non-exporter and a new exporter, respectively.

3.3 Analytical relations between firm innovation, exporting and financial constraints

In this section, we will interpret the first-order condition regarding R&D expenditure to get insight regarding how firm innovation decisions are closely linked to firm exporting status and financial constraints. To emphasize the importance of financial constraints in our model and to support our empirical findings, we compare two scenarios: one without any financial constraints and one with financial constraints on working capital financing. The following analysis will focus on the steady-state of the dynamic model constructed above, and we will drop the time subscript in the subsequent context.

(1) A financial frictionless world

We first consider the case where firms have no financial constraint. In such a case, it would always be that $\mu^j(\hat{z}_x) = 0$. We will show that the firm will always engage in more innovation as an exporter compared to being a non-exporter because an exporter gains additional benefits from export sales, such that $k^{nx}(\hat{z}_x^{nx}) < k^x(\hat{z}_x^x)$, and $\hat{z}_x^{nx} < \hat{z}_x^x$. The reasoning is as follows.

For this given firm with the marginal productivity of z_x, the first-order conditions (FOCs) with respect to R&D for being a non-exporter and being an exporter are respectively given by Eqs. (14) and (18), with $\mu^k = 0, k = x, nx$. The LHS and RHS in each equation are the marginal benefit and marginal cost of doing innovation, respectively.

Suppose the non-exporter and the new exporter choose the same amount of innovation, $k^{nx}(\hat{z}_x^{nx}) = k^x(\hat{z}_x^x)$. According to the FOCs of Eqs. (14) and (18), the marginal cost of innovation will be identical. However, the marginal benefit is larger for the new exporter since it gains additional sales benefit from exporting, which will motivate the new exporter to innovate more than a comparable non-exporter, even if they both have the same marginal productivity. It is worth pointing out that, with the same amount of innovation, the domestic benefits are identical as the two firms will have identical post-innovation productivity ($\hat{z}_x^{nx} = \hat{z}_x^x$), charge the same product prices in the domestic market and hence have identical domestic sales, as shown in the innovation-productivity function, Eqs. (12) and (15), and the market demand functions, Eqs. (2) and (3).

(2) A financially constrained world

In a world with financial constraint where $\mu^{j}(\hat{z}_x) > 0$, if a marginal firm chooses to be an exporter, and $\phi^{RD,x}$ is sufficiently larger than $\phi^{RD,nx}$, which capture the external financing reliance of innovation cost for the exporters and non-exporters respectively, the new exporter may engage in less innovation as the finding in the empirical study, when the marginal cost of innovation rises more than that of the marginal benefit of innovation as a new exporter.

To illustrate this, we first look at the case where the non-exporters and exporters have identical external reliance on R&D financing, $\phi^{RD,d} = \phi^{RD,x}$. Again, suppose the two types of firms make identical innovation investment. From the FOCs on R&D investment, Eqs. (14) and (18), we notice that they would have identical marginal cost of innovation, as well as identical pricing and production in domestic market. The only difference is that the new exporter has additional sales from the foreign market, which raises the marginal benefit of innovation for the new exporter. As a result, the new exporter is more willing to do innovation.

However, if exporters' external reliance on R&D financing is sufficiently larger than that of non-exporters, $\phi^{RD,x} \gg \phi^{RD,d}$, the same innovation would lead to much larger marginal cost for being a new exporter than being a non-exporter. This may reduce the marginal benefit gained from selling abroad, causing the exporter to do less innovation than a comparable non-exporter. This analysis suggests a type of substitutability between exporting and innovation activities for small exporters.

4. Quantitative Analysis

It is not possible in the current model environment to solve for analytical relationships between R&D investment and endogenous capital structure, so we rely upon numerical simulation and sensitivity experiments to illustrate the mechanism at work. Given that the empirical facts are cross-sectional in nature, our strategy is to solve numerically for the steady state of the model, which provides a stationary distribution of firm innovation and leverage ratios.

4.1 Parameter values

Most trade-related parameters are taken from the literature. Following Ghironi and Melitz (2005), the Pareto distribution parameter, domestic and export market substitution elasticities are set at $\theta = 3.8$ and $\sigma = \sigma^* = 3.8$, respectively. Following Bergin et al. (2021), the iceberg trade cost is set at $\tau_x = 0.16$. The sunk cost of domestic firm entry is normalized ($K_t^E = 1$), as its absolute level does not affect the model implications for the ratios reported below.

Given that we solve a partial equilibrium in this small open economy, foreign export prices P^{x^*}, foreign consumer price P^*, home price index P, home wage w and home national income Y are all exogenously given, setting at $P^{x^*} = 1,\ P^* = 0.16$, $P = 0.4230$, $w = 1.9754$ and $Y = 0.8025$, following Bergin et al. (2021). We also follow trade literature in setting the rest of world income at 5 times that of the small open economy ($Y^* = 5Y$, see Feenstra et al., 2018).

Regarding parameters related to firm financing, some values we take directly from the finance literature. We follow Jermann and Quadrini (2012) to set the tax benefit parameter at $\tau = 0.35$, which differentiates debt from equity financing. The exogenous death shock probability is set to $\lambda = 0.005$.[11] Following the norm in the literature (Kohn et al., 2016), firms in the benchmark model calibration are required to externally finance a fraction of the value of working capital for domestic production ($\phi^d = 0.5$), with a greater share of external financing for exports ($\phi^x = 1.0$). The higher value for

[11] This value is taken from Atkeson and Burstein (2010), who match the average annual employment-based failure rate of U.S. firms with more than 500 employees, 1997-2002.

exporters reflects the idea that there is a larger lag time before firms receive revenue from export sales (Amiti and Weistein, 2011). Sensitivity analysis will explore implications of differing financing requirements for exports and domestic sales.

For nine key parameters, we choose values to maximize the model's fit to a set of outside target moments. The parameters chosen are: the fraction of firm value usable as collateral (ξ), the benefit of R&D (ε), the domestic fixed costs (f^d), the export fixed costs (f^x), the export entry cost (K^{EX}), parameters associated with the variable R&D investment (C_I and C_{I2}), and parameters governing the degree of external financing for R&D for exporters, ($\phi^{RDx}$and ϕ^{RDd}).

These parameters are chosen by an algorithm minimizing a weighted sum of squared percent differences between moments for our data and moments generated from the model.[12] The set of targeted moments includes the regression coefficients of R&D on size (0.470), export dummy (-0.394) and the interaction of size and export status (0.0838), from Table 2, as well as the regression coefficients of leverage ratio from Table 3 on R&D (-0.0216), size (0.0130), export dummy (-0.0144) and the interaction of R&D and export status (0.00978). We also include the average leverage ratio for exporters (0.438) and for non-exporters (0.39), as well as the share of firm that engage in export (0.17).

See Table 4 for a full listing of parameter values. We take note that the moment-fitting exercise selects the maximum value possible for the financial friction on R&D financing for exporters, $\phi^{RD,x} = 1$, while it chooses a value close to the minimum value of zero for the financial friction on R&D for non-exporters, $\phi^{RD,d} = 0.0011$. Recall that these parameters indicate the share of expenditure on R&D that must be prepaid and financed using external financing. A very small value for domestic firms is

[12] See replication files for details of the minimization algorithm.

plausible, given that it coincides with the common notion that firms tend to finance R&D internally. A value of 1 for exporting firms warrants further explanation. A higher value for exporters than non-exporters for this external financing parameter may be viewed as similar to the parallel parameters governing external financing of production activity for exporters and non-exporters, ϕ^d and ϕ^x. These we calibrated above based on outside estimates from Kohn et al. (2016) at ϕ^d =0.5 and ϕ^x =1.0, respectively, reflecting estimates that exporters must pre-finance a greater share of their production activity, since they face a longer lag time in receiving revenue from export sales due to the greater shipping times involved in exporting (Amiti and Weistein, 2011). A similar logic may apply to finance R&D, since firms do not receive profits in the current period in time to finance R&D spending. While the fitting algorithm indicates a value of 1 for $\phi^{RD,x,}$ best fits the full set of regression moments, sensitivity analysis to follow will show that a much more modest value for $\phi^{RD,x}$ (around 0.2) is sufficient for the model to replicate the most important of our empirical facts, that an exporter engages in less R&D than a comparable non-exporter.

The other fitted parameters are less remarkable. The sunk cost of exporting ($K^{EX} = 0.1599$), the export fixed costs ($f^x = 0.000123$), the fraction of firm value usable as collateral ($\xi = 0.0644$), and the sensitivity of innovation cost (C_{I2} = 0.00076), and the benefit of R&D (ε = 0.000444). The estimates of the fixed cost of domestic production (f^d) and the linear portion of the R&D cost function (C_I) are approximately 0.[13]

[13] In the case of f^d, the fitting algorithm presses closely against the lower bound of 0 imposed on the search. In the case of C_I, a small negative value of -9xe-7 is found to be optimal. This serves to shift the cost function for R&D, which the fitting algorithm finds useful in fitting the empirical moments. We confirm that the value of the R&D cost ($c_I k_t^j(\hat{z}_{it}) + \frac{1}{2} c_{I2} \left(k_t^j(\hat{z}_{it})\right)^2, j = x, nx$) and the R&D investment ($k_t^j(\hat{z}_{it})$) are both positive for all firms in our sample.

4.2 Benchmark Results

This section reports the model's main implications for R&D investment, leverage ratios, and the degree to which the model can replicate the facts uncovered in the empirical section.

(1) Simulation regression coefficients

Regression results reported in column (2) of Table 5 show that the simulation model is able to match the signs of all the regression coefficients from the empirical regressions; success in matching the magnitudes of coefficients varies. Of particular interest is the coefficient on the exporter dummy in the R&D regression in Panel A. The model generates a coefficient of -0.336, which is fairly close to the estimate from the empirical regression (-0.394). This estimate reiterates the implication from the empirical section that an exporter, when controlling for size of sales, has a lower level of R&D expenditure than a non-exporter. However, exporting still can promote R&D through its ability to augment sales. The regression coefficient on sales is positive (1.3307 vs. 0.470 in data), and also for the coefficient on the interaction term of sales with exporting status (0.0189 vs. 0. 0838 in data). So, it appears that R&D rises even faster with sales for exporters.

The simulated model also implies coefficients in the leverage ratio regression which match all the signs of those from the empirical regression (See Column 2 of Table 5 Panel B). The coefficient on R&D investment is negative (-0.0060 vs. -0.0216 in data), showing that increased R&D is associated with falling long-term leverage ratios. This finding is consistent with the fact well documented in the literature that innovation investment relies more on internal financing than on external financing (Hall and Lerner, 2010). However, the positive coefficient on the interaction term between export dummy and R&D investment (0.00144 vs. 0.00978 in data) also indicates that, the reliance of R&D on external financing rises with a firm's exporting status. The coefficient on the exporter dummy is negative (-0.0267 v.s. -0.0144 in data), indicating that exporters on average have lower leverage ratios than comparable non-exporters. The coefficient on firm size is positive (0.0080 v.s. 0.0130 in data), indicating the size effect in firm leverage ratios.

(2) Cross-sectional Distributions

Intuition for the model's regression results can be gained by examining the cross-sectional distributions of variables. See Figure 1 for plots. Foremost, see panel 1 plotting the level of R&D for firms at each level of exogenous productivity level z_i. Given that firms are heterogeneous in only one dimension, z_i, there is a single cut-off level of productivity, z_i, at which a firm is indifferent between being an exporter or a non-exporter. So, it is at this margin that we can compare the behavior of an exporting firm and a comparable non-exporter in our simulation sample. Panel 1 of the figure shows that for this marginal firm, at z_x, it chooses a lower level of R&D spending when it is an exporter compared to when it is a non-exporter; that is, there is a downward jump in the R&D distribution line at the exporting margin. This jump reflects the negative sign of the coefficient in the R&D regression on the exporter indicator variable.

The figure shows corresponding jumps in financial variables at this exporting margin. There is a jump down in the leverage ratio of this firm when it is an exporter compared to non-exporter, reflecting the negative coefficient on the exporter indicator variable in the Leverage Ratio regression. This cut in log-term leverage comes from a higher level of equity and lower level of long-term bond debt, also observed as jumps in the plot at the export margin. This restructuring of firm capital is in response to the rise in infratemporal loan observed in the figure. Exporters have greater working capital needs, due to the higher share of outside financing for production and R&D for exporters, and they adjust their capital structure to have a greater share of equity in order to use this as collateral.

(3) Showing the mechanism: counterfactuals for the marginal exporting firm

Further insight into the mechanism linking firm financing to the drop in R&D can be gained by studying the marginal exporting firm in more detail. In the steady state of the benchmark model, the export productivity cutoff is at z_x =2.2075, and the marginal firm's optimal R&D is at $k^x(\hat{z}_x^x) = 0.13704$ if it chooses to export, and at $k^{nx}(\hat{z}_x^{nx}) = 0.16288$ if choosing to be a non-exporter. We conduct a few counterfactuals based on firms with the cutoff productivity, z_x.

Counterfactual Exercise #1: Marginal benefit v.s. marginal cost of innovation for the marginal firm

We fix the firm's productivity at the cutoff z_x, while allowing the firm to vary its innovation investment, and then calculate the marginal benefit and the marginal cost for this marginal firm, following Eq. (14) if the firm chooses to be a non-exporter and Eq. (18) if the firm chooses to be an exporter. Figure 2 plots the marginal benefit and the marginal cost for these two versions of the marginal firm. While it is true that the marginal benefit of R&D is greater for the exporter than the non-exporter due to the sales from foreign market, the marginal cost of R&D is also higher. As discussed in the analytical section 3.3 above, this higher cost of R&D arises from the larger reliance of innovation cost on external funds for exporters than for non-exporters, $\phi^{RD,d} \gg \phi^{RD,x}$. Because of the higher marginal cost of R&D, the exporter chooses less R&D.

Counterfactual Exercise #2: Marginal firm exporting but choosing R&D level as if it were not exporting

To understand the role of firm financing in the R&D decision, we construct a hybrid counterfactual case for this marginal firm, where it is an exporter, but suppose it were to choose the same R&D as the non-exporter for this level of z_x at $k^{nx}(\hat{z}_x^{nx}) = 0.16288$ instead of $k^x(\hat{z}_x^x) = 0.13704$. See the appendix B for an explanation of how we use the equilibrium condition to compute this counterfactual case. The higher R&D lowers marginal cost of production and hence price, which raises demand and production. Since production requires sufficient collateral, the higher innovation investment leads to the optimal capital structure decision to reduce bond issuance and raise equity value. But since this implies a loss of tax benefits associated with bond issuance, the rise in equity value is smaller than the fall in bond, and this implies a fall in the total firm value. Computation in the Appendix Table 1 shows that firm value for this counterfactual exporter falls slightly to 3.149498, compared to 3.149547 for the marginal exporter. Lower firm value indicates this is not the optimal firm decision. Further, taking this firm value to the export entry condition, it no longer is sufficient to cover the sunk cost of entry. We thus complete our proof by contradiction: the exporting version of the marginal firm must have lower R&D than the non-exporter; if it did not lower R&D, the adjustment in capital structure would imply a fall in total firm value that means the firm could not actually be the marginal exporter.

In contrast, if the firm is willing to lower R&D, the reduction in required working capital allows for capital structure with more long-term bonds and hence higher firm value that justifies export entry. Total firm value thus is maximized as an exporter, but with a lower level of R&D. See Figure 3, where we plot the counterfactual exporter's total firm value by varying its innovation investment, and assume binding financial constraint. The firm must choose between higher R&D or being an exporter. This is the sense in which exporting and R&D are substitutes in this model due to financial constraints.

Counterfactual Exercise #3: Counterfactual firms exporting but choosing R&D level as if they were not exporting, for firms with different level of productivities

This tradeoff between R&D investment and exporting is different for larger firms whose productivity z_i is sufficiently high. For these firms, becoming an exporter does not require a fall in R&D to generate enough firm value to justify export entry. See Figure 4 where the vertical axis, $F(z_i)$, is the firm value difference, net off export entry cost, between a counterfactual new exporter and a non-exporter, whose initial productivities are identical and whose innovation investment are both set at the optimal level of the non-exporter.[14] Small exporters with low productivity have lower additional firm value than comparable non-exporters, and may need to cut innovation to raise firm value. In contrast, large exporters have sufficient additional firm values to cover export entry costs and do not need to cut their innovation to export. This implies that R&D and exporting are substitute for small exporters but not for large exporters.

4.3 Sensitivity Analysis

(1) The financial mechanism

To explore the financial mechanism, we conduct sensitivity analysis for alternative parameterizations of the financial friction parameters. Column (3) of Table 5 reports the result where we assume no working capital is needed for any activity: $\phi^d = \phi^x = \phi^{RD,d} = \phi^{RD,x} = 0$. Regressions on data from simulating this version of the model

[14] $F(z_i) = (1+r)\big(q^x(\hat{z}_i^{nx}) - q^{nx}(\hat{z}_i^{nx})\big) + b^x(\hat{z}_i^{nx}) - b^{nx}(\hat{z}_i^{nx}) - K^{EX}$, where $\hat{z}_i^{nx}$ indicates that the productivity of Firm *i* chooses its optimal level of R&D in the case of not exporting.

show that the exporter dummy in the R&D regression remains negative, but its magnitude is cut in half: from -0.3357 to - 0.1547. This indicates that financial frictions account for about half of the negative effect of exporting on R&D (controlling for sales), with half of the effect coming from a different mechanism in the model separate from financing. This other mechanism will be taken up below.

Another observation is that this alternative version of the model utterly fails to account for the heterogeneity of leverage among firms. The coefficients in the leverage regression all are zeros. This is because there is no benefit from equity holdings as financial collateral, so all firms choose 100% leverage since debt financing is cheaper than equity financing. This result indicates that financial frictions, while helpful in explaining the R&D result, are absolutely essential for the model's success in replicating the leverage ratio coefficients.

When we set financial frictions for R&D for exporters to be the same as non-exporters ($\phi^{RD,d} = \phi^{RD,x} = 0.0011$), column (4) shows that the model generates a similarly low exporter dummy coefficient (-0.115) in the R&D regression as that above where all of the financial friction parameters are set to zero. This confirms that it is the financial friction on R&D that is essential for our result of substitution between innovation and exporting for small exporters. Columns (5) and (6) show that we get a very similar coefficient on the exporter dummy when both of the R&D financial frictions are calibrated at the same value, either at 1 or 0.5. This makes clear that what is required for the result is a difference in the financial friction for R&D between exporters and non-exporters, not a high value of financial friction for exporters, per se.

While a value of $\phi^{RD,x}$ =1 is chosen by the fitting algorithm fit the data best, it turns out that to get our key result of a fall in R&D for the marginal exporter, only a modest value of $\phi^{RD,x}$ is needed. Figure 5 plots the optimal choices of R&D for the marginal firm as exporter or non-exporter respectively, varying the value of $\phi^{RD,x}$, holding the value of $\phi^{RD,d}$ at zero. As $\phi^{RD,x}$ rises, the level of R&D chosen by the exporter falls, and eventually is lower than that of the non-exporters. The figure shows that value of only 0.2 is needed to imply the exporter choses a lower value of R&D than the non-exporter.

To further identify the role of financial frictions on firm innovation, we examine the performance of the marginal exporter from the benchmark in two different financial settings, the benchmark setting with $\phi^{RD,d} = 0.0011, \phi^{RD,x} = 1$, and the column (6) setting of Table 5 with $\phi^{RD,d} = \phi^{RD,x} = 0.0011$. The benchmark marginal exporter has a productivity level of z_x =2.2075. In the setting of column (6) of Table 5, the marginal productivity is z_x =2.2068, which implies this benchmark marginal exporter now has productivity greater than the cutoff level in the column (6) setting. We find that, when financial friction on innovation for exporters is reduced from $\phi^{RD,x} = 1$ to $\phi^{RD,x} = 0.0011$, this marginal exporter does more innovation, rising by 24.65%.

(2) The functional form of innovation costs

It was noted above that financial frictions account for about half of the magnitude of the exporter dummy in the R&D regression results. The other half comes from the particular functional form of R&D costs and benefits, which was taken directly from Aghion, et al. (2024). The functional form of R&D benefits implies that a given amount of R&D expenditure (Δk) lowers the marginal cost of production for a certain amount ($\varepsilon\Delta k$) and hence raises firm productivity correspondingly. For firms with higher productivity and lower marginal cost to start with, a given drop in marginal cost presents a larger percentage drop in marginal cost, hence a lager proportionate gain. So, when the regression implicitly compares two firms while controlling for sales, where one achieves this level of sales by exporting to the larger foreign market along with domestic sales, and the other purely through domestic sales, the latter firm must have a higher level of exogenous productivity. This implies that the firm will have larger gains from a given level of R&D expenditure and hence a stronger incentive to do R&D than exporters with equal sales.

(3) The elasticity of substitution in foreign market

Another sensitivity check of interest is the value of σ^*, the elasticity of substitution facing exports. Bergin, Feng and Lin (2021) estimated this elasticity at a value well below the standard value of 3.8, finding this value is helpful in explaining the higher leverage ratios of exporters compared to non-exporters, as it implies a higher markup and profit for exports compared to domestic sales, and hence raises firm value relative to sales and working capital needs.

In the present model, a lower elasticity of substitution facing exports tends to imply lower R&D relative to sales, since it implies the export market is less price-sensitive, so there is a smaller gain in terms of export sales from R&D improving price competitiveness. This suggests a third mechanism that an alternatively calibrated version of our model to explain why exporting lowers R&D expenditure controlling for sales, as it lowers the benefits or R&D.

Column (7) reports regression results for the model with σ^* chosen to fit the export dummy in the R&D regression. We find that with a value of 3.43, we can fully match the exporter dummy coefficient of -0.39. It also somewhat improves the match to the coefficient on the interaction term of sales with exporting, which equals 0.0384, which is closer to the empirical target of 0.084 than was the benchmark model.

5. Conclusion

This paper challenges the prevailing view in international trade literature that exporting and innovation are always complementary, especially for smaller firms. While larger firms with high productivity can engage in both activities without sacrificing R&D, smaller exporters face financial constraints that force a tradeoff between R&D investment and exporting. Different from the literature, we emphasize the critical role of firm financing, particularly the adjustment of firm capital structure, in understanding the substitution effect observed among small exporters.

Empirically, we study data of public U.S. manufacturing firms focusing on exporting, R&D expenditure, and financial leverage. Our findings reveal a new stylized fact: although exporting is typically linked with increased R&D, small exporters actually invest less in R&D compared to similar non-exporters, once sales are controlled for. Additionally, our examination of financial data highlights differences in capital structure among firms: while non-exporting firms use internal financing for R&D, exporting firms rely more on external financing for their R&D activities.

We propose a theoretical explanation that small exporters are unable to reap the full benefits of exporting due to their limited ability to finance both innovation and the costs of export participation. Specifically, low-productivity exporters adjust the capital structure toward equity to provide collateral to secure extra financing for export working capital needs, reducing firm leverage ratios. However, such a switch may lower overall firm value, and offset the rise in firm value from higher productivity due to innovation or larger market sales from exporting and reduce the ability of firms to pay the sunk entry cost of exporting. To continue participating in exports, they need to cut back on their innovation investments. Model simulations reveal a consistent pattern: firms adjust their capital structures in response to financial constraints, which impact their ability to invest in both R&D and export activities simultaneously. Sensitivity analyses and counterfactual exercises reinforce our conclusions, demonstrating that financial frictions play a crucial role in explaining why small exporters might reduce their R&D investment.

References

[1] Acharya, V., and Z. Xu (2017). Financial dependence and innovation: The case of public versus private firms. *Journal of Financial Economics* 124(2), 223-243.

[2] Aghion, P., A. Bergeaud, M. Lequien, and M. J. Melitz (2024). The heterogeneous impact of market Size on innovation: evidence from French firm-level exports. *Review of Economics and Statistics* 106(3), 608–626.

[3] Akcigit, U., and M. J. Melitz (2022). International Trade and Innovation. *Handbook of International Economics* 5: 377-404.

[4] Altomonte, C., S. Gamba, M. L. Mancusi, and A. Vezzulli (2016). R&D investments, financing constraints, exporting and productivity. *Economics of Innovation and New Technology* 25(3), 283-303.

[5] Amiti, M., and D. E. Weinstein (2011). Exports and financial shocks. *Quarterly Journal of Economics* 126, 1841-1877.

[6] Atkeson, A. and A. T. Burstein (2010). Innovation, firm dynamics, and international Trade, *Journal of Political Economy* 118, 433-484.

[7] Baggs, J., and J. A. Brander (2006). Trade liberalization, profitability, and financial leverage. *Journal of International Business Studies* 37(2), 196-211.

[8] Benfratello, L., F. Schiantarelli, and A. Sembenelli (2008). Banks and innovation: Microeconometric evidence on Italian firms[J]. *Journal of Financial Economics* 2,197-217.

[9] Bergin, P., L. Feng and C. Lin (2018a), "Financial Frictions and Trade Dynamics", *IMF Economic Review* 66, 480-526.

[10] Bergin, P.R., Ling Feng, and Ching-Yi Lin (2018b). Firm entry and financial shocks. *The Economic Journal* 128(609), 510-540.

[11] Bergin, Paul R., Ling Feng, and Ching-Yi Lin (2021). "Trade and Firm Financing", *Journal of International Economics,* volume 131, *online published*.

[12] Bernstein, S. (2015). Does going public affect innovation? *The Journal of Finance* 70(4), 1365-1403.

[13] Brown, J. R. and B. C. Petersen (2009). Why has the investment-cash flow sensitivity declined so sharply? Rising R&D and equity market developments. *Journal of Banking and Finance* 33(5), pp.971–984.

[14] Bustos, P. (2011). Trade liberalization, exports and technology upgrading: evidence on the impact of MERCOSUR on Argentinean firms. *American Economic Review*, 101, 304-340.

[15] Campa, J. M., and J. M. Shaver (2002). Exporting and capital investment: on the strategic behavior of exporters. *Discussion Paper* n469. IESE Business School, University of Navarra.

[16] Chaney, T. (2016). Liquidity constrained exporters. *Journal of Economic Dynamics and Control*, 72(C), 141-154.
[17] Chen, J. P., S. A. Cheng, J. He, and J. Kim (1997). An investigation of the relationship between international activities and capital structure. *Journal of International Business Studies*, 28(3), 563-577.
[18] Chor, D. and K. Manova (2012). Off the Cliff and Back? Credit Conditions and International Trade during the Global Financial Crisis. *Journal of international economics*, 87, 117-133.
[19] Comin, D. and R. Nanda. 2019. Financial Development and Technology Diffusion. *IMF Economic Review*, 67(2), 395-419.
[20] Costantini, J, and M. J. Melitz (2007). The dynamics of firm-level adjustment to trade liberalization. *The Organization of Firms in a Global Economy*, edited by Elhanan Helpman, Dalia Marin, and Thierry Verdier. Cambridge: Harvard University Press.
[21] Eaton, J., and S. Kortum (2002). Technology, Geography, and Trade. *Econometrica*, 70(5): 1741-1779.
[22] Egger, P., and Keuschnigg, C. (2015). Innovation, trade, and finance. *American Economic Journal: Microeconomics*, 7(2), 121-57.
[23] Feenstra, R., Z. Li and M. Yu (2014): "Exports and Credit Constraints under Incomplete Information: Theory and Evidence from China", *Review of Economics and Statistics*, 96, 729-744.
[24] Feenstra, R. C., P. Luck, M. Obstfeld, and K.N. Russ, 2018. "In search of the Armington elasticity," *The Review of Economics and Statistics*, 100(1), 135-150.
[25] Föllmi R., S. Legge, and A. Tiemann (2015). Innovation and trade in the presence of credit constraints. Available at *SSRN*.
[26] Foley, C. F., and K. Manova (2015). International trade, multinational activity, and corporate finance. *Annual Review of Economics*, 7(1): 119-146.
[27] Gorodnichenko Y. and M. Schnitzer (2010), Financial constraints and innovation: why poor countries don't catch up. *NBER working paper 15792*.
[28] Gorodnichenko Y. and M. Schnitzer (2013), Financial constraints and innovation: why poor countries don't catch up. *Journal of the European Economic Association* 11(5), 1115-1152.
[29] Greenaway, D., A. Guariglia, and R. Kneller (2007). Financial factors and exporting decisions. *Journal of International Economics* 73(2): 377-395.
[30] Hall, B. H.， and J. Lerner (2010). The financing of R&D and innovation. *Handbook of the Economics of Innovation*, North-Holland, Volume 1, 609-639.
[31] Howell, S. T. (2017). Financing Innovation: Evidence from R&D Grants. *American Economic Review* 107 (4): 1136-64.

[32] Hsu P., X. Tian, and Y. Xu (2014). Financial development and innovation：Cross-country evidence. *Journal of Financial Economics* 1, 116 -135.
[33] Iacovone, L., E. Ferro, M. Pereira-López, V. Zavacka (2019). Banking crises and exports: lessons from the past. *Journal of Development Economics* 138, 192-204.
[34] Jermann, U. and V. Quadrini (2009). Macroeconomic effects of financial shocks. *NBER Working Paper* 15338.
[35] Jermann, U. and V. Quadrini (2012). Macroeconomic effects of financial shocks, *American Economic Review* 102(1), 238-271.
[36] Kohn, D., F. Leibovici, and M. Szkup (2016). Financial frictions and new exporter dynamics. *International economic review* 57(2), 453-486.
[37] Lileeva, A. and D. Trefler (2010). Improved access to foreign markets raises plant-level productivity…for some plants. *Quarterly Journal of Economics* 125 (2), 1051-1099.
[38] Lim, S. C., A. J. Macias, and T. Moeller (2020). Intangible assets and capital structure. *Journal of Banking and Finance* 118, 105873.
[39] Lin, C., S. Liu, and L. Wei (2018). Banking and Innovation: A Review. *ADBI Working Papers 815*, Asian Development Bank Institute.
[40] Maican, F., M. Orth, M. J. Roberts, and V. A. Vuong (2023). Dynamic impact of exporting on firm R&D investment. *Journal of the European Economic Association* 21(4), 1318-1362.
[41] Manova, K. (2013). Credit constraints, heterogeneous firms, and international trade. *Review of Economic Studies* 80, 711-744.
[42] Manova, K., S.J. Wei, and Z. Zhang (2015). Firm exports and multinational activity under credit constraints. *Review of Economics and Statistics* 97, 574-588.
[43] Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71(6), 1695-1725.
[44] Mittoo, U. R., and Z. Zhang (2008). The capital structure of multinational corporations: Canadian versus U.S. evidence. *Journal of Corporate Finance* 14(5), 706–720.
[45] Paravisini, D., V. Rappoport, P. Schnabl, and D. Wolfenzon (2015). Dissecting the effect of credit supply on trade: Evidence from matched credit-export data. *Review of Economic Studies* 82(1), 333-359.
[46] Peters, B., M. J. Roberts, and V. A. Vuong (2022). Firm R&D investment and export market exposure. *Research Policy* 51(10), 104601,
[47] Tadesse, S. (2006). Innovation, information, and financial architecture. *Journal of Financial and Quantitative Analysis* 4, 753-786.
[48] Xu, J. (2012). Profitability and capital structure: Evidence from import penetration. *Journal of Financial Economics* 106(2), 427-446.

Table 1: Summary Statistics

	total sample	not exporting	exporting
means:			
log of R&D expense	1.68	1.037	3.224
size (log of sales)	4.768	3.997	6.617
R&D to sales ratio	3.557	5.004	0.086
R&D to total assets	0.085	0.097	0.058
Book Leverage ratio	0.404	0.39	0.438
Book equity ratio	0.596	0.61	0.562
Retained earnings ratio re/A	-0.477	-0.727	0.122
Long-term debt to total assets	0.136	0.13	0.153
Debt in current liabilities to total assets	0.05	0.054	0.042
standard deviation of R&D expense (within)	0.883	0.801	0.647
standard deviation of size (within)	0.863	0.822	0.546
Observations	49351	34837	14514

Table 2: R&D Regressions

	(1)	(2)
	log of R&D expense	**log of R&D expense**
size	0.478***	0.470***
	(0.00425)	(0.00425)
export dummy	0.110***	-0.394***
	(0.0120)	(0.0303)
export dummy*size		0.0838***
		(0.00462)
Observations	49351	49351

Table 3: Leverage Ratio Regressions

	Book Leverage ratio	Retained earnings ratio re/A	Long-term debt to total assets	Debt in current liabilities to total assets
log of R&D	-0.0216***	0.305***	-0.00173*	-0.00371***
Expense	(0.00104)	(0.0147)	(0.000879)	(0.000461)
size	0.0130***	0.289***	0.00969***	0.00195***
	(0.00103)	(0.0145)	(0.000870)	(0.000457)
export dummy	-0.0144***	0.307***	-0.0139***	-0.00274
	(0.00362)	(0.0510)	(0.00306)	(0.00161)
export dummy*	0.00978***	-0.0323*	0.00486***	0.00209***
log R&D expense	(0.000950)	(0.0134)	(0.000803)	(0.000422)
N	49351	49309	49328	49340

Table 4: Benchmark Model Parameterization

From literature	
Pareto distribution parameter	$\theta = 3.8$
Substitution elasticity (domestic)	$\sigma = 3.8$
Probability of death shock	$\lambda = 0.005$
Iceberg trade cost	$\tau_x = 0.16$
Tax benefit	$\tau = 0.35$
Domestic market production cost financed externally	$\phi^a = 0.5$
Export market production cost financed externally	$\phi^x = 1$
Rest-of-world income	$Y_t^* = 5Y$
Rest-of-world export price	$P^* = 0.16$
Substitution elasticity (foreign) consumption bundle	$\sigma *= 3.8$
Moment matching	
Domestic fixed cost	$f^d = 0.0000$
Export fixed cost	$f^x =0.000123$
Export Entry cost	$K^{EX} = 0.1599$
Enforcement parameter	$\xi =0.0644$
R&D cost and benefit related parameters	
Non-exporters' R&D cost financed externally	$\phi^{RD,d} = 0.0011$
Exporters' R&D cost financed externally	$\phi^{RD,x} = 1.0000$
R&D cost	$c_I= 0.0000$
	$c_{I2} =0.00076$
R&D benefit	$\varepsilon = 0.000444$

Table 5. Regression from Model Simulations

	1 Data	2 Benchmark model	3 ϕ^{d}=ϕ^{x}= $\phi^{RD,d}$= $\phi^{RD,x}=0$	4 $\phi^{RD,x}$ $=0.0011$	5 $\phi^{RD,d}=1$	6 $\phi^{RD,x}=$ $\phi^{RD,d}$=0.5	7 Lower export elasticity (σ^{*}=3.425)
Panel A: Dependent variable: Log of RD expense							
sales	0.470***	1.3307	1.3257	1.3307	1.3243	1.3275	1.3235
exporter	-0.394***	-0.3357	-0.1547	-0.1152	-0.1084	-0.1118	-0.3942
sales*exporter	0.0838***	0.0189	0.0203	0.0204	0.0253	0.0228	0.0388
Panel B: Dependent variable: Leverage Ratio							
R&D	-0.0216***	-0.0060	0	-0.0054	-0.0053	-0.0055	-0.0237
sales	0.0130***	0.0080	0	0.0071	0.0069	0.0072	0.0313
exporter	-0.0144***	-0.0267	0	-0.0254	-0.0252	-0.0253	-0.0277
R&D*exporter	0.00978***	0.0014	0	0.0014	0.0014	0.0014	0.0072
Panel C: Other moments							
LR-Domestic	0.390	0.4333	1.000	0.4333	0.4333	0.4333	0.4333
LR-exporter	0.438	0.4074	1.000	0.4075	0.4070	0.4072	0.4044
export participation rate	17.00	16.97	24.15	16.97	16.97	16.97	35.57

Figure 1. Benchmark model, distribution of firm variables in steady state

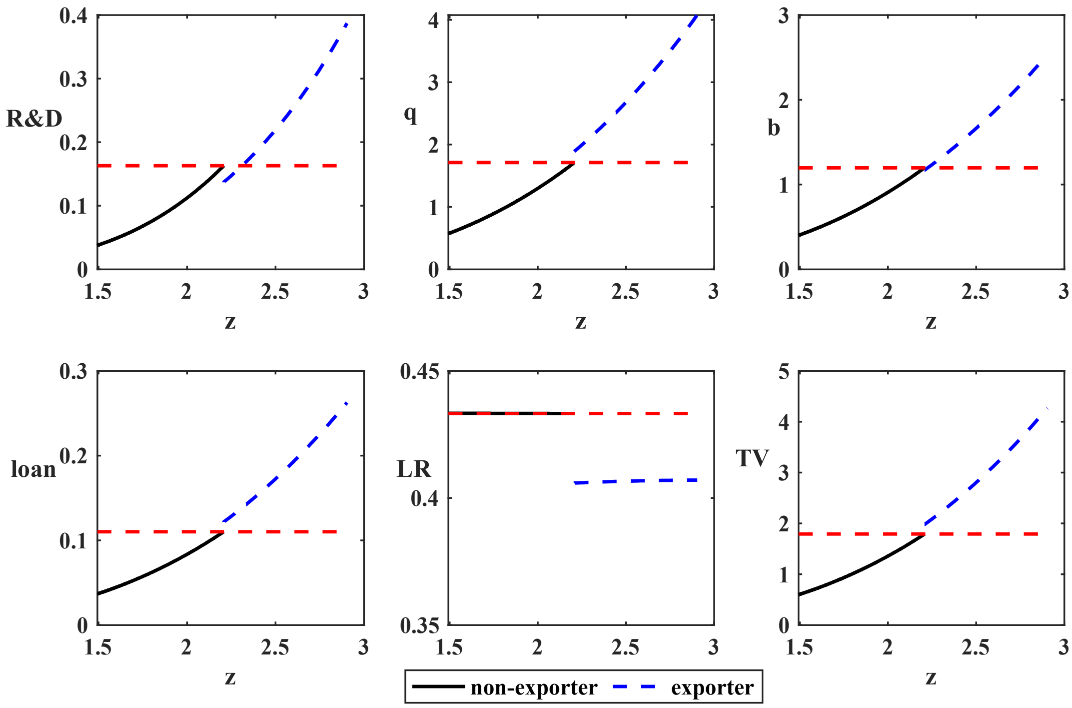


Figure 2. Marginal Cost and Benefit of R&D for Marginal Exporter

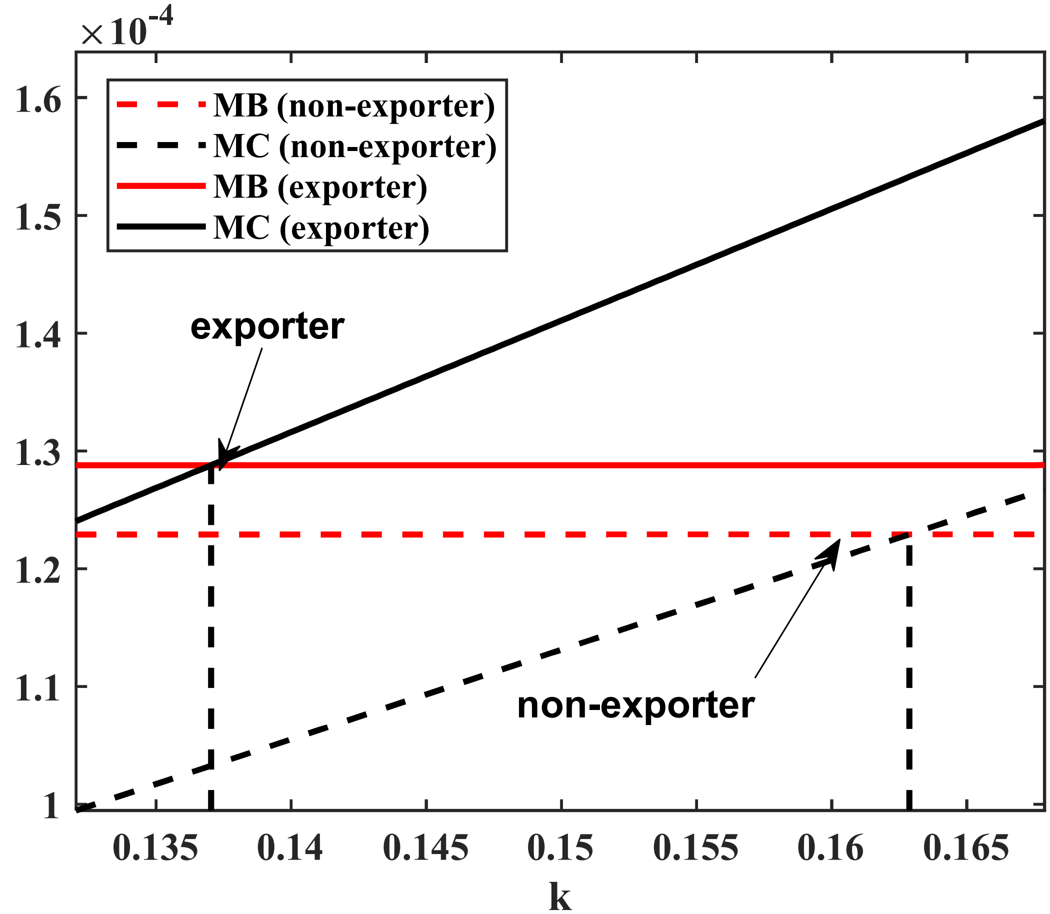


Figure 3. Total firm value of R&D for marginal exporter

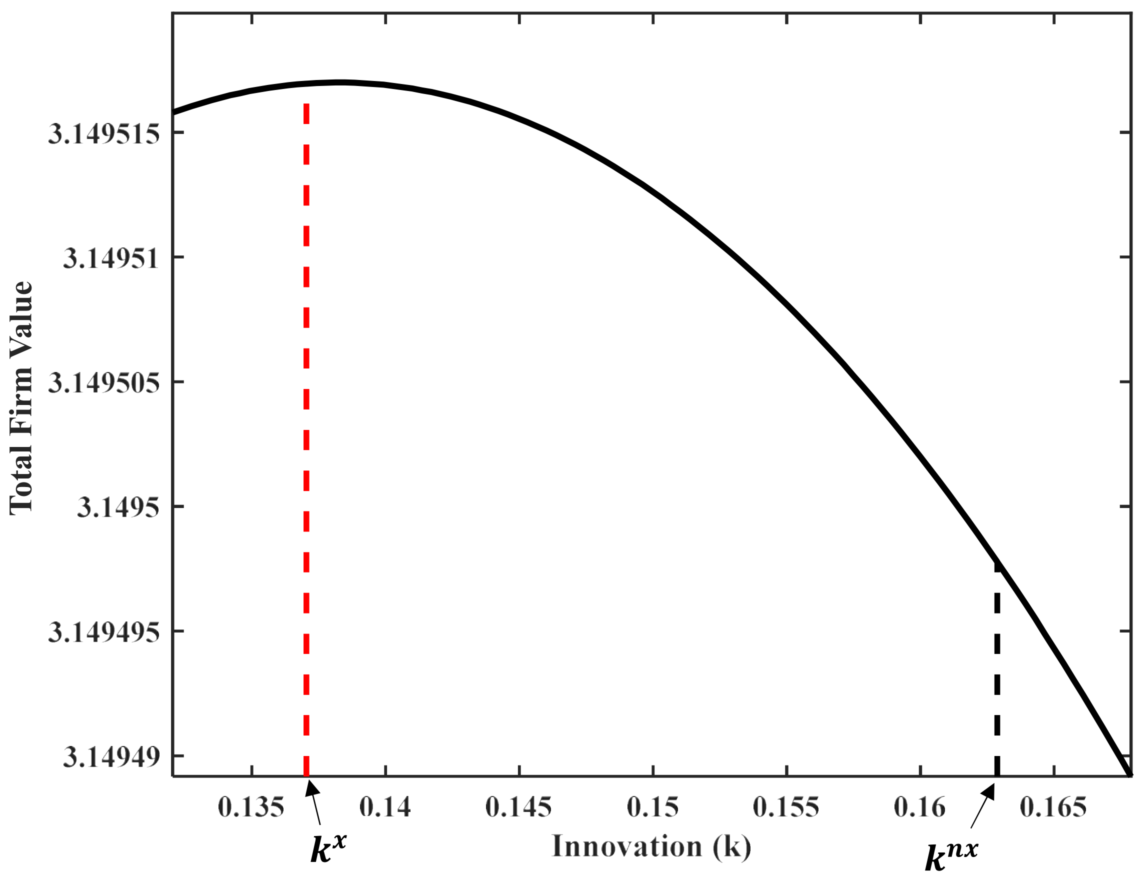
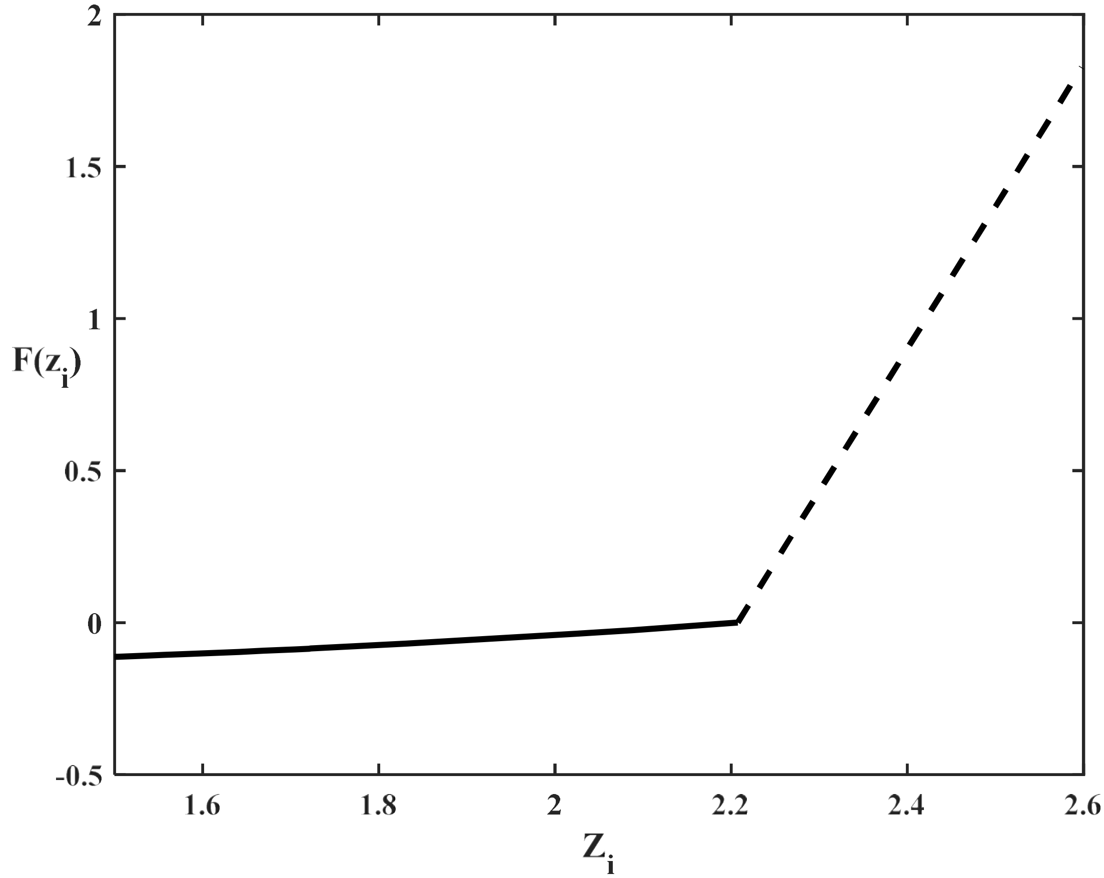


Figure 4. Counterfactual exercise if firm i exports but choosing $\boldsymbol{k^{nx}(\hat{z}_i^{nx})}$



Note: $F(z_i) = (1+r)\big(q^x(\hat{z}_i^{nx}) - q^{nx}(\hat{z}_i^{nx})\big) + b^x(\hat{z}_i^{nx}) - b^{nx}(\hat{z}_i^{nx}) - K^{EX}$, where $\hat{z}_i^{nx}$ indicates that the productivity of Firm *i* chooses its optimal level of R&D in the case of not exporting.

Figure 5. The optimal level of R&D for the marginal firm for different $\phi^{RD,x}$