Can Tariffs Spur Innovation?*†

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Abstract

We study sector-specific import tariffs and innovation in a dynamic model of trade and endogenous growth where technology gaps between domestic and foreign firms determine the degree of competition and their innovation incentives. Tariffs alter this competitive pressure and, thereby, firms' innovative effort. A tariff increase initially stimulates innovation only when domestic firms are sufficiently laggard in technology: by raising the cost of imports, it brings the home market within their reach and intensifies the competition to serve it. Tariffs weaken innovation when domestic firms are only moderately behind or the tariff increase is so large as to effectively shield domestic firms from foreign competition. Permanent tariff increases can reverse early gains as domestic firms regain their home market and competitive pressure weakens; temporary tariffs limit this decline. Retaliatory tariffs by the foreign country have little effect in sectors it leads, while foreign export subsidies can diminish U.S. market gains obtained via higher tariffs. Consistent with the theoretical mechanism, patent data around the 2018–2019 U.S.-China tariffs show stronger U.S. and Chinese patenting responses to tariff exposure in products where the U.S. lagged considerably.

JEL Classification: F13, O31, O33, O41, L13

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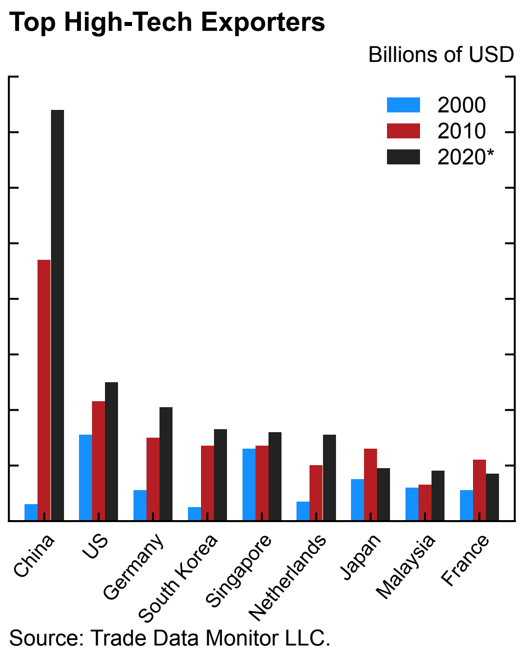
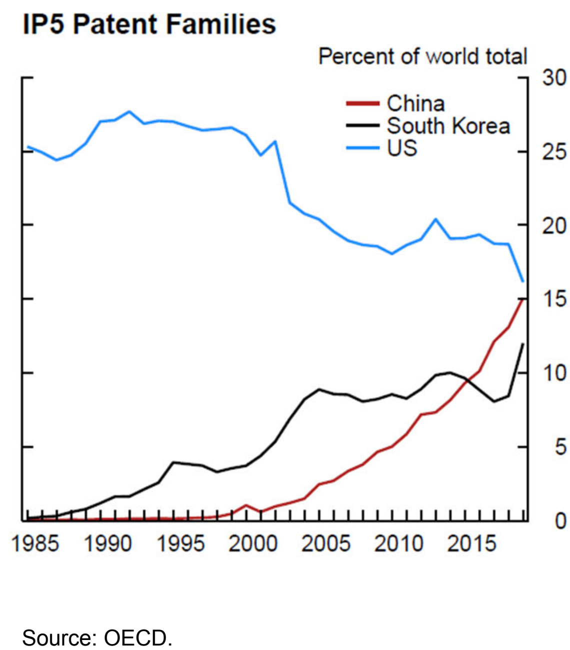
1. Introduction

Global innovation leadership has shifted markedly over the past two decades. China's high-technology export share rose from negligible levels in the early 2000s to more than 30 percent of global high-tech exports by the early 2020s (Figure 1a). At the same time, China's share of global patents increased sharply, and the technology gap between the U.S. and its competitors narrowed in many sectors (Figure 1b).

Figure 1. Global technological competition has intensified.



(a) High-tech exports



(b) IP5 patent family shares

Note: IP5 patents are those registered in at least two of the five largest intellectual property offices (EU, US, China, Japan, South Korea). Sources: Trade Data Monitor (panel a); OECD patent statistics, IP5 patent families by inventor country and priority date (panel b).

This shift has prompted major policy responses. The 2023 G7 Communiqué (G7, 2023) and the Draghi Report (Draghi, 2024) identify technological leadership as a strategic priority. Governments across advanced economies have responded with trade and technology policies ranging from sharp U.S. tariff increases to direct support for domestic innovation through the CHIPS Act and analogous measures in Europe and Japan. These interventions rest on the view that policy can stimulate innovation and maintain technological competitiveness. Yet the relationship between trade policy, competition, and innovation is subtle. On the one hand, higher tariffs raise the cost of serving the domestic market for foreign rivals, improving domestic firms' prospects of a larger market share and thereby the return to innovation and the effort they devote to it. On the other hand, a tariff barrier can become so high that it shields domestic firms from any significant foreign competition, allowing them to protect their market comfortably and relax their innovation effort. The implications of trade policy for innovation therefore depend on how it affects the degree of competition domestic firms face, and they change over time as competitive conditions evolve in response to the policy itself.

This paper asks when a tariff raises innovation. The answer turns on three aspects: the initial technological gap between the domestic firm and its foreign rival, the size of the tariff increase relative to that gap, and the duration of the policy. Our theoretical framework is a two-country dynamic endogenous growth model developed in Akcigit et al. (2026). This framework features the U.S. and a "Foreign" country representing an aggregate of its major trading partners, with a continuum of intermediate-good sectors in which one firm per country competes à la Bertrand. Firms advance their technology through discrete quality steps whose size depends on their distance to the technology frontier. The framework incorporates iceberg trade costs, ad-valorem tariffs, and endogenous entry and exit through a fringe of potential domestic entrants. Unlike static trade models, which treat technology as exogenous or focus on one-time reallocation effects, this framework endogenizes innovation decisions and allows policy to reshape firms' long-run technology positions (cf. Arkolakis et al., 2012).

The main theoretical result is that tariffs can raise innovation by technologically laggard domestic firms. The mechanism stems from the way competition shapes R&D incentives. A firm's incentive to innovate is strongest when competition is most intense, and a technological improvement can change which markets the firm serves: a laggard domestic firm under the threat of losing its home market to imports has a strong incentive to innovate to defend that market. A tariff weakens the foreign rival's competitive position in the home market. For a domestic firm that is significantly behind, this makes capturing the home market achievable and strengthens its R&D incentive. For a firm that is only moderately behind, by contrast, the same tariff merely insulates it from foreign competition and weakens its incentive to innovate.

We calibrate the balanced growth path (BGP) of the model to the period between 2010 and 2017 using data on the U.S. and its eight major trading partners that actively register patents in the U.S. Importantly, we use the patent data to discipline the technology gap distribution across sectors on the BGP. In the main quantitative exercise, we examine the transitional dynamics that changes in trade policy trigger in particular sectors. When doing so, we vary three dimensions: (i) the initial technology gap between firms, (ii) the duration of the policy (temporary vs. permanent), and (iii) the size of the increase relative to the gap. In addition to allowing us to study temporary policy changes, our analysis of transitional dynamics also helps us distinguish short- and long-term policy implications.

Our main quantitative exercise shows that the case for tariffs to spur innovation is strongest when tariffs are temporary and target sectors that are sufficiently laggard. By contrast, when tariffs are sustained permanently, applied in sectors where the domestic firm is only moderately behind, or set too high relative to the initial technology gap, they shield the domestic firm from foreign competition and allow it to retain its market comfortably, weakening its incentive to innovate. We also contrast tariff policy with R&D subsidies as a policy alternative. R&D subsidies lower research costs without changing trade barriers. Consequently, domestic innovation benefits from permanently higher subsidies regardless of the size of the initial technology gap. The results highlight that the scope for tariffs in managing global technology competition is highly nuanced.

We then study foreign retaliation within the sector targeted by the U.S. tariff, through a tariff on imports from the U.S. or an export subsidy. The two instruments act on different margins: a retaliatory tariff raises the technology lead a U.S. firm needs to export, whereas an export subsidy lowers the lead a foreign firm needs to sell in the U.S., partially offsetting the U.S. tariff. When the U.S. increases tariffs in a sector in which it is significantly behind, foreign retaliation through tariffs generates a small response because the laggard U.S. firm is far from the lead it needs to export. By contrast, an export subsidy serves the objective of preserving the foreign country's technological edge: a temporary U.S. tariff helps U.S. firms close the technology gap faster, and the export subsidy can undo this catch-up. But if the foreign country instead focuses on the level of its firms' innovation, an export subsidy works against that objective. The reason is that higher U.S. tariffs lead to a narrowing of the technology gap while stimulating R&D for both economies because, by raising the cost for foreign exporters, U.S. tariffs erode foreign firms' competitive edge and intensify competition for both sides. The reverse occurs when the foreign country responds with export subsidies to higher U.S. tariffs in a sector in which the U.S. is initially only moderately behind: a retaliatory export subsidy restores foreign innovation but limits the gain in the foreign firm's technological lead caused by higher U.S. tariffs.

We use the 2018–2019 U.S. Section 301 tariff increases on imports from China to test the model's prediction that innovation responses depend on initial technology gaps. We match USPTO patents to HS6 products, measure each product's pre-tariff

U.S. technology position, and ask whether products in which the U.S. starts far behind foreign competitors exhibit larger post-2018 patenting responses when they face greater tariff exposure. The estimates are consistent with the model's mechanism. A 10 percentage point increase in import-effective tariff exposure is associated with an additional 8.7 percent increase in U.S. patenting in initially US-laggard products in 2019–2022. The response is concentrated in the most-laggard quartile. Chinese patenting shows a similar pattern in the same products, while the estimated response of other foreign producers, which the tariffs did not target, is smaller and imprecise.

Our analysis relates to several strands of work. The model builds on the step-by-step innovation framework initiated by Aghion et al. (1997, 2001, 2005), in which firms engage in R&D races and competition shapes innovation incentives. Acemoglu et al. (2018) study the interplay between innovation, reallocation, and growth. Akcigit and Ates (2021, 2023) apply step-by-step models to the decline in U.S. business dynamism. Linking trade and innovation dynamics, our study also relates to the pioneering work by Rivera-Batiz and Romer (1991) and Grossman and Helpman (1991). In more recent work, Perla et al. (2021) show that trade openness changes the distribution of firm profits and thereby affects technology adoption, diffusion, and growth. The key mechanism in our framework highlights the effect of tariffs on innovative activity through the competition channel. Melitz and Redding (2021) provide an extensive survey of the work on the nexus of international trade, innovation and economic growth.

Closest to our framework is Akcigit et al. (2026), who developed the model adopted in this work and used it to analyze the aggregate growth and welfare implications of innovation and trade policies and optimal policy schemes. The two papers inherently share the underlying mechanisms. However, our analysis concerns individual sectors and focuses on policy-induced dynamics specifically in technologically laggard sectors. It highlights the importance of key sectoral characteristics and policy features in shaping the effect of trade policy on innovation: the initial technology gap between firms, the size of the tariff increase, and its duration. We also use the model to characterize the conditions under which a foreign government would retaliate through a tariff of its own or through export subsidies. In addition, we complement the analysis with new empirical evidence on the heterogeneous response of sector-level patenting to tariff changes corroborating the model's theoretical predictions.

Empirically, we connect to work on trade exposure and firm-level innovation. Bustos (2011) shows that trade liberalization induced Argentinean firms to upgrade their technologies, while Iacovone et al. (2011) find heterogeneous innovation responses to import competition in Mexico. Bloom et al. (2016) provide evidence that Chinese import competition stimulated innovation in European firms, while Autor et al. (2020) document negative effects of Chinese import competition on U.S. patenting. Aghion et al. (2022) reconcile these findings by showing that the effect of market size on innovation depends on the firm's distance to the technology frontier. Recent surveys by Shu and Steinwender (2019) and Akcigit and Melitz (2022) document the broader evidence linking trade exposure to innovation outcomes. Our empirical exercise adds a tariff-increase setting and tests a model-implied pattern of heterogeneity: tariff exposure should be associated with more patenting mainly when the domestic technology position is sufficiently weak.

Finally, we connect to strategic trade policy and endogenous growth. The strategic trade policy literature, initiated by Spencer and Brander (1983) and Eaton and Grossman (1986), provides a rationale for government intervention in industries with imperfect competition. More recent contributions by Ossa (2014) and Costinot and Rodríguez-Clare (2014); Costinot et al. (2012) study tariff policy and the gains from trade in multi-country frameworks. Barattieri et al. (2021) study the macroeconomic effects of protectionism while Ferrante et al. (2026) emphasize that the effects depend on the composition of the tariff schedule, showing that tariffs on consumption, intermediate, and capital goods have sharply different implications on imports, investment, output, and inflation. Rodrik (2004) articulates the broader case for industrial policy in developing and advanced economies.

The rest of the paper is organized as follows. Section 2 introduces the model environment, technology-gap dynamics, and equilibrium. Section 3 studies how tariffs and R&D subsidies affect firms' innovation incentives. Section 4 takes the model to the data. Section 5 presents the policy experiments, including the joint innovation response of U.S. and foreign firms and the implications for foreign retaliation. Section 6 describes the data, the empirical design, and the results. Section 7 concludes.

2. The Model

We analyze trade policy in a two-country model similar to Akcigit et al. (2026). The economy consists of two countries ($c \in \{\text{US}, \text{FN}\}$), where FN denotes Foreign, and a continuum of intermediate-good sectors indexed by $j \in [0, 1]$. In each sector, one U.S. firm and one foreign firm compete à la Bertrand to supply the representative final-good producers in both countries. Firms differ in their quality of products, which they improve through successive innovations, and their production cost, which reflects country-level wages. Trade is costly due to iceberg costs and tariffs.

2.1. Environment

Consumers in country c have CRRA preferences over consumption and supply labor inelastically. The final good in country c is produced via a Cobb-Douglas aggregator over differentiated intermediate inputs:

$$Y_{ct} = \left(\frac{1}{\beta}\right)^{\beta/(1-\beta)} \int_0^1 \left(q_{\mathrm{US},jt}^{\beta/(1-\beta)} k_{\mathrm{US},jt} + q_{\mathrm{FN},jt}^{\beta/(1-\beta)} k_{\mathrm{FN},jt}\right)^{1-\beta} dj, \tag{1}$$

where $\beta \in (0,1)$ is the intermediate goods' cost share, $q_{c,jt}$ is the quality (productivity) of intermediate good j produced in country c at time t, and $k_{c,jt}$ is the quantity of that input used.

In each sector j, intermediate goods are supplied by one firm per country. These firms compete à la Bertrand in prices, subject to symmetric iceberg trade cost $\kappa \geq 0$ and an ad-valorem tariff τ_t^c imposed by country c on imports. A firm in country c with quality $q_{c,jt}$ produces with unit cost $\eta w_{c,t}/Q_{c,t}$, where $w_{c,t}$ is the wage in country c at time t, $Q_{c,t}$ is the domestic technology frontier (average quality of domestic firms), and η is a constant. A firm from country c is the technology leader (follower) in sector j if $q_{c,j} > q_{c',j}$, $c \neq c'$ ($q_{c,j} < q_{c',j}$), and the competitors are in neck-and-neck position if their qualities are the same. In some product lines the U.S. firm leads, in others the foreign firm leads, and in still others the two are neck-and-neck (Figure 2). The qualities and heterogeneous technology gaps evolve endogenously as a result of firms' forward-looking innovation decisions. The market leader can differ from the technology leader as a result of production and trade costs. In equilibrium, the firm with the better price-adjusted quality (inclusive of trade costs) supplies the market.[1]

2.2. Innovation Dynamics and Technology Gaps

Qualities evolve through innovation. A successful innovation during the time interval Δt improves the incumbent firm's quality multiplicatively:

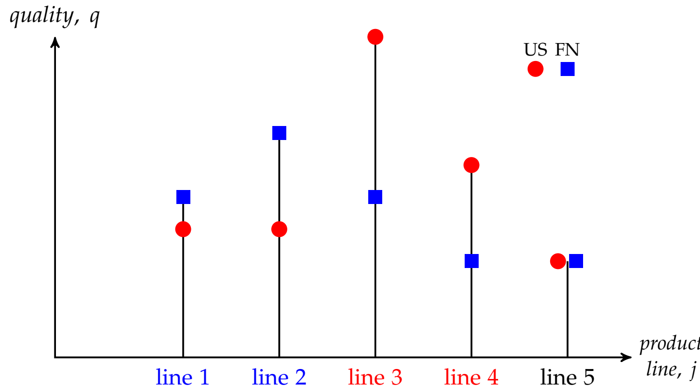
$$q_{c,j}(t + \Delta t) = \lambda^{\sigma}\, q_{c,j}(t), \tag{2}$$

where $\lambda > 1$ is the unit step size. Innovations are of heterogeneous magnitude, determined by the number of steps $\sigma \in \mathbb{N}$, which is an exogenous random variable that we specify below.

Because every innovation multiplies a firm's quality by an integer power of λ, the

[1]Assumption 1 (defined in Section 2.3) ensures that, in each sector, only one firm serves each market.

Figure 2. Model economy



Note: Two countries (U.S. and Foreign) each contain a continuum of intermediate-good sectors. In each sector, one firm per country (red circle for U.S. and blue square for FN) supplies the intermediate good at country-specific quality $q_{c,j}$, and the technologically superior firm captures the market under Bertrand competition. Quality differences across sectors generate heterogeneity in technological leadership.

relative quality of the two competitors in a sector moves in integer powers of λ as well.[2] The U.S. firm's technological position relative to its foreign competitor in sector j is therefore fully summarized by the number of innovation steps that separate the two firms, which we denote by $m_{US,j}$:

$$m_{US,j} = \frac{\log(q_{\text{US},j}/q_{\text{FN},j})}{\log(\lambda)} \in \mathbb{Z}. \tag{3}$$

Negative values indicate that the U.S. firm is behind, zero indicates neck-and-neck competition, and positive values indicate U.S. leadership.[3] To keep the state space finite, we cap the gap at an exogenously chosen $\bar{m}$, so that $m_{US,j}$ takes values in $\{-\bar{m}, \ldots, 0, \ldots, \bar{m}\}$. Naturally, $m_{FN,j} = -m_{US,j}$, and we denote the industry-level gap as $m_j = |m_{c,j}| \geq 0$. The technology gap $m_{c,j}$ is the key payoff-relevant state variable for a firm because it influences the degree of competition, the size of the market, as we shall see below, and the innovation incentives.

Innovations arise from two sources: incumbent firms and potential entrants. An incumbent firm chooses the Poisson arrival rate of innovation $x_{c,j,t}$ subject to the convex cost $\alpha_c \frac{x_{c,j,t}^{\gamma_c}}{\gamma_c} q_{c,j,t}$, with $\alpha_c > 0$ and $\gamma_c > 1$ denoting the country-specific scale and curvature parameters, respectively, and $q_{c,j,t}$ the incumbent's current quality. A

[2]This requires initial relative qualities to be integer powers of λ, which is a normalization: the analysis concerns the stationary distribution of gaps and does not depend on initial conditions.

[3]Division by $\log(\lambda)$ in equation (3) rescales the log quality ratio so that $m_{US,j}$ directly counts the number of innovation steps separating the two firms.

fringe of potential entrants directed at each product line in each country also invests in R&D. Entrants choose $\tilde{x}_{c,j,t}$ subject to the cost $\tilde{\alpha}_c \frac{\tilde{x}_{c,j,t}^{\tilde{\gamma}_c}}{\tilde{\gamma}_c} q_{c,j,t}$, with $\tilde{\alpha}_c > 0$ and $\tilde{\gamma}_c > 1$, so that entry costs scale with the quality of the incumbent they target. When an entrant successfully innovates, it replaces the domestic incumbent in the specific sector (creative destruction), ensuring that firms face competitive pressure from both foreign rivals and domestic entrants.

The step-size distribution. Innovation step sizes are drawn from an exogenous probability mass distribution $\mathbb{F}_m(\cdot)$, which we characterize next. Following Akcigit et al. (2026), we start from a single benchmark distribution and derive the position-specific distributions from it. The benchmark distribution is defined over the most laggard gap $-\bar{m}$. An innovation can advance the firm at $-\bar{m}$ to any better position $\{-\bar{m}+1, \ldots, \bar{m}\}$, meaning that σ can take any integer value $\{1, \ldots, 2\bar{m}\}$, with the probability distribution across possible step sizes defined by the following power form:

$$\mathbb{F}(\sigma) = c_0\, \sigma^{-\phi}, \tag{4}$$

where $\phi > 0$, and c_0 normalizes the probabilities to sum to one. Probability decays in size: receiving a multi-step innovation is less likely than a single-step improvement.

A firm at gap m can only advance to positions $\{m+1, \ldots, \bar{m}\}$. As such, the set of step-sizes possible for innovations by this firm is $\{1, \ldots, \bar{m}-m\}$. Defining $\hat{m} \equiv m + \bar{m}$, the gap-specific step-size probability mass distribution is given by

$$\mathbb{F}_m(\sigma) = \mathbb{F}(\hat{m}+\sigma) + A(m) \cdot \mathbb{I}\{\sigma = 1\}, \tag{5}$$

where $\mathbb{I}$ is the indicator function and $A(m) \equiv \sum_{s=1}^{\hat{m}} \mathbb{F}(s)$ is a probability mass. This structure implies that the probability of advancing to $m' > m+1$ is the same for firms at any gap $m < m'-1$, while the probability of receiving a one-step improvement rises gradually with the $A(\cdot)$ component for better positions on the technology ladder. In other words, the further ahead a firm already is, the more of the benchmark mass has accumulated in $A(m)$ and the more its innovations are one-step improvements. This property reflects the advantage of backwardness (Gerschenkron, 1962): a firm far behind the frontier draws on the knowledge embodied in the leader's technology and is more likely to close the gap in a single multi-step jump, whereas a firm pushing the frontier advances one original step at a time.[4] By construction, $\mathbb{F}_{-\bar{m}} = \mathbb{F}$, and

[4]See Akcigit et al. (2026) for a discussion of this construct and other alternatives.

$\mathbb{F}_{\bar{m}}(\sigma) = \mathbf{1}\{\sigma = 1\}$ is a step function that takes the value one only for $\sigma = 1$—i.e., firms at the largest gap only receive one-step innovations.

Akcigit et al. (2026) introduce this structure to give their model enough flexibility to mimic the convergence dynamics observed in the empirical distribution of technology gaps. Similarly, it helps the balanced growth path of our model align with the empirical distribution of technology gaps between U.S. firms and their foreign rivals across sectors. The curvature parameter ϕ, which is the single object that defines the theoretical step-size distribution, governs the probability assigned to multi-step innovations and the pace of catch-up by followers. As $\phi \to \infty$ the mass concentrates on $\sigma = 1$ and the model collapses to the standard step-by-step model in which every innovation is one step; lower values of ϕ make multi-step catch-up more likely. In the calibration exercise, the shape of the empirical technology gap distribution will discipline the key parameter ϕ.

2.3. Static Equilibrium and Trade Thresholds

Under Bertrand competition, firms in a sector engage in price competition implying that the more advantaged firm follows a limit pricing rule when setting its optimal price and captures the market. For the sake of tractability, we adopt the following assumption to ensure that the market leader can set the unconstrained monopoly price.

Assumption 1. *In every product line j, incumbents engage in a two-stage game. Each pays an arbitrarily small fee $\varepsilon > 0$ in the first stage in order to engage in Bertrand competition and bid prices in the second stage.*

This assumption ensures that only the firm with the highest quality once adjusted for additional costs chooses to pay the fee in the first stage. That firm therefore becomes the sole monopolist in the second stage.

The flow payoffs collected by a firm depend on the markets it serves. Under Assumption 1, the flow profit a U.S. firm earns serving the domestic market is

$$\Pi_{US}(q_{j,t}) = \left(\frac{1}{\bar{w}_{\mathrm{US},t}}\right)^{(1-\beta)/\beta} \bar{\pi}\, q_{j,t}, \tag{6}$$

where $\bar{w}_{c,t} \equiv w_{c,t}/Q_{c,t}$ denotes the productivity-adjusted wage in country c, and $\bar{\pi}$ is a constant that depends on model parameters. If the firm also exports, it earns the flow profit

$$\hat{\Pi}_{US}(q_{j,t}) = \left(\frac{1}{(1+\kappa)(1+\tau_t^{\mathrm{FN}})\bar{w}_{\mathrm{US},t}}\right)^{(1-\beta)/\beta} \bar{\pi}\, q_{j,t}. \tag{7}$$

Equation (7) differs from equation (6) due to the cost of reaching foreign consumers, which dilutes profits per unit sold. Both expressions scale linearly with the firm's own quality $q_{j,t}$. Combining these pieces, the total flow profit of a generic firm is given by $\pi_c(m;\tau_t^{\text{US}},\tau_t^{\text{FN}})\cdot q_{j,t}$, with $\pi_c(m;\tau_t^{\text{US}},\tau_t^{\text{FN}})$ defined as

$$\pi_c(m;\tau_t^{\text{US}},\tau_t^{\text{FN}}) = \frac{1}{q_{j,t}}\begin{cases}0 & \text{if } m < \bar{m}_{c,t}^{\text{imp}} \\ \Pi_c(q_{j,t}) & \text{if } \bar{m}_{c,t}^{\text{imp}} \leq m < \bar{m}_{c,t}^{\text{exp}} \\ \Pi_c(q_{j,t}) + \hat{\Pi}_c(q_{j,t}) & \text{if } m \geq \bar{m}_{c,t}^{\text{exp}}\end{cases} \tag{8}$$

Here $\bar{m}_{c,t}^{\text{imp}}$ and $\bar{m}_{c,t}^{\text{exp}}$ are the import and export cutoffs derived below. A firm well behind its foreign rival earns no profits; one that is not far enough behind to lose its home market earns the domestic flow only; and one with a substantial lead earns both.

Bertrand competition and iceberg trade costs imply that trade occurs only when a firm commands a technological advantage that is large enough to cover the trade costs and other production cost differences. The U.S. firm exports to the foreign market if and only if its gap exceeds the export cutoff:

$$m_{US,jt} \geq \bar{m}_{US,jt}^{\text{exp}} \equiv \frac{1-\beta}{\beta}\cdot\frac{\log\left[(1+\kappa)(1+\tau_t^{\text{FN}})/\omega_t\right]}{\log(\lambda)}, \tag{9}$$

where $\omega_t \equiv \bar{w}_{\text{FN},t}/\bar{w}_{\text{US},t}$ is the relative wage. The cutoff $\bar{m}_t^{\text{exp}}$ rises with iceberg costs and the foreign tariff, and falls with the foreign-to-US wage ratio, as relatively higher domestic wages erode the competitiveness of domestic firms. The analogous condition for foreign exports to the U.S. defines an import cutoff $\bar{m}_{US,jt}^{\text{imp}}$ for the U.S., which depends symmetrically on the U.S. tariff τ_t^{US}, on κ, and on ω_t and below which the U.S. final-good producer obtains the specific good from abroad. The U.S. intermediate producer faces import competition around the import cutoff $\bar{m}_{US,jt}^{\text{imp}}$. Together, the two cutoffs partition sectors into three regions of the gap distribution: U.S. import / foreign export ($m_{US,j} < \bar{m}_{US,jt}^{\text{imp}}$), no trade ($\bar{m}_{US,jt}^{\text{imp}} \leq m_{US,j} < \bar{m}_{US,jt}^{\text{exp}}$), and U.S. export / foreign import ($m_{US,j} \geq \bar{m}_{US,jt}^{\text{exp}}$). In the first region, the foreign firm supplies both markets; in the second, each serves respective domestic markets; and in the third, the U.S. firm sells to both markets. Notice that $\bar{m}_{FN,jt}^{\text{exp}} = -\bar{m}_{US,jt}^{\text{imp}}$ and $\bar{m}_{FN,jt}^{\text{imp}} = -\bar{m}_{US,jt}^{\text{exp}}$.

2.4. Value Functions and Optimal R&D

The firm chooses R&D intensity to maximize the present discounted value of profits net of innovation costs. Let $V_{\text{US},m,t}(q_{j,t})$ denote the value of a U.S. firm at time t with technology gap m and current quality $q_{j,t}$. It satisfies the Bellman equation

$$\begin{aligned} r_{\text{US},t}\, V_{\text{US},m,t}(q_{j,t}) - \dot{V}_{\text{US},m,t}(q_{j,t}) = \max_{x_{\text{US},m,t}} \Big\{ \\ \pi_{US}(m;\tau_t^{\text{US}},\tau_t^{\text{FN}})q_{j,t} - (1-s_t^{\text{US}})\,\alpha_{\text{US}}\,\frac{x_{\text{US},m,t}^{\gamma_{\text{US}}}}{\gamma_{\text{US}}}\,q_{j,t} \\ + x_{\text{US},m,t}\sum_{\sigma=1}^{\bar{m}-m}\mathbb{F}_m(\sigma)\Big[V_{\text{US},m+\sigma,t}\big(\lambda^\sigma q_{j,t}\big) - V_{\text{US},m,t}(q_{j,t})\Big] \\ + \tilde{x}_{\text{US},m,t}\Big[-V_{\text{US},m,t}(q_{j,t})\Big] \\ + \big(x_{\text{FN},-m,t}+\tilde{x}_{\text{FN},-m,t}\big)\sum_{\sigma=1}^{\bar{m}+m}\mathbb{F}_{-m}(\sigma)\Big[V_{\text{US},m-\sigma,t}(q_{j,t}) - V_{\text{US},m,t}(q_{j,t})\Big]\Big\}. \end{aligned} \tag{10}$$

where $\dot{V}_{\text{US},m,t}$ denotes the time derivative of $V_{\text{US},m,t}$ along the transition path, $r_{\text{US},t}$ is the interest rate, $\pi_{US}(m;\cdot)$ is the flow profit per unit of quality, and s_t^{US} is the country-specific R&D subsidy rate. The summation indices σ range over possible gap improvements with an innovation.

The right-hand side separates four forces. The first line contains flow profit and the R&D cost. The second line captures own innovation: a successful innovation by the incumbent at gap m moves it to gap $m+\sigma$ with quality $\lambda^\sigma q_{j,t}$. The third line reflects creative destruction: a successful entrant at home replaces the incumbent, forcing it to exit with zero flow value. The fourth line captures foreign innovation, by the incumbent or the entrant, which worsens the U.S. firm's relative position by moving the foreign firm to a higher gap.

The optimal R&D intensity equates the marginal cost of R&D to the expected marginal value gain:

$$(1-s_t^{\text{US}})\alpha_{\text{US}}\left(x^*_{\text{US},m,t}\right)^{\gamma_{\text{US}}-1} q_{j,t} = \sum_{\sigma=1}^{\bar{m}-m}\mathbb{F}_m(\sigma)\left[V_{\text{US},m+\sigma,t}\big(\lambda^\sigma q_{j,t}\big) - V_{\text{US},m,t}(q_{j,t})\right]. \tag{11}$$

The firm problem in equation (10) is an infinite-dimensional problem depending on quality levels $q_{j,t}$. The following lemma renders the firm problem independent of the current level and transforms the state space into a finite dimension. Crucially, it also implies that the relevant state of the firm is the technology gap, which sums up all the relevant information for the firm's optimal decision.

Lemma 1. *The value functions are linear in quality such that $V_{cmt}(q) = qv_{cmt}$ for $m \in \{-\bar{m},\dots,\bar{m}\}$. This property ensures that, at any time, the firm's innovation decision is* *independent of j once controlled for m.*

Proof. By guess-and-verify method, substituting qv_{cmt} for $V_{cmt}(q)$ in equation (10) obtains the desired definition of v_{cmt} independent of the quality level. □

2.5. Equilibrium

A Markov perfect equilibrium consists of optimal R&D choices $\{x_{c,m,t}, \tilde{x}_{c,m,t}\}$ for all firms and entrants; a relative wage ω_t that clears labor markets; and a law of motion for the cross-sectoral distribution of technology gaps, $\boldsymbol{\mu}_t = \{\mu_{m,t}\}_{m=-\bar{m}}^{\bar{m}}$. On a balanced growth path, $\boldsymbol{\mu}$ is stationary and aggregate output grows at a constant rate determined by innovation. The experiments of Section 5 follow a single sector along the transition path triggered by a policy change starting from the BGP. Because one sector is small relative to the economy, we hold the relative wage and the interest rate at their BGP values.

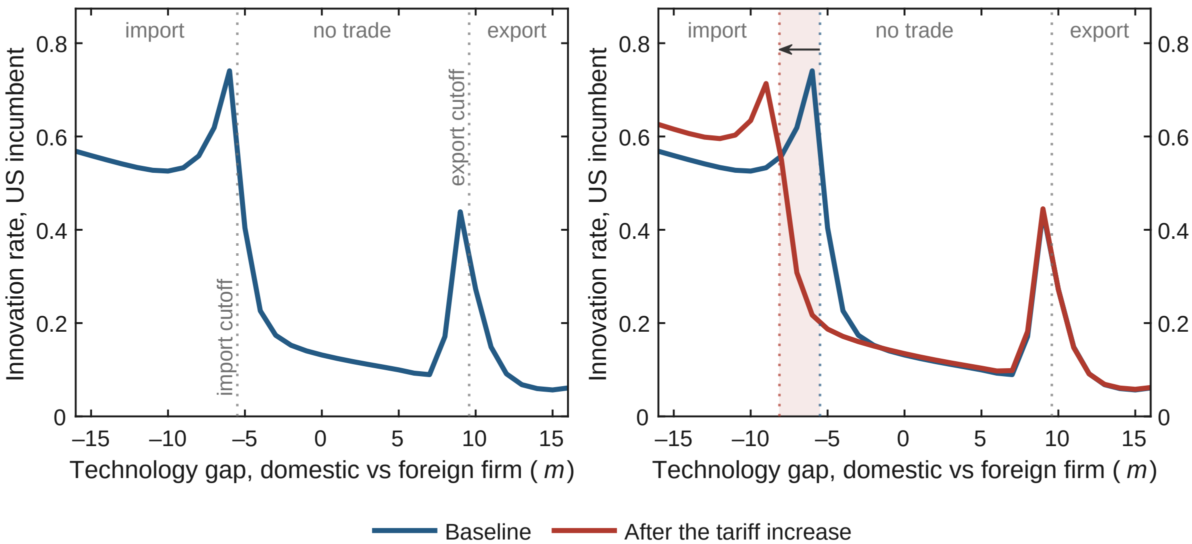
3. Innovation Incentives and Policies

The Bellman equation (10) implies three main innovation motives, each tied to a specific profit object:

1. *Expansion to new markets.* A U.S. firm just below the export cutoff has a strong incentive to innovate because a successful innovation can help it access the foreign market, yielding the additional flow $\hat{\Pi}(q_{j,t})$ in equation (7).
2. *Defense of domestic markets.* A U.S. firm just below the import cutoff has a strong incentive to innovate to recapture the home market and reclaim the domestic flow $\Pi(q_{j,t})$ in equation (6).
3. *Quality improvement.* Firms benefit from improving their quality regardless of their technology gap as it expands the market size and profits. This motive also applies to firms so far behind that they do not currently produce: profits are proportional to quality, so a higher quality today raises the profits the firm will earn once it captures a market, and its forward-looking value reflects this prospect (Lemma 1).

The first two motives generate a double-peaked profile of R&D effort as a function of the technology gap (Figure 3, left panel). R&D intensity peaks near the import cutoff, where firms invest defensively to reclaim the domestic market, and near the export cutoff, where firms invest to enter foreign markets. Between these peaks, firms in the "no-trade" zone face weaker competitive pressure and invest less.

Figure 3. Incumbent innovation effort as a function of the technology gap (U.S. perspective).



Note: The left panel shows the baseline double-peaked profile of innovation effort. Innovation rate is the incumbent's Poisson arrival rate of innovations, by technology gap, at the calibrated point. Dotted lines mark the import and export cutoffs (−5.5 and 9.6 steps); the regions are labelled along the top. The right panel adds the profile under an illustrative permanent increase in the U.S. tariff, which moves the import cutoff to the left; the shaded band marks the gaps that leave the import region. Both profiles are computed at the baseline interest rate and relative wage.

3.1. Tariffs and the Profit Channel

Tariffs affect innovation incentives through the *profit channel*. Consider a U.S. import tariff τ_t^{US}. Equation (7) implies that the foreign firm's profit from selling in the U.S. market is

$$\hat{\Pi}_{\text{FN}}(q_{\text{FN},j,t} \mid m, \tau_t^{\text{US}}) = \left(\frac{1}{(1+\kappa)(1+\tau_t^{\text{US}})\bar{w}_{\text{FN},t}} \right)^{(1-\beta)/\beta} \bar{\pi}\, q_{\text{FN},j,t}. \tag{12}$$

A higher τ_t^{US} increases the relative price of U.S. imports and reduces the foreign firm's profit from exporting to the U.S. It generates changes in both intensive and extensive margins. Foreign exporters earn and export less in sectors they still dominate, but also, some foreign firms lose their export status, as the domestic variety becomes relatively cheap enough so that the U.S. final-good producer starts buying from them. Effectively, a higher tariff shifts the import cutoff $\bar{m}_t^{\text{imp}}$ leftward: the U.S. firm faces import competition only at gaps further behind than before (Figure 3, right panel).

The right panel of Figure 3 reveals that the effect of a U.S. import tariff on R&D varies with the domestic firm's technology position. For a firm well below the import cutoff (e.g., $m_{US,j} = -10$ when $\bar{m}_t^{\text{imp}} = -5.5$ before the tariff change, as at the calibrated point), the new (more negative) cutoff moves closer to the firm's position. The firm now has a bigger chance of recapturing the domestic market and increases defensive R&D. Therefore, the red line in the right panel of Figure 3 shows higher R&D effort for firms in the significantly laggard region.

For a domestic firm just above the import cutoff (e.g., $m_{US,j} = -5$ when $\bar{m}_t^{\text{imp}} = -5.5$ before the tariff change), the new cutoff moves farther from the firm's position. Already protected from import competition, the firm becomes even more comfortable in its position. As competitive pressure falls, the firm becomes complacent and reduces R&D effort. The aggregate R&D response to a tariff is therefore heterogeneous across firms: those whose gap places them at or just below the new import cutoff experience a boost; those whose gap places them comfortably in between the cutoffs experience complacency.

The complacency effect also depends on the expected duration of protection. Because $V_{\text{US},m,t}$ depends on the entire path of future tariffs $\{\tau_s^{\text{US}}\}_{s\geq t}$, a firm under permanent protection has no expectation of renewed competitive pressure and reduces defensive R&D, while a firm under temporary protection retains incentives to maintain defensive R&D effort. This dynamic asymmetry anticipates the quantitative finding in Section 5 that temporary tariffs outperform permanent ones for technology catch-up.

Higher domestic tariffs do not directly affect the export threshold (which depends on τ_t^{FN} and κ). In partial equilibrium, the expansionary R&D motive is largely unaffected, although general-equilibrium wage effects can indirectly reduce export competitiveness. The profit channel also operates on the foreign firm, and the direction of its response depends on the foreign firm's position relative to its threshold for exporting to the U.S. market. This threshold is the U.S. firm's import cutoff $\bar{m}_t^{\text{imp}}$ seen from the foreign side, so the U.S. tariff that shifts the cutoff also moves the foreign firm's export prospect. When the U.S. firm is very laggard, the foreign firm is exporting and the U.S. tariff brings it closer to losing that position, intensifying its R&D to defend its export position; when the U.S. firm is only moderately laggard, the foreign firm sits below the export threshold and the U.S. tariff pushes that threshold further out of reach, weakening its expansionary R&D motive. We quantify this joint response in Section 5.1.1. Section 5.2 then asks whether the foreign country would rationally retaliate, and with which instrument—the answer depends on its objective and on the U.S. firm's initial technology position.

3.2. R&D Subsidies and the Cost Channel

In contrast to tariffs, which operate through the profit channel and produce heterogeneous incentive responses across the gap distribution, R&D subsidies operate through the *cost channel* and produce a positive response at every gap. An R&D subsidy at rate s_t^c in country c directly reduces the cost of innovation:

$$C(x_{c,m,t} \mid s_t^c) = (1 - s_t^c)\, \alpha_c \, \frac{(x_{c,m,t})^{\gamma_c}}{\gamma_c} \, q_{j,t}. \tag{13}$$

Unlike tariffs, subsidies do not directly alter trade cutoffs. Instead, they lower the marginal cost of innovation for domestic firms, regardless of their position in the technology gap distribution. Both defensive and expansionary R&D receive the same cost reduction, avoiding the cutoff-shifting effects of tariffs. Subsidies therefore avoid the import-protection channel that generates complacency in the model.

From the first-order condition, the direct effect of a subsidy on the optimal R&D level is:

$$\frac{\partial x^*_{c,m,t}}{\partial s_t^c} = \frac{x^*_{c,m,t}}{(1 - s_t^c)} \cdot \frac{1}{\gamma_c - 1} > 0, \tag{14}$$

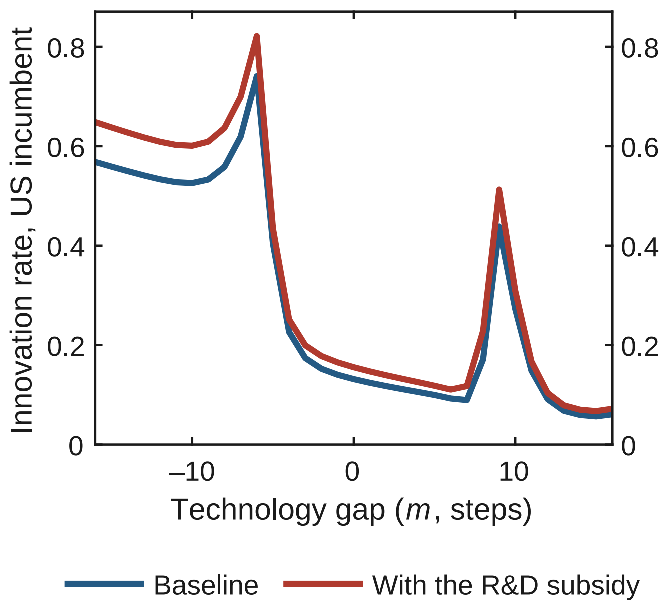
which is positive given convex R&D costs ($\gamma_c > 1$). The subsidy also changes the value of the positions the firm can reach by innovating, and hence the return to R&D; Figure 4 shows that the overall effect remains an upward shift in innovation effort at every technology gap. Because the direct effect is proportional to the level of effort, the shift is largest at the two peaks.

4. Calibration

This section explains the calibration of the model. We calibrate the BGP of the economy to the data spanning the years between 2010 and 2017—the period that precedes the 2018 tariff escalation. The domestic economy is the U.S., and the "Foreign" economy is a composite of the eight major countries that intensively trade with and register patents in the U.S. These countries are Japan, Korea, Germany, China, Taiwan, Canada, the United Kingdom, and France. Every moment below that pertains to this foreign composite is a weighted average over its members, with the specific weights depending on the variable of interest.

An important object in the calibration exercise is the empirical distribution of technology gaps, which help determine the step-size distribution in the model. We construct the empirical technology gap distribution following Akcigit et al. (2026). For

Figure 4. Innovation response to an R&D subsidy.



Note: The figure plots the incumbent's innovation rate by technology gap in the baseline and under an illustrative increase in the U.S. R&D subsidy. The subsidy raises effort at every gap and leaves the cutoffs unchanged.

each of the 538 CPC4 (Cooperative Patent Classification) patent classes with at least 100 patents of any assignee filed between 2010 and 2017 in the USPTO data, we compute the share s of patents granted in 2010–2017 to assignees located in the U.S. (1-s denotes the share granted to assignees located in the eight foreign countries). We map these shares to 33 equal-width bins dividing the unit length (each bin covering roughly 3 percent) representing technology positions $m \in \{-16, \dots, 0, \dots, 16\}$ with $\bar{m} = 16$. For example, bin -16 holds classes with a U.S. share roughly below 3 percent and bin 16 those roughly above 97 percent.

4.1. Identification

The model has the following parameters:

$$\Omega \equiv \{\underbrace{\alpha_c, \tilde{\alpha}_c, \gamma_c, \tilde{\gamma}_c,}_{\text{R\&D costs}} \ \underbrace{\phi, \lambda,}_{\text{innovation}} \ \underbrace{\kappa, \tau^c, s^c,}_{\text{trade and policies}} \ \underbrace{\psi, \rho, \beta, \eta, \bar{m},}_{\text{preferences and technology}} \ \underbrace{L^c}_{\text{scale}}\}, \quad c \in \{\text{US}, \text{FN}\}.$$

We set the preference and technology parameters, the tariffs, the R&D subsidies, and the market sizes outside the model. The CRRA curvature $\psi = 2$, the discount rate $\rho = 0.01$, and the R&D cost curvatures $\gamma = \tilde{\gamma} = 2$ (quadratic costs) are conventional values. The intermediate-input share $\beta = 0.5$ implies a demand elasticity of 2 for intermediate goods. The unit labor requirement of the intermediate technology is

$\eta = 1 - \beta = 0.5$, and the gap grid is bounded at $\bar{m} = 16$. These values are the same as in Akcigit et al. (2026). The U.S. tariff on the foreign composite is $\tau^{\text{US}} = 1.72$ percent and the foreign composite's tariff on the U.S. is $\tau^{\text{FN}} = 2.22$ percent. These values reflect effective applied rates on manufactures in 2017 obtained from WITS. The U.S. rate is weighted by U.S. imports from each member of the composite, and the composite's rate is weighted by U.S. exports to each member.[5] The R&D subsidies are $s^{\text{US}} = 0.060$ and $s^{\text{FN}} = 0.136$, the OECD implied tax subsidy rate on R&D for a large profitable firm in 2017, with the composite's rate weighting members by business R&D.[6] Finally, the two countries are assumed to be of equal market size with $L^c = 1$. Table 1 lists these values.

Table 1. Parameters.

		Value	Source or main targets
Set externally			
ψ	CRRA curvature	2.00	Conventional value
ρ	Discount rate	0.010	Conventional value
β	Intermediate-input share	0.50	Demand elasticity $1/\beta$ of 2
η	Unit labor requirement	0.50	Set to $1 - \beta$
$\gamma, \tilde{\gamma}$	R&D cost curvature	2	Quadratic R&D cost
$\bar{m}$	Maximum technology gap	16	Bound of the gap grid
τ^{US}	US tariff on the composite	0.0172	WITS 2017, import-weighted
τ^{FN}	Composite tariff on the US	0.0222	WITS 2017, export-weighted
s^{US}	R&D tax subsidy, US	0.060	OECD, 2017
s^{FN}	R&D tax subsidy, composite	0.136	OECD, 2017, BERD-weighted
L^{FN}/L^{US}	Relative market size	1.00	Assumed equal
Calibrated			
α_{US}	R&D cost, US incumbents	2.217	mean gap; share of gaps ≥ 8
α_{FN}	R&D cost, composite incumbents	6.750	mean gap; share of gaps ≥ 8
$\tilde{\alpha}_{US}$	R&D cost, US entrants	60.02	US entry rate; US R&D/GDP
$\tilde{\alpha}_{FN}$	R&D cost, composite entrants	53.83	composite birth rate; composite R&D/GDP
ϕ	Step-size distribution curvature	1.116	growth; composite R&D/GDP
$\lambda - 1$	Innovation step size	0.0184	trade / GDP; composite R&D/GDP
κ	Iceberg trade cost	0.1248	trade / GDP; US R&D/GDP

Note: The seven parameters of the middle block are calibrated to the moments of Table 2; the last column names, for each, the two moments that respond most to it at the calibrated point. Tariffs are 2017 effectively applied rates on manufactures (WITS), weighted by bilateral trade. R&D subsidies are the OECD implied tax subsidy rate on R&D for a large profitable firm in 2017; the composite's rate weights the eight by business R&D.

We calibrate the remaining seven parameters—six parameters related to R&D and innovation technology and the iceberg cost—by matching eleven empirical moments (see Table 2 and notes). Let M^E denote the vector of targeted empirical values

[5] WITS has no entry for Taiwan, which accounts for 3 percent of U.S. imports from the eight. We set the U.S. rate on Taiwan at Japan's 1.6 percent and Taiwan's rate on the U.S. at an approximate 2.0 percent.

[6] The OECD does not report Taiwan. Its rate is built from its 15 percent R&D tax credit.

and $M(\Omega_7)$ the vector of model-based counterparts, with Ω_7 denoting the subset of parameters to be calibrated. We choose Ω_7 to solve

$$\min_{\Omega_7} \sum_{m=1}^{11} \left(\frac{M_m^E - M_m(\Omega_7)}{M_m^E} \right)^2 .$$

The parameters are calibrated jointly, and no single moment listed in Table 2 identifies one of them alone. Still, the following discussion gives an intuition of how the moments we choose discipline them (see Table 2 for data sources). Data on business R&D over GDP and entry rates for both regions mainly inform the cost scale parameters of incumbent and entrant R&D, respectively. Data on trade flows pin down the model counterpart, informing the model about the level of trade cost κ. Data on productivity growth disciplines the BGP growth rate in the model, which is closely related to the unit step size λ. Growth also depends on the size of innovations, which is determined by the step-size distribution $\mathbb{F}(\cdot)$. Additional information concerning the curvature parameter ϕ, which defines this distribution, comes from the moments characterizing the empirical technology gap distribution, as the step-size distribution is the object that largely determines the shape of the model-implied technology gap distribution. The moments related to dispersion are particularly informative.

4.2. Calibration Results

Tables 1 and 2 report the calibrated parameters and the model fit to the targeted moments. The model matches the targeted moments well. Importantly, the calibrated value of ϕ implies a strong advantage of backwardness: the probability of a firm in the most laggard position receiving a multi-step innovation is 71 percent. The U.S. import cutoff is at -5.5 steps, so the U.S. firm loses its home market when it is six or more steps behind, and the export cutoff is 9.6, so it exports when ten or more steps ahead. The U.S. is a technology laggard in 30 percent of sectors. Figure 5 shows the model-implied technology gap distribution superimposed with its empirical counterpart.

5. Quantitative Analysis

We conduct partial-equilibrium counterfactuals in the calibrated model. Each experiment focuses on a single hypothetical U.S. industry that begins behind its foreign competitor. We hold aggregate wages and interest rates fixed to isolate the sectoral innovation effect of the policy.

We consider heterogeneity along three dimensions. First, the initial technology

Table 2. Targeted moments: model and data.

	Model	Data	Source
Business R&D / GDP, US (percent)	1.97	2.08	OECD MSTI
Business R&D / GDP, composite (percent)	1.91	1.84	OECD MSTI
Establishment entry rate, US (percent)	9.52	9.97	Census BDS
Enterprise birth rate, composite (percent)	9.97	9.61	OECD SDBS
Productivity growth (percent per year)	1.12	1.12	OECD, APO
US trade with the composite / GDP (percent)	10.06	10.06	Census, WDI
Mean technology gap (steps)	2.37	1.80	PatentsView
S.d. of the technology gap (steps)	5.89	5.46	PatentsView
Skewness of the technology gap	-0.20	-0.07	PatentsView
Share of lines with gap ≤ -7 (percent)	6.57	6.51	PatentsView
Share of lines with gap ≥ 8 (percent)	16.90	17.10	PatentsView

Note: Rates in percent; gap moments in steps. Data windows: R&D intensities and entry rates 2015–2017, trade flows 2017, productivity growth and patent grants 2010–2017. R&D intensity and productivity growth are averaged with 2017 GDP weights at purchasing-power parity. The composite entry rate is an average over the six members the OECD source covers (missing China and Taiwan).

gap determines how far behind the U.S. firm starts. To highlight the contrasts, we choose two starting positions with different levels of import competition—one below and one above the calibrated import cutoff. As shown in Section 4, the U.S. firm loses its home market to imports once it is six or more steps behind. We consider a moderately laggard firm at $m_0 = -5$—just above the import cutoff so that it serves its home market—and a significantly laggard firm at $m_0 = -10$—well below the cutoff so that the foreign firm exports to the U.S. and the U.S. firm does not produce.[7] The second dimension we consider is the duration of the policy—whether the tariff change is permanent or temporary—which we can distinguish in our analysis of transitional dynamics. Finally, the third dimension we vary is the size of the increase, highlighting its interaction with the initial technological position of the firm. Every experiment reports the 20-year transition path, allowing us to contrast short- and long-run effects.

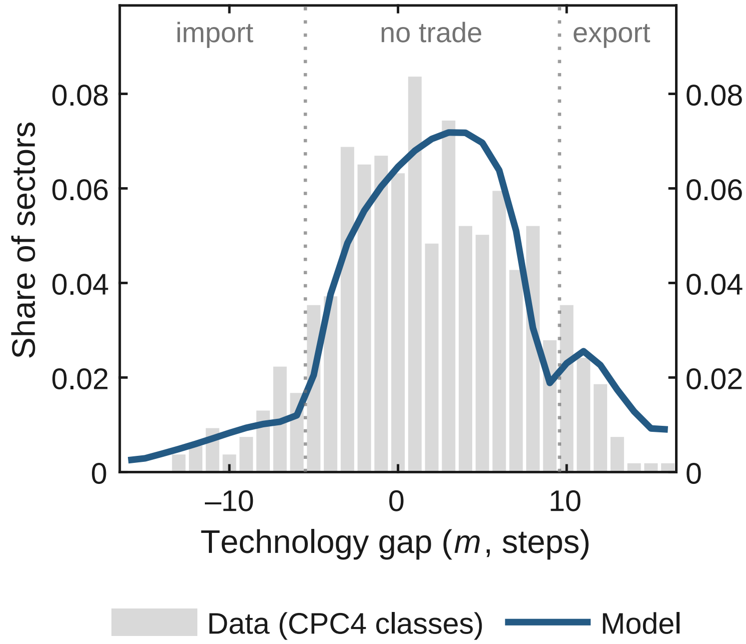
5.1. Policy Experiments

5.1.1. Permanent versus Temporary Tariff Increases

We raise the U.S. tariff on imports in the targeted sector by 3.9 percentage points from the calibrated 1.72 percent to 5.6 percent, corresponding to the size of the effective tariff

[7] In the data of Section 4 the moderately laggard position includes sectors like electric-vehicle propulsion, solar cells, and magnets and transformers, which comprise technology classes in which U.S. firms hold about a third of the patents. The significantly laggard position corresponds to sectors like LCD and LED display panels, where U.S. firms hold about a fifth of the patents.

Figure 5. The distribution of technology gaps: data and model.



Note: Bars: the share of CPC4 technology classes in each of 33 equal-width bins of the U.S. share of patents granted in 2010–2017 against the eight largest foreign patentees (538 classes with at least 100 patents of any assignee filed in 2010–2017, the eligibility rule of Section 6; shares from grants of 2010–2017, counted fractionally across classes and assignee countries); bin m holds shares between $(m + 16)/33$ and $(m + 17)/33$. Line: the model's stationary distribution of gaps across sectors at the calibrated point. Dotted lines mark the import and export cutoffs (−5.5 and 9.6 steps).

rate increase in 2018–2019.[8] The increase moves the import cutoff from −5.5 to −7.6 steps. We consider two durations: a permanent increase, and a temporary one that reverts to the calibrated level after ten years. The baseline path remains at the BGP.

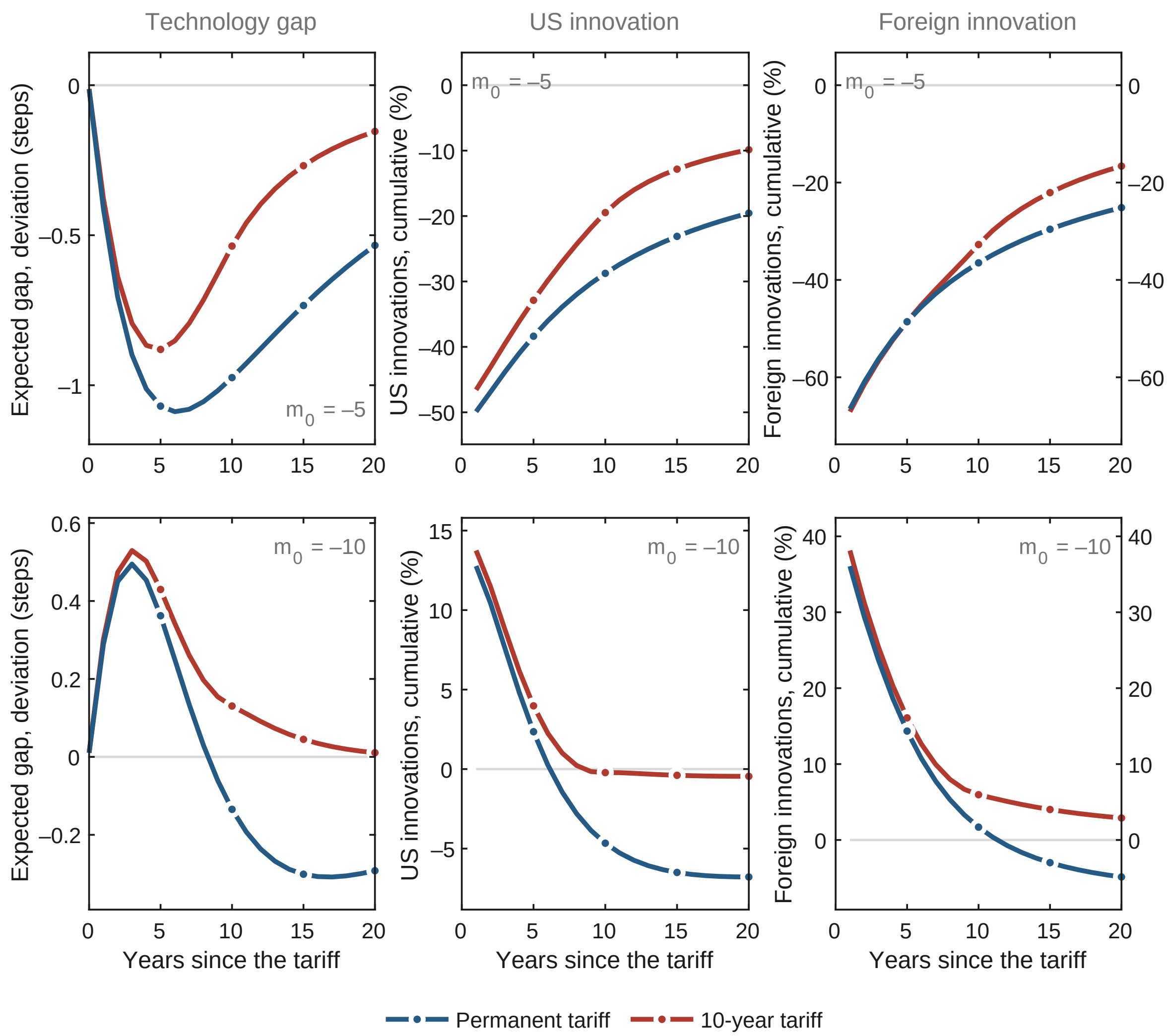
Figure 6 shows how the tariff changes the expected technology gap and the innovation of the U.S. and the foreign incumbent for the two initial conditions, measured against the path the sector would have followed on BGP absent the tariff increase.[9] The left panels show the expected technology gap in deviation from the corresponding baseline path measured in number of steps. The middle and right panels show the two incumbents' cumulative innovation response over time.[10] When

[8]Because the Section 301 tariffs covered imports from China alone while the foreign competitor in the model is the composite of the eight largest foreign patentees, we scale each product's statutory Section 301 rate by China's share of that product's U.S. imports, and this import-effective rate (Section 6) rose by 3.9 percentage points on average across the eligible products.

[9]Because innovation is probabilistic, the output is the expected technology gap. Appendix A.5 reports sectoral wage-income and price deviations from baseline under the same tariff and R&D subsidy experiments.

[10]Appendix A.1 displays the foreign firm's innovation schedule—the analogue of Figure 3—that underlies the path in the right panels.

Figure 6. Responses to the 3.9-percentage-point U.S. tariff increase: technology gap, U.S. innovation, and foreign innovation.



Note: Rows: initial gap $m_0 = -5$ (U.S. in the no-trade zone) and $m_0 = -10$ (U.S. importing). Left column: the expected technology gap, deviation from the baseline path in steps. Middle and right columns: for the U.S. and for the foreign incumbent, the expected number of innovations the firm makes from the tariff (year 0) to the end of year t, divided by the same number without the tariff increase, minus one, in percent. Expected cumulative innovations are obtained by averaging the firm's innovation rate over the distribution of technology gaps at each date and integrating over time. The point at year t reports the percentage change in cumulative innovations over the first t years, so early gains or losses can persist in the series after the innovation rate returns to baseline. Navy: permanent increase; red: temporary increase.

the initial gap is moderate ($m_0 = -5$, top row), both temporary and permanent tariff increases worsen the U.S. firm's expected technology position (Figure 6, top-left panel). The worsening reflects the complacency effect discussed in Section 3: the tariff leaves the U.S. firm more protected by reducing the competitive pressure, and the firm responds by lowering its innovative effort. The foreign firm cuts back as well, as the threshold for exporting to the U.S. market moves further out of its reach weakening its expansionary R&D motive. With both firms innovating less, the gap moves against the U.S. because the U.S. firm loses more innovations in absolute terms: although its percentage decline is smaller, it starts from a much higher innovation rate than the foreign firm (Figures 3 and A.1), and it is the number of innovations that determines the gap. The expected technology gap therefore falls below the baseline path, more so and more persistently under the permanent increase.

When the initial gap is larger ($m_0 = -10$, bottom row), both tariff increases initially cause both firms to increase their innovation effort. Moving the import cutoff closer to the U.S. firm raises its chances of gaining the domestic market and strengthens the defensive R&D motive (Figure 6, bottom middle panel). The foreign firm faces a greater risk of losing access to the U.S. market and responds by increasing its R&D effort in the face of stiffer competition (Figure 6, bottom right panel). Although foreign innovation rises by more in percentage terms, the U.S. firm again adds more innovations in absolute terms, and the expected technology gap runs above the baseline path for some time (Figure 6, bottom left panel). These gains fade, however, as the U.S. firm improves its position and moves away from the import cutoff. As competitive pressure weakens, its innovation effort falls below the baseline level. The U.S. cumulative innovation increase is largely exhausted by year 8, and under the temporary increase the gap returns to its baseline path once the tariff is removed in year 10. Under the permanent increase, protection continues to depress the U.S. firm's effort after its position has improved, and the expected gap falls below the baseline path in the long run.

A second indicator of the cost of permanent protection is the probability that the U.S. firm becomes an exporter. A laggard U.S. firm needs sustained innovation to climb the technology ladder far enough to overtake its rival and export. Higher tariffs reduce the likelihood of this event because the firm relaxes its effort once it has moved away from the now more distant import cutoff. Figure A.2 in Appendix A.2 shows that under permanent increases, the likelihood of exporting is lower than in the baseline either immediately or eventually, mirroring the path of expected technology gaps. In the significantly laggard case, higher tariffs generate short-to-medium term gains that eventually turn negative under permanent increases.

5.1.2. *Technology Catch-Up Policy*

The exercises above showcase the heterogeneous effect of higher tariffs on different sectors depending on initial technological conditions while highlighting the possibility of temporary gains from tariff increases maintained for a limited period. We next ask what would be the best combination of policy size and duration if the policy goal is to maximize the gains in the technology race. Naturally, the answer depends on the initial condition and the policy horizon. For illustrative purposes, we consider three initial gaps $m_0 \in \{-15, -10, -5\}$ and a policy horizon of two decades. For each initial technology gap, we select the best size and duration combination for a U.S. tariff increase to maximize the average expected technology gap over 20 years:

$$\text{Technology catch-up policy} = \arg\max_{\Delta\tau^{\text{US}},T} \frac{1}{20} \int_0^{20} m_t(\tau^{\text{US}} + \Delta\tau^{\text{US}}, T)\, dt, \tag{15}$$

where $m_t(\tau^{\text{US}} + \Delta\tau^{\text{US}}, T)$ is the expected technology gap at year t under a tariff increase of $\Delta\tau^{\text{US}}$ percentage points lasting T years. This objective captures the size and persistence of catch-up gains.

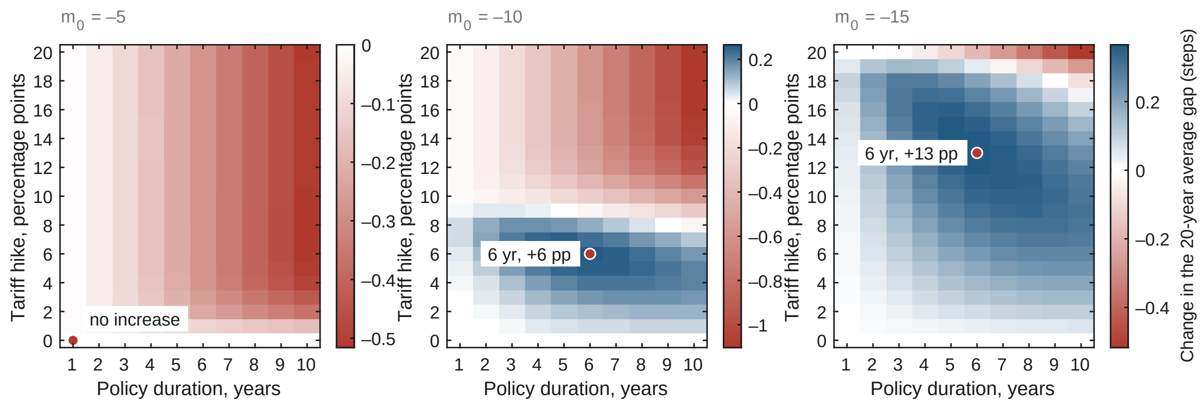
Figure 7 reports the findings with the red dots indicating the optimal size-duration combination. For the moderately laggard sector ($m_0 = -5$), no tariff increase improves on the baseline. For the significantly laggard sector ($m_0 = -10$), the best policy is a six percentage-point increase for six years, which generates an average gain of 0.27 steps. Finally, for a severely laggard sector ($m_0 = -15$), the best combination is a 13 percentage-point increase for six years.

The results point to a positive association between the size of the initial gap and the size of the tariff increase and its duration. Moreover, they underline that the policy requires careful design: a tariff increase that may help a significantly laggard sector can be detrimental for a sector that starts from more favorable initial technological condition. Overshooting the tariff increase can put the domestic firm in the latter sector in a more complacent position under tariff protection, hurting innovation incentives. Therefore, whether a tariff helps innovation depends jointly on the initial technology gap and the size of the tariff increase relative to that gap. That said, it is also true that for most laggard sectors, the range of combinations with positive outcomes is wider, reducing the chances of overshooting.

5.1.3. *R&D Subsidies*

Faced with more intense technological competition globally, governments have also resorted to industrial policy. We next consider the implications of a prominent form of

Figure 7. Change in the 20-year average technology gap across tariff increases and durations.



(a) Initial gap: $m_0 = -5$ **(b)** Initial gap: $m_0 = -10$ **(c)** Initial gap: $m_0 = -15$

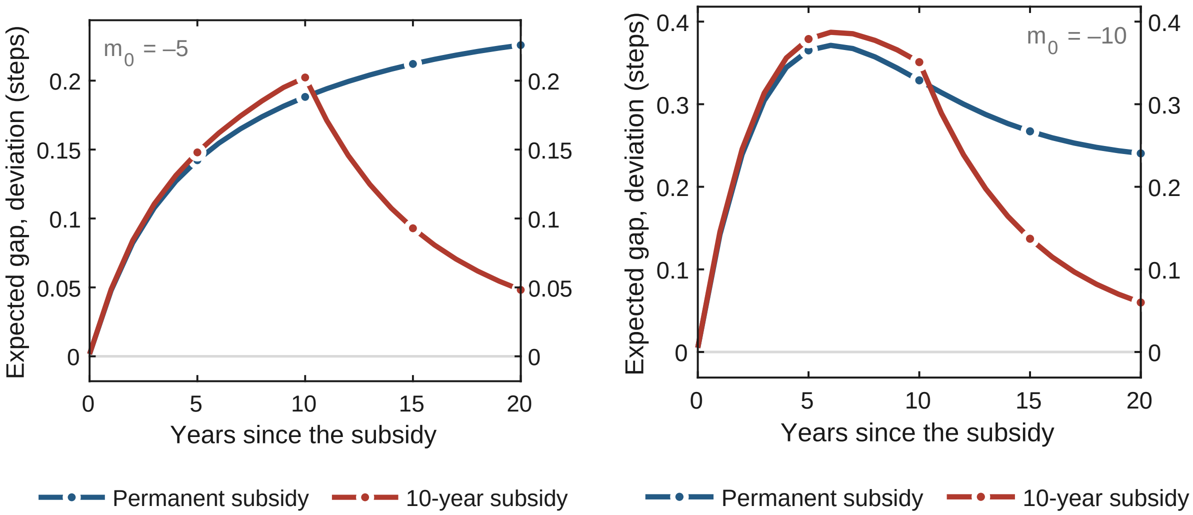
Note: Each panel plots, for a tariff increase (vertical axis, percentage points above the calibrated 1.72 percent) lasting a given number of years (horizontal axis), the change in the average expected technology gap over years 0–20 relative to no increase, in steps: white is no change, navy an improvement, red a deterioration. The red dot marks the maximum within the grid; at $m_0 = -5$ it is the zero increase.

industrial policy geared toward innovation, R&D subsidies, raising the U.S. subsidy rate from 6.0 to 13.6 percent (the calibrated foreign rate). In both moderately and significantly laggard cases, R&D subsidies improve the expected path of technology gaps relative to the baseline (Figure 8). As shown in Figure 4, R&D subsidies operate mainly through increasing innovation effort across the board by reducing the cost of doing R&D without affecting the cutoffs and the specific incentives that arise around them. The temporary-subsidy effect partially depreciates after expiration, while the permanent subsidy sustains the incentive for longer. Hence, unlike higher tariffs, R&D subsidies boost innovation, with permanent policies generating a more positive effect.

5.2. Foreign Retaliation

The U.S. tariff of Section 5.1.1 changes the foreign firm's position in the race as much as the U.S. firm's, and in practice the foreign country may respond. We consider two retaliatory instruments, both applied within the sector targeted by the U.S. tariff. The first is a tariff of its own on imports from the U.S., which raises the export cutoff $\bar{m}^{\text{exp}}_{US,t}$ for U.S. firms and so changes what a U.S. firm gains from pulling ahead. However, the foreign firm is already ahead in these exercises; therefore, a higher foreign tariff on U.S. exports is likely to have a limited impact. The second policy lever we consider is an export subsidy by the foreign country paid to its own exporters. This policy reduces their effective cost of selling in the U.S. market, lowers the bar for exports to the U.S. $\bar{m}^{\text{exp}}_{FN,t}$—i.e., shifts $\bar{m}^{\text{imp}}_{t}$ rightward—and thereby partially offsets the leftward

Figure 8. Expected technology gap under an R&D subsidy (deviation from baseline).



(a) Initial gap: $m_0 = -5$ (no trade) **(b)** Initial gap: $m_0 = -10$ (U.S. importing)

Note: U.S. R&D subsidy rate raised from 6.0 to 13.6 percent, permanently (navy) or for 10 years (red). Values are deviations of the expected technology gap from the baseline path, in steps; the horizontal axis is in years.

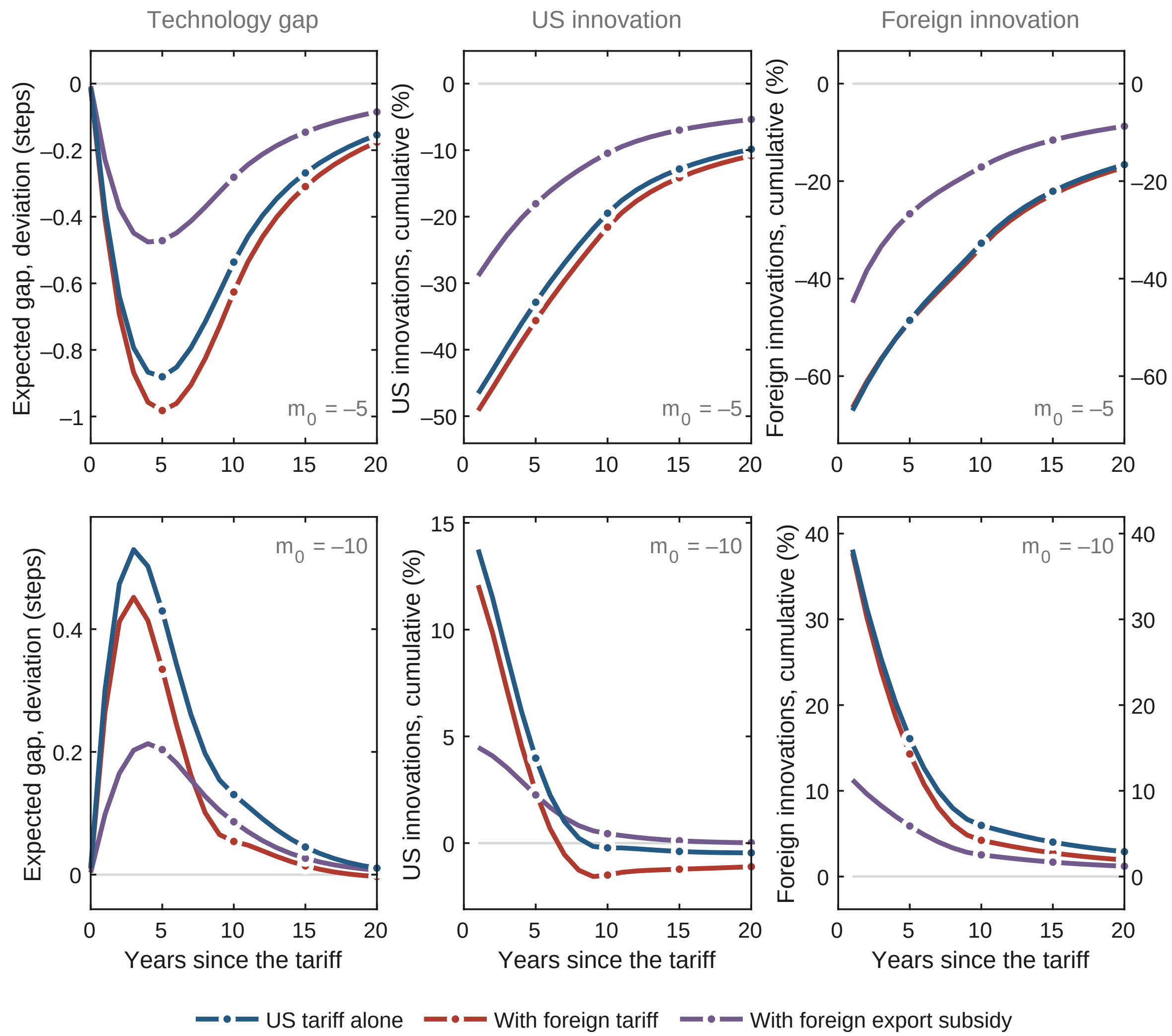
shift induced by the U.S. tariff.[11]

To illustrate the effects of the foreign tariff response, we calibrate the foreign tariff increase to the 2018–2019 episode. China's average tariff on U.S. goods rose by 12.7 percentage points (from 8.0 to 20.7 percent; Bown, 2021). Weighting this increase by China's share of U.S. exports to the composite gives a 2.3 percentage point increase in the composite's tariff. For comparability, we also set the export subsidy at 2.3 percent, which offsets about six tenths of the U.S. increase. In both exercises, we consider temporary foreign policies lasting ten years in response to the U.S. tariff of the same duration. Figure 9 displays the effects of each foreign instrument (in red and plum) superimposing them on the temporary tariff effects from Figure 6 (navy), for the same two initial conditions and the same three outcomes: the expected gap, and the U.S. and the foreign incumbent's cumulative innovations in percent of the baseline count. Appendix A.3 repeats the exercise with permanent U.S. tariffs and foreign responses.

The two instruments work very differently in a laggard sector. A foreign tariff in the same sector affects the U.S. firm on two margins: it raises the U.S. export cutoff, so the firm needs a larger technological lead to export and its prospect of reaching that position falls, and it lowers the profits the firm would earn from exporting once it does.

[11] From the perspective of a foreign firm, an export subsidy at rate $\hat{s}^{FN}$ enters only through the foreign firm's delivered cost, $(1+\kappa)(1+\tau_t^{US})(1-\hat{s}^{FN})$, so it is equivalent to a cut in the U.S. tariff to $(1+\tau_t^{US})(1-\hat{s}^{FN})-1$.

Figure 9. Responses to the 3.9-percentage-point U.S. tariff increase, alone and with foreign retaliation: technology gap, U.S. innovation, and foreign innovation (10-year policies).



Note: Rows, columns, and units as in Figure 6. Navy: the 10-year U.S. tariff alone, the red line of Figure 6. Red: the same tariff with the composite's tariff on the U.S. raised by 2.3 percentage points for the same ten years (which moves the export cutoff from 9.6 to 10.8 steps). Plum: the same tariff with an export subsidy of 2.3 percent to the composite's exporters for the same ten years (which moves the import cutoff back from −7.6 to −6.3).

Both weaken its expansionary R&D motive. At $m_0 = -5$ or -10, however, the U.S. firm starts far from the export cutoff even before the change, so the prospect of exporting carries little weight in its return to innovation, and the effect on its R&D effort is small. Reciprocally, the leading foreign firm's innovation response is also small. An export subsidy, by contrast, acts on the same cutoff as the U.S. tariff in place and directly affects the competition between the two firms. Therefore, it generates much stronger responses, partially offsetting the effects of the U.S. policy.

Whether the foreign government would prefer to use any of these levers depends on its objective. We restrict attention to objectives related to innovation, setting aside welfare, revenue, and other considerations, and consider two: preserving its technological leadership over the U.S. or sustaining its own level of innovation. If the foreign government seeks to preserve its technological lead, the relevant outcome is the expected technology gap (left panels of Figure 9). At $m_0 = -10$, the U.S. tariff is closing the gap against the foreign firm's interest, and the export subsidy serves the foreign objective: it restores much of the pre-tariff environment, weakens the U.S. firm's defensive R&D motive, and slows its catch-up, diminishing the gains in technology competition the U.S. obtains through higher tariffs. The foreign tariff has a much smaller effect because it does not act on the import cutoff. At $m_0 = -5$, the U.S. tariff widens the gap in the foreign firm's favor through the domestic firm's own complacency. Foreign tariff retaliation would compound it, albeit to a small extent, and an export subsidy would partially offset a favorable effect that already suits the foreign objective.

If the foreign government instead seeks to sustain its own innovation (right panels), its incentive to use an export subsidy reverses. At $m_0 = -10$, foreign innovation already rises in response to the higher U.S. tariff due to the intensified competition. The export subsidy would give up most of that gain even though it helps the foreign country limit the U.S. firm's gains in technology gaps. At $m_0 = -5$, the U.S. tariff pushes the foreign firm's export prospect further out of reach and its innovation falls; here, the export subsidy restores about a third of the lost innovation, and the foreign government has an incentive to use it. However, that would imply giving up on the relative gains in terms of the expected technology gap from the foreign perspective. Whether the foreign country retaliates and the instrument it prefers is therefore not a property of the U.S. tariff alone but depends jointly on the U.S. firm's initial technology gap and the foreign government's objective.

5.3. Sensitivity to Innovation Step Size Distribution

A salient model component that shapes the return to innovation is the step-size distribution, which is increasingly relevant for laggard firms, as the calibrated shape of the distribution reflects an advantage of backwardness, meaning that the average expected step size increases as the firm lags further. Therefore, we investigate how the model-implied responses to changes in tariffs and, consequently, the import cutoff vary with the shape of the step-size distribution governed by the curvature parameter ϕ. We recompute the responses under a lower and higher level of ϕ than the calibrated value—implying a quicker or slower catch-up, on average, respectively—and discuss the results in Appendix A.4. Figure A.4 shows the change in average expected technology gap over 20 years in response to a U.S. tariff increase depending on the initial degree of the U.S. firm's initial laggardness level in the sector. The analysis reveals that the results are qualitatively similar, and the main mechanism, the interplay between competition and innovation, is unchanged. Quantitatively, the positive response of the laggard firm is larger when the catch-up is slower (higher ϕ). The reason is that with quicker catch-up, the chances that a significantly laggard U.S. firm approaches the import cutoff and captures the home market through innovation is higher, and the innovation effort is relatively larger to start with than in the case when catch-up occurs slowly, requiring many innovations. Under slow catch-up, significantly laggard firms are relatively more discouraged initially, and when tariffs make them more competitive raising their prospects of capturing home market, their innovation response is larger.

6. Empirical Evidence

This section examines empirically the relationship between the innovation effect of tariffs and the initial technology position of domestic firms employing patent and trade data around the 2018–2019 U.S. Section 301 tariff increases on imports from China. The empirical exercise investigates whether products exposed to higher tariffs in which the U.S. starts from a weak technological position relative to foreign rivals experience larger post-2018 increases in U.S. patenting as predicted by the theoretical model. We also examine patenting by Chinese and other foreign countries' entities in the same products.

6.1. Data and Measurement

We build a panel of six-digit HS2007 products including information on patents, imports, and tariffs. For patents, we use the USPTO data obtained through PatentsView, which report application dates, Cooperative Patent Classification (CPC) technology classes, assignees, assignee locations, and patent citations for granted patents.[12] We keep utility patents with application dates from 2010 through 2022, date patents by application year, and identify assignee country using the disambiguated assignee-location tables. Because PatentsView contains granted patents, recent application-year outcomes may be affected by grant lags; we return to this limitation below.

The tariff data measure the 2018–2019 U.S. Section 301 tariff increases on imports from China. The original data are reported at detailed HTS product lines; we collapse them to HS6 categories and map them to HS2007 using UN Statistics Division correspondence tables.[13] Import exposure comes from U.S. Census international trade data. We take annual HS6-level U.S. import values from China and from all countries for 2016–2022 and map to HS2007. Finally, we assign patents to HS6 products using the CPC4-to-product mapping from Goldschlag et al. (2019).[14]

The treatment variable is the tariff increase scaled by each product's pre-tariff reliance on U.S. imports from China. Let τ_g^{301} denote the tariff increase on U.S. imports from China for HS6 product g, measured in percentage points. Let

$$s_g^C = \frac{\text{US imports from China}_{g,2016-2017}}{\text{US imports from world}_{g,2016-2017}}$$

denote China's pre-tariff (2016–2017) share of U.S. imports in product g. The measure of tariff exposure is

$$E_g = \tau_g^{301} \times s_g^C. \tag{16}$$

Thus a product with a 25 percentage point tariff increase and a 40 percent pre-tariff China share of U.S. imports has $E_g = 10$. We report effects for a 10 percentage point increase in E_g. This exposure measure reflects the fact that a tariff on U.S. imports from China should matter most in products where China accounted for a large pre-tariff import share.[15]

The empirical analogue of the model's initial gap $m_{US,j}$ is the pre-period U.S. technology position relative to a foreign frontier. We measure this position using patent stocks accumulated from 2010 through 2017. To account for patent quality, we

[12]We use the PatentsView release of December 30, 2025, which covers grants through 2025.

[13]The correspondence tables are available at `https://unstats.un.org/unsd/classifications/Econ#Correspondences`.

[14]When a patent is linked to more than one CPC class, HS6 product, or assignee-country group, we distribute its contribution across those links evenly rather than count it once in each.

[15]Appendix B.1 shows that this import-effective measure is strongly related to subsequent changes in U.S. imports from China.

weight each patent by one plus its number of forward citations. The foreign frontier is the group of the eight largest foreign patentees at the USPTO in 2015–2017 (Japan, Korea, Germany, China, Taiwan, Canada, the United Kingdom, and France)—the same group against which the model is calibrated in Section 4, ensuring that the empirical and model-based objects are measured against the same rival.[16] Let $C^{\mathrm{US}}_{g,\mathrm{pre}}$ be the resulting stock for U.S. assignees in product g, and let $C^{F}_{g,\mathrm{pre}}$ be the corresponding stock for this foreign group. The U.S. initial technology share is

$$S_g^{\mathrm{US,cit}} = \frac{C^{\mathrm{US}}_{g,\mathrm{pre}}}{C^{\mathrm{US}}_{g,\mathrm{pre}} + C^{F}_{g,\mathrm{pre}}}. \tag{17}$$

Low values of $S_g^{\mathrm{US,cit}}$ proxy for lower values of $m_{US,j}$ in the model: the U.S. starts behind the foreign frontier. The eligible sample keeps HS6 products with at least 100 total patents during 2010–2017, leaving 1,172 products. Citation weights are used only to measure the initial technology position; the baseline outcome variable adopted below is the flow of patent counts mapped to HS6 products. Appendix B reports alternative foreign-frontier definitions, including the six advanced economies, all non-US assignees, and China-only assignees, as well as the unweighted patent-count version and continuous-share specifications.

6.2. Empirical Specifications

We organize the empirical design around the model's prediction that tariff effects vary with the initial technology position. The main specification uses the bottom quartile of the initial U.S. technology-share distribution because the model predicts the largest patenting response when the U.S. starts sufficiently far behind. Define

$$D_g = \mathbf{1}\left\{ S_g^{\mathrm{US,cit}} \leq Q_{25}\left(S_j^{\mathrm{US,cit}} \mid j \in \mathcal{E} \right) \right\}, \tag{18}$$

where $\mathcal{E}$ is the eligible sample and $Q_{25}(\cdot)$ denotes its 25th percentile. Thus $D_g = 1$ for products in the bottom quartile of the initial U.S. technology-share distribution; this group contains 293 HS6 products.

[16] China accounts for about 9 percent of the group's patent counts over 2010–2017 (7.6 percent of the citation-weighted stock), so a low U.S. patent share in a certain technology class is not a statement about China specifically. The six-country frontier of advanced economies gives the same estimate for U.S. patenting (8.7 percent in the most-laggard quartile).

Our primary regression uses annual product-level outcomes:

$$\log(1 + Y^{\text{US}}_{g,t}) = \mu_g + \delta_{HS4(g),t} + \beta \left(E_g \times \text{Post}_t \times D_g\right) \\ + \chi \left(E_g \times \text{Post}_t\right) + \rho \left(D_g \times \text{Post}_t\right) + \varepsilon_{g,t}, \tag{19}$$

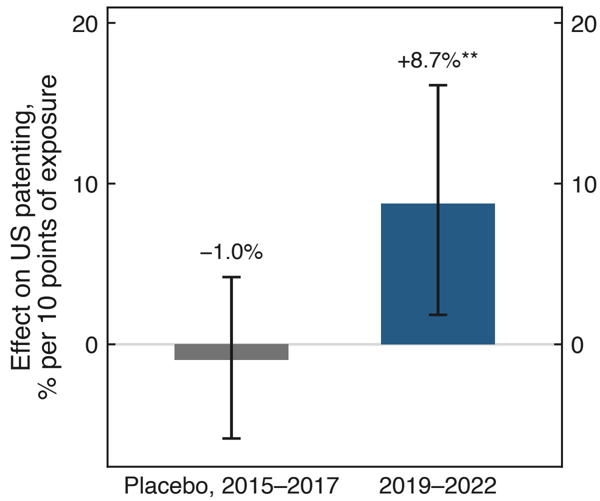
where $Y^{\text{US}}_{g,t}$ is US-assignee patenting in product g and year t, and Post_t marks the post-tariff years. This is a triple-difference specification in tariff exposure E_g, the laggard indicator D_g, and the post-tariff window. Because E_g and D_g are fixed within a product, their levels and their interaction $E_g \times D_g$ are absorbed by the product fixed effects μ_g, which also absorb permanent differences across HS6 products. HS4-by-year fixed effects $\delta_{HS4(g),t}$ absorb annual shocks common to narrow product families; because we estimate the equation separately for each innovator group, these fixed effects are innovator-specific and net out that innovator's national and sectoral patenting trends. The coefficient β measures the additional post-2018 patenting response to tariff exposure in initially laggard products, relative to other products within the same HS4 category. The post-tariff indicator pools 2019–2022 against a 2010–2017 baseline, with 2018 excluded as the tariff-implementation year; we also estimate the equation for alternative post-period windows and report a placebo estimate that treats 2015–2017 as the post-period against 2010–2014 as a diagnostic for differential pre-trends. Standard errors are clustered on HS6. Since E_g is measured in percentage points, we report the effect of a 10 percentage point increase as $100[\exp(10\hat{\beta}) - 1]$.

We also extend the analysis to a heterogeneous-effects specification in which the tariff-exposure interaction is allowed to differ across quartiles of $S^{\text{US,cit}}_g$, ordered from highest U.S. share to lowest U.S. share, with each quartile reported as a contrast relative to all other products. This tests whether the response is concentrated in the most-laggard tail rather than spread uniformly across products. We estimate the specification separately with U.S., Chinese, and other foreign patent counts as the dependent variable, so that the same US-share quartiles reveal whether foreign patenting also rises where the U.S. starts most laggard.

6.3. Results

Figure 10 reports estimates from the main bottom-quartile specification in equation (19). A 10 percentage point increase in tariff exposure is associated with an additional 8.7 percent increase in U.S. patenting in initially laggard products in 2019–2022 ($p = 0.036$). Consistent with the model, higher U.S. tariffs are associated with higher innovation effort by U.S. firms in products where they are noticeably laggard. A placebo that

Figure 10. Tariffs and U.S. patenting in initially US-laggard products.



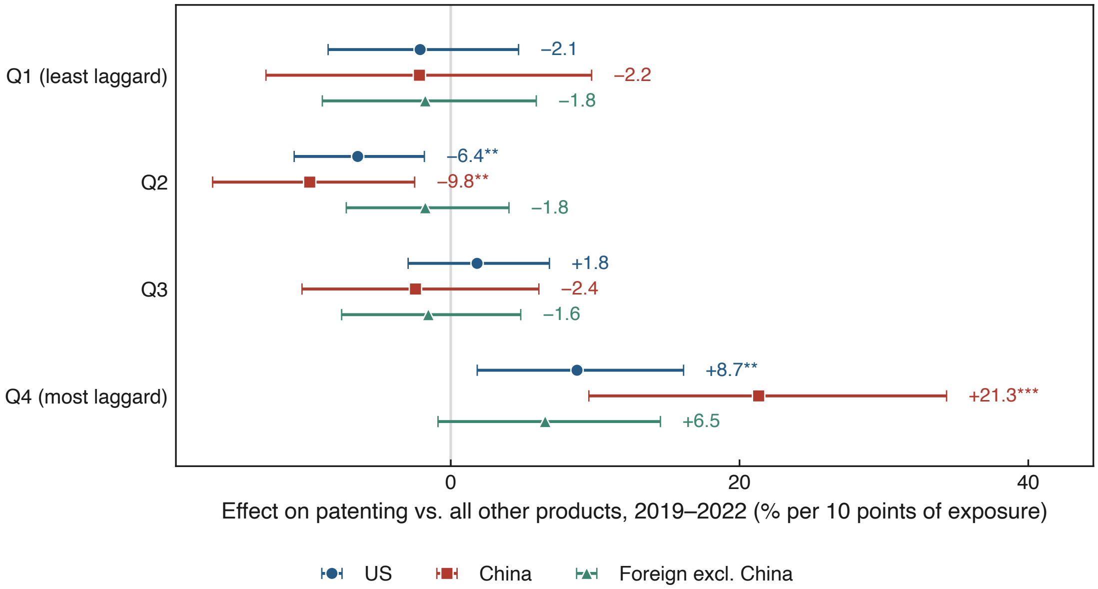
Note: The outcome is US-assignee patent counts. Each bar shows the estimated effect of a 10 percentage point increase in Section 301 tariff exposure scaled by the pre-tariff China share of U.S. imports, interacted with an indicator for products in the bottom quartile of the citation-weighted U.S. patent share relative to the eight largest foreign USPTO patentees (Japan, Korea, Germany, China, Taiwan, Canada, the United Kingdom, and France). Sample: 1,172 HS6 products with at least 100 patents in 2010–2017, observed 2010–2022 with 2018 excluded; 14,064 product-years. Estimates include HS6 and HS4-by-year fixed effects, and standard errors are clustered on HS6. Whiskers show 90 percent confidence intervals. The gray bar is the placebo estimate, which treats 2015–2017 as the post-period against 2010–2014. One, two, and three stars denote $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

treats 2015–2017 as the post-period against 2010–2014, before any tariff change, yields a small and statistically insignificant estimate, consistent with no differential pre-trend.

Figure 11 shows the heterogeneity across quartiles and regions, in which the regression's tariff-exposure interaction is allowed to differ across quartiles of $S_g^{\text{US,cit}}$, with each quartile estimate measured relative to all other products. Looking at the estimates for the U.S., the most-laggard quartile accounts for the positive differential response, and the U.S. estimate is the same value as in Figure 10. The estimates for the remaining quartiles are close to zero or negative, consistent with the model's complacency prediction for firms closer to the frontier. The products in the most-laggard U.S. quartile most closely resemble the initially laggard sectors in the quantitative experiments.

Chinese patenting exhibits a similar gap-dependent pattern. In the most-laggard quartile, where the foreign composite is the technology leader, a 10 percentage-point increase in tariff exposure is associated with a 21.3 percent increase in Chinese patenting in 2019–2022 (Figure 11). This result echoes the model prediction for the leading foreign firm when the U.S. starts far behind (right panel of Figure 6): tighter competition

Figure 11. Innovation response by initial technology state and innovator location.



Note: Each marker shows a 2019–2022 annual triple-difference estimate for U.S., Chinese, or foreign-excluding-China assignee patent counts, with each quartile of $S_g^{\text{US,cit}}$ reported as a contrast relative to all other products, ordered from highest initial U.S. share to lowest initial U.S. share. Regressions include HS6 and HS4-by-year fixed effects, and standard errors are clustered on HS6. Horizontal lines show 90 percent confidence intervals. One, two, and three stars denote $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

encourages its R&D, just like it does for the firm's laggard U.S. rival.[17] The estimated response for other foreign producers (excluding China) is also positive but imprecise in the most-laggard quartile (6.5 percent, $p = 0.15$). Because the Section 301 tariffs apply to Chinese imports alone, they affect these producers only indirectly, through second-order channels such as trade diversion. The smaller and imprecise response of producers the tariffs did not target, together with the concentration of the U.S. and Chinese effects in the most-laggard quartile, is consistent with the model's key mechanism that tariffs operate through the competition channel.

These results survive a range of alternative choices (Appendix B). The U.S. response is not specific to the eight-country definition of the foreign frontier: defining the frontier as the six advanced economies, excluding China, obtains an estimate of 8.7 percent ($p = 0.022$), and defining it as all non-US assignees obtains 9.1 percent ($p = 0.019$). Measuring the U.S. position against China alone, by contrast, obtains a small and imprecise estimate (3.2 percent, $p = 0.38$). China holds under a tenth of the frontier group's patents, so this share is a noisy measure of the U.S. distance

[17]The observation that China's response is larger than that of the U.S. is directionally consistent with the model-implied responses in Figure 6.

to the technology frontier; the contrast indicates that the response is tied to being behind the frontier rather than behind the country the tariffs target, consistent with the model's competition mechanism. The U.S. response is smaller and less precise, at 5.4 percent ($p = 0.12$), when initial laggardness is defined from unweighted patent counts rather than citation-weighted stocks (Appendix B.3), while the Chinese response remains large and significant (15.6 percent). Restricting the post-period to 2019–2021, which drops the most truncated final application year, obtains 7.5 percent ($p = 0.066$; Appendix B.5), and a continuous standardized laggardness measure yields the same pattern for U.S. patenting (5.2 percent, $p = 0.010$), with the Chinese gradient remaining significant at the 10 percent level (6.5 percent, $p = 0.061$; Appendix B.4).

Taken together, the estimates support the model's joint prediction: U.S. and Chinese patenting respond more strongly to tariff exposure in products where the U.S. starts from a weak technology position.

7. Conclusion

This paper studies how tariffs affect technology dynamics—especially in sectors in which a country lags the frontier—in a dynamic trade model with endogenous technology gaps. The central result is that the effect of tariffs on innovation is state dependent. A tariff weakens the foreign rival's competitive position in the home market and changes the value of R&D for the domestic firm. For a domestic firm that starts sufficiently far behind its foreign rival, higher tariffs can make the home market more attainable and boost innovation incentives. The key condition is that the tariff is sized appropriately relative to the initial gap, so that the laggard domestic firm becomes more competitive and faces more intense foreign competition. For a firm closer to the frontier, the same policy reduces competitive pressure and weakens R&D effort. In quantitative exercises, tariff policies that close the technology gap are temporary, sized to the gap, and concentrated in sectors with a large initial gap. Permanent protection is less effective because it eventually weakens the incentive to invest. These results highlight the limited scope for tariffs in managing global technological competition and the need to tailor them carefully to initial conditions and policy duration, even absent foreign retaliation.

The model also speaks to the foreign side of the technology competition. When the U.S. starts far behind, a U.S. tariff raises R&D by both firms and the gap narrows; when it starts only moderately behind, innovation falls on both sides and the gap widens. A retaliatory tariff has little effect in laggard sectors, while an export subsidy partially offsets the effects of the U.S. tariff. The foreign government's incentive to use the subsidy depends on its objective. When the U.S. starts far behind, the subsidy slows U.S. catch-up but reduces the foreign firm's innovation gains. When the U.S. starts moderately behind, the subsidy partly restores foreign innovation but limits the increase in the foreign firm's technological lead. As such, the gains in foreign innovation and technology gaps go in opposite directions.

The empirical evidence is consistent with the gap-dependent mechanism. Using USPTO patent data matched to HS6 products, we find a stronger U.S. patenting response to tariff exposure in the most-laggard quartile following the 2018–2019 Section 301 tariffs on imports from China. Chinese patenting shows the same pattern, consistent with the model's prediction that tariffs can intensify R&D incentives on both sides of a technology race. Patenting by other foreign producers, which the tariffs did not target, responds less and imprecisely, a pattern more consistent with the competition channel than with a blanket product-level shock.

Our analysis focuses on the innovation channel of trade policy. A complete welfare evaluation would have to account for general equilibrium price effects, fiscal costs, distributional consequences, and cross-sector spillovers (Akcigit et al., 2026). Governments may also weigh objectives such as national security or geopolitical resilience that are outside the present framework (Akcigit et al., 2024). The model itself admits several natural extensions, including learning-by-doing in production, general-equilibrium feedback through wages and interest rates, asymmetric country size, heterogeneous R&D productivity, and differential absorptive capacity. We see these as productive avenues for future work that can build on the gap-dependent mapping between trade policy and innovation developed here.

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Appendix

A. Additional Model Results

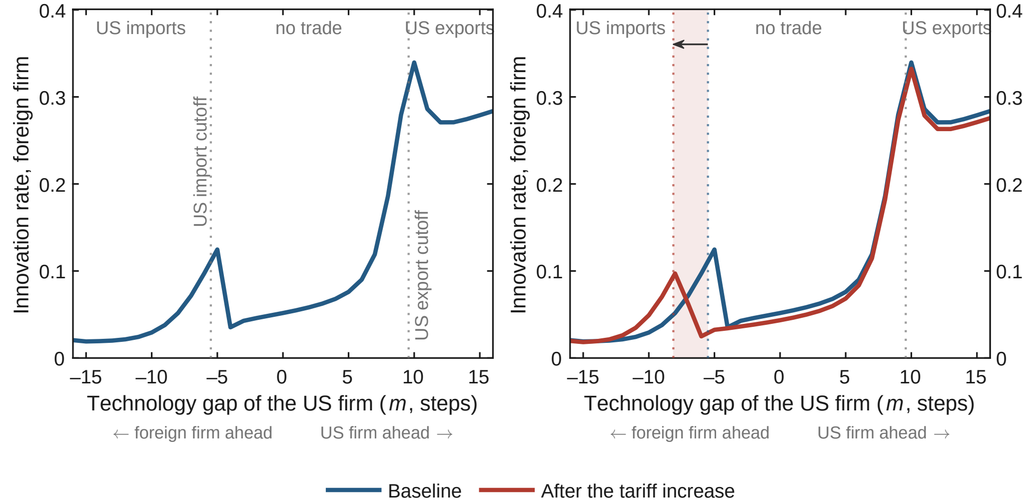
A.1. The Foreign Firm's Innovation Schedule

Figure 3 in the main text shows the U.S. incumbent's innovation effort as a function of the technology gap. Figure A.1 shows the same for the foreign incumbent as a function of U.S. technology gap. The foreign firm's schedule has two peaks. The left peak sits around the cutoff beyond which the foreign firm starts exporting to the U.S.—reciprocally, the U.S. import cutoff—to the right of which an innovation allows the foreign firm to gain access to the U.S. market. The right peak sits where the foreign firm is about to lose its home market to U.S. exports, just above the U.S. export cutoff. The right panel shows the schedule under the illustrative permanent U.S. tariff increase of Figure 3. The tariff moves the U.S. import cutoff, and with it the foreign firm's export threshold, to the left: foreign firms leading by more than the new cutoff now push harder to keep or reach the U.S. market, while those leading by less, which now have lower prospects of exporting to the U.S., cut back. The export cutoff, and hence the right peak, is untouched by a U.S. import tariff. These two shifts produce the foreign responses in Figure 6: the foreign firm's innovation rises when the U.S. starts far behind and falls when the U.S. starts moderately behind.

A.2. The Probability of Exporting

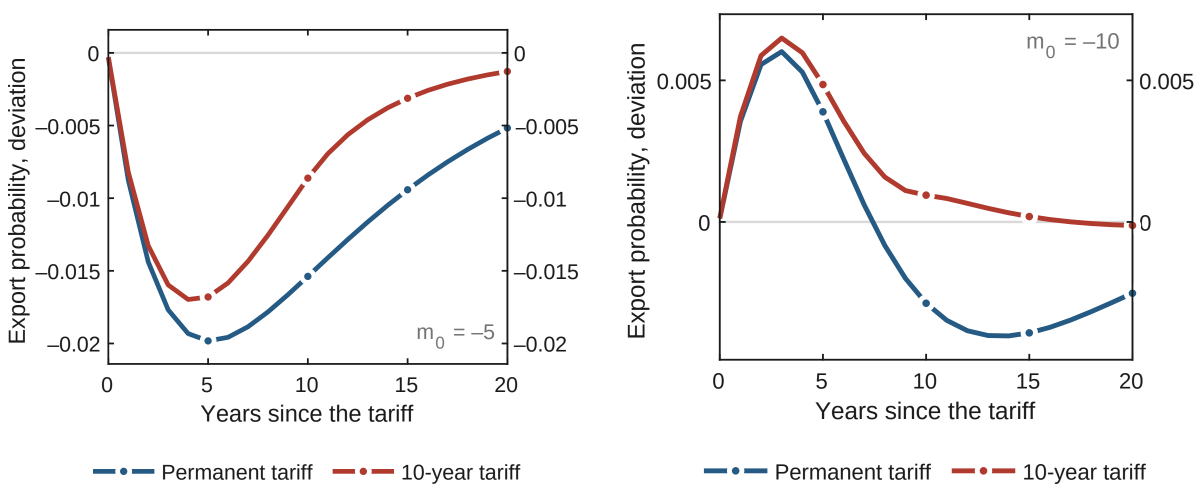
Figure A.2 shows the probability of a laggard U.S. firm entering the foreign market in deviation from the baseline path and the effect of U.S. tariffs. For a moderately laggard firm ($m_0 = -5$), neither permanent nor temporary tariffs improve the probability of export; in fact, the probability declines as the firm's innovation incentives diminish in response to higher tariffs. For a significantly laggard firm ($m_0 = -10$), the temporary tariff generates a small boost in export probability in the first decade due to the improved innovation incentives initially. However, the boost fades by the time the tariff is removed after 10 years, and under the permanent tariff, the probability falls below baseline within a decade.

Figure A.1. Foreign incumbent innovation effort as a function of the U.S. firm's technology gap.



Note: The horizontal axis is the technology gap from the U.S. firm's side: negative values mean the foreign firm leads. Left panel: the foreign incumbent's Poisson innovation rate by gap at the calibrated point; dotted lines mark the U.S. import and export cutoffs (−5.5 and 9.6 steps) and the regions are labelled by the U.S. firm's trade status. Right panel: the same under the illustrative permanent U.S. tariff increase of Figure 3, which moves the import cutoff to the left; the shaded band marks the gaps that leave the import region. Both schedules are computed at the baseline interest rate and relative wage.

Figure A.2. Probability of being an exporter (deviation from baseline, in probability points).



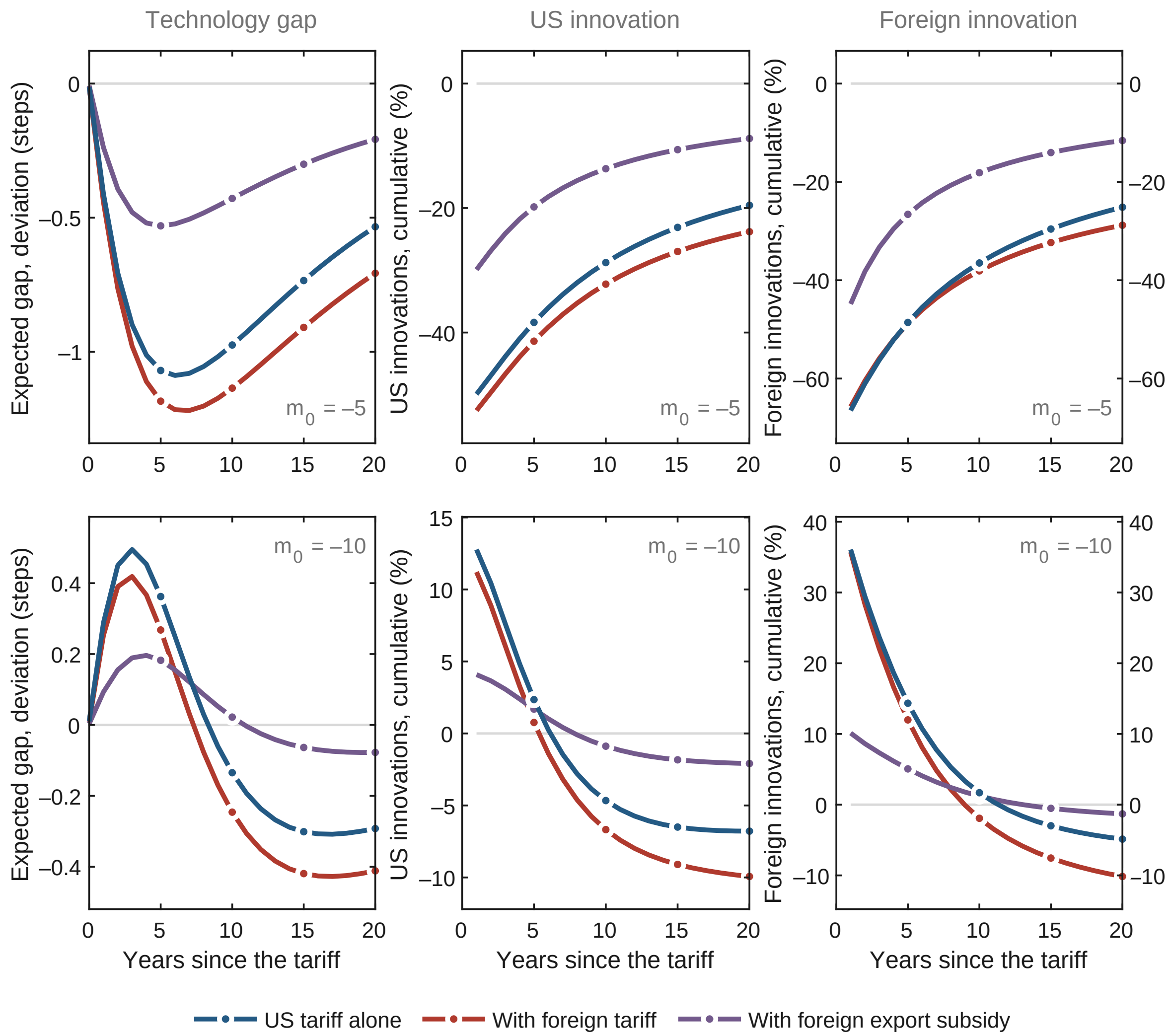
(a) Initial gap: $m_0 = -5$ (no trade) **(b)** Initial gap: $m_0 = -10$ (U.S. importing)

Note: Navy: permanent 3.9-percentage-point increase; red: 10-year increase (see the legend). Values are deviations of the probability that the U.S. firm exports from the baseline path; the horizontal axis is in years since the tariff.

A.3. Retaliation under a Permanent U.S. Tariff

Figure A.3 repeats Figure 9 for a permanent U.S. tariff with a permanent foreign response. The reading is the same: the foreign tariff barely impacts the laggard sector, and the export subsidy undoes most of what the U.S. tariff does. In response to the permanent tariff, the export subsidy is, if anything, more consequential for the U.S. firm at $m_0 = -10$. Absent the retaliatory export subsidy, the U.S. firm's cumulative innovation falls below the baseline within a decade, as protection causes complacency, and the expected gap falls below its baseline path as well. The foreign subsidy mitigates these deviations, and the U.S. firm follows a path close to the baseline.

Figure A.3. Responses to a permanent 3.9-percentage-point U.S. tariff increase, alone and with a permanent foreign retaliation: technology gap, U.S. innovation, and foreign innovation.

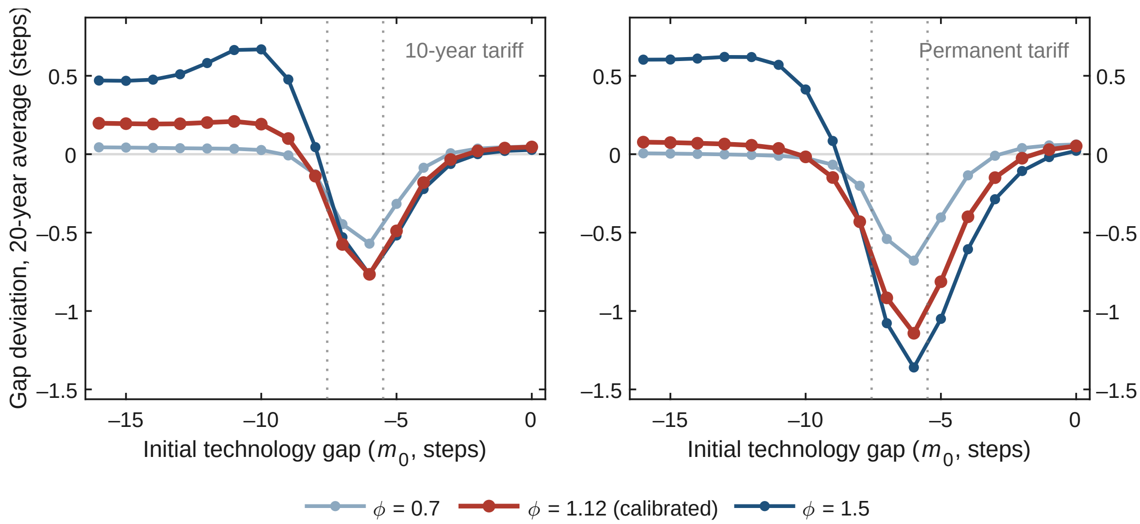


Note: As Figure 9, for a permanent U.S. tariff and a permanent foreign response: the composite's tariff on the U.S. raised by 2.3 percentage points (red) or an export subsidy of 2.3 percent to its exporters (plum); navy is the U.S. tariff alone. Rows $m_0 = -5$ and -10; columns the expected gap (deviation, steps) and the U.S. and foreign incumbent's cumulative innovations to the end of each year in percent of the baseline count.

A.4. Sensitivity: The Curvature of the Step-Size Distribution

Figure A.4 reassesses the effect of higher U.S. tariffs on the evolution of the technology gap under different values of the curvature parameter that governs the shape of the step-size distribution. For every initial gap from −16 to 0 it plots the change in the average expected technology gap over the 20 years following a 3.9-percentage-point tariff increase relative to the baseline path without the tariff change for both the 10-year and the permanent hike. Each curve repeats the main partial-equilibrium exercise holding parameters other than ϕ fixed at their calibrated values.

Figure A.4. Sensitivity to the curvature ϕ of the step-size distribution: change in the 20-year average technology gap by initial gap.



Note: Each curve plots, by the initial technology gap m_0, the change in the average expected technology gap over years 0–20 caused by the 3.9-percentage-point tariff increase, in steps (positive: the U.S. firm gains), for the 10-year increase (left) and the permanent increase (right).

The patterns are qualitatively the same for each ϕ. Quantitatively, the positive response of substantially laggard firms is larger when ϕ is high—i.e., the average innovation size is smaller. When jumps are large, a laggard can leap over the whole import region faster; therefore, higher tariffs that bring the cutoff closer matter less. By contrast, when jumps are small, reaching the cutoff through successive innovations is harder, and lowering the threshold to capture the domestic market leads to a larger change in the return to and effort for innovation.

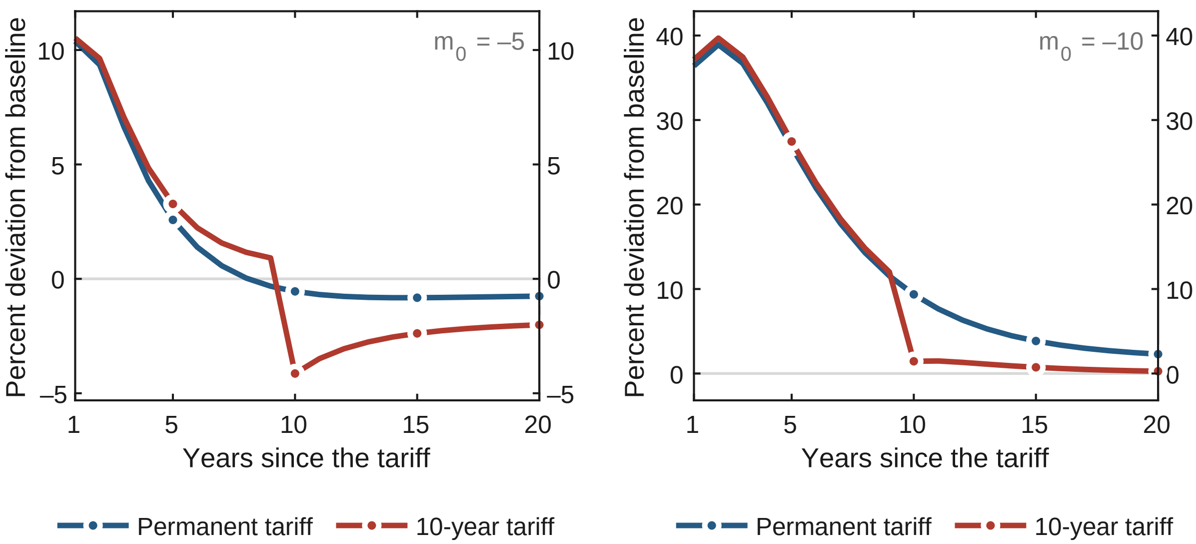
A.5. Sectoral Wage Income and Price Effects

This appendix reports two partial-equilibrium outcomes from the tariff and R&D subsidy experiments: the wage income in the targeted sector and the price of the sector's output. Because the experiments hold aggregate wages fixed, the wage-income series tracks labor input in the sector and serves as a measure of sectoral employment; the price series tracks the sector's output price, not an aggregate consumer price index.

A.5.1. Tariff Experiments

Figure A.5 displays the percent deviation of sectoral wage income from its baseline path after the 3.9-percentage-point tariff increase, for both the moderately laggard ($m_0 = -5$) and significantly laggard ($m_0 = -10$) cases. Tariffs raise sectoral wage income through increased demand for domestic production, but they also raise the sector's output price even when the dynamic innovation effects are positive. Figure A.6 shows the corresponding price deviations.

Figure A.5. Sectoral wage income, percent deviation from baseline under the 3.9-percentage-point tariff increase.



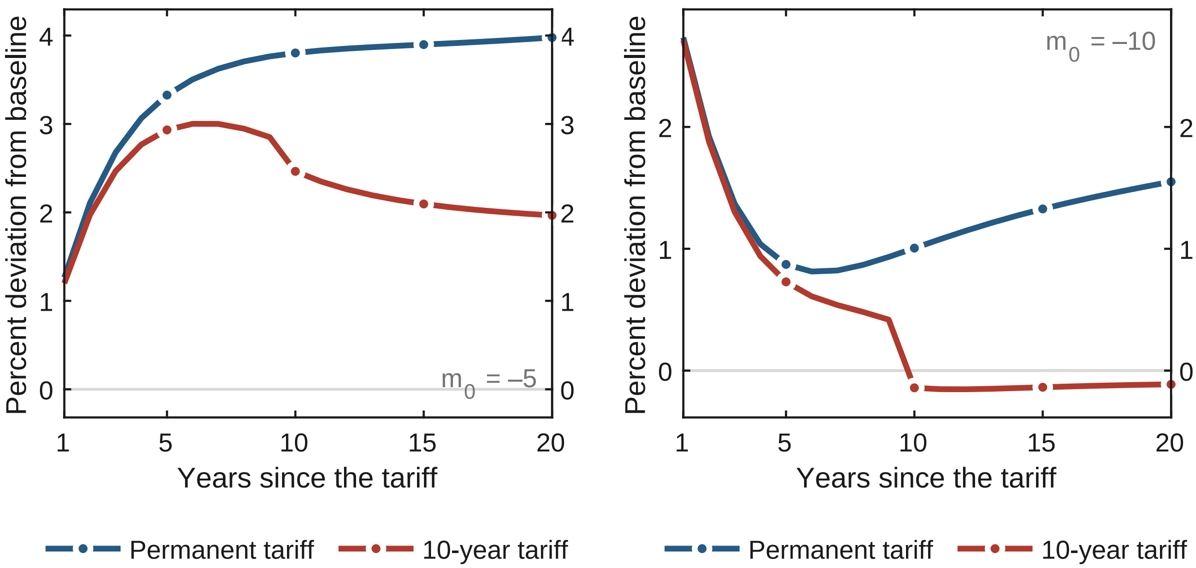
(a) Initial gap: $m_0 = -5$ **(b)** Initial gap: $m_0 = -10$

Note: Permanent (navy) vs. 10-year (red) increase of 3.9 percentage points; percent deviation from the baseline path at the end of each year.

A.5.2. R&D Subsidy Experiments

Figures A.7 and A.8 present the analogous sectoral wage-income and price effects under the R&D subsidy. In contrast to tariffs, R&D subsidies do not directly raise the sector's output price because they do not alter trade barriers or limit import competition. Any price effects arise indirectly through changes in the pace of quality improvement.

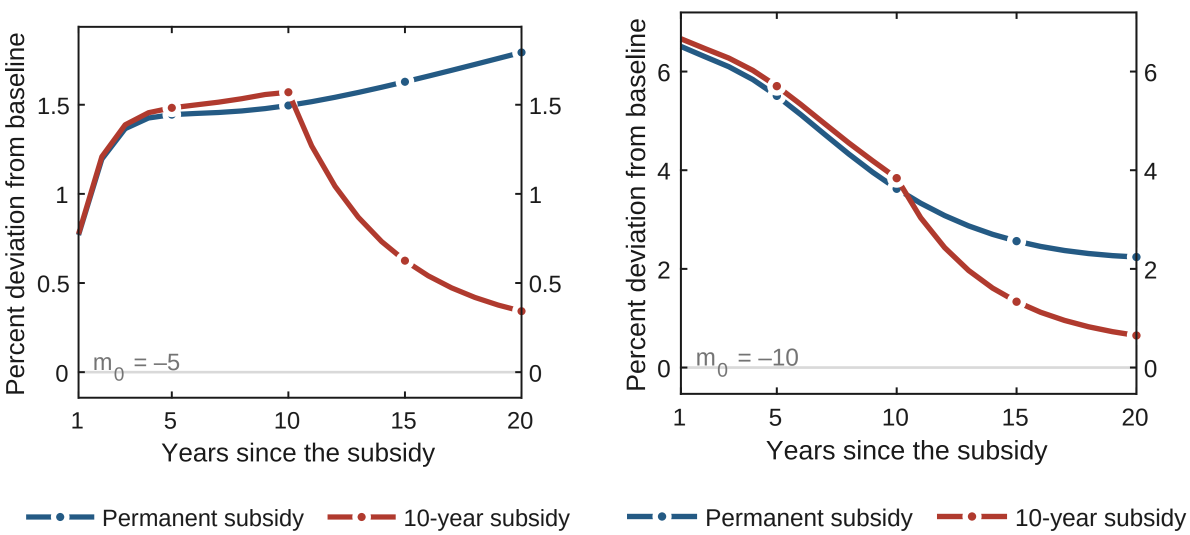
Figure A.6. Sectoral price, percent deviation from baseline under the 3.9-percentage-point tariff increase.



(a) Initial gap: $m_0 = -5$ **(b)** Initial gap: $m_0 = -10$

Note: Permanent (navy) vs. 10-year (red) increase of 3.9 percentage points; percent deviation from the baseline path at the end of each year.

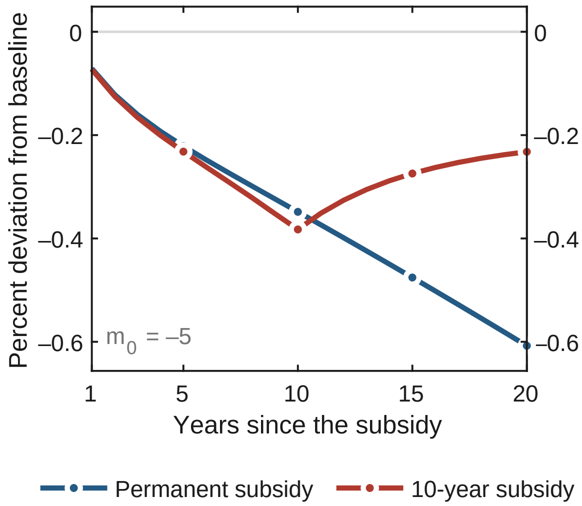
Figure A.7. Sectoral wage income, percent deviation from baseline under the R&D subsidy.



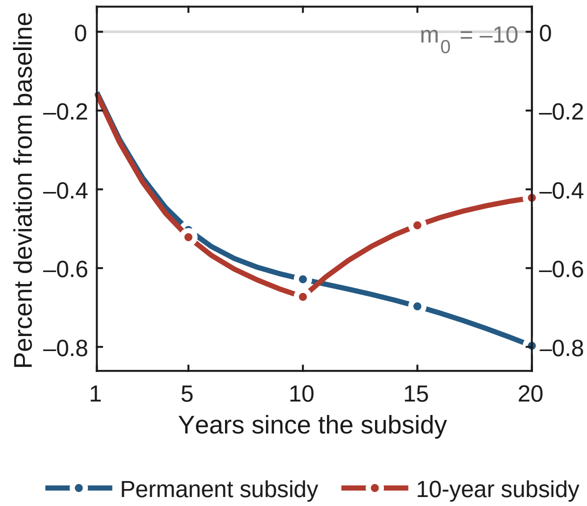
(a) Initial gap: $m_0 = -5$ **(b)** Initial gap: $m_0 = -10$

Note: U.S. R&D subsidy rate raised from 6.0 to 13.6 percent, permanently (navy) or for 10 years (red); percent deviation from the baseline path at the end of each year.

Figure A.8. Sectoral price, percent deviation from baseline under the R&D subsidy.



(a) Initial gap: $m_0 = -5$



(b) Initial gap: $m_0 = -10$

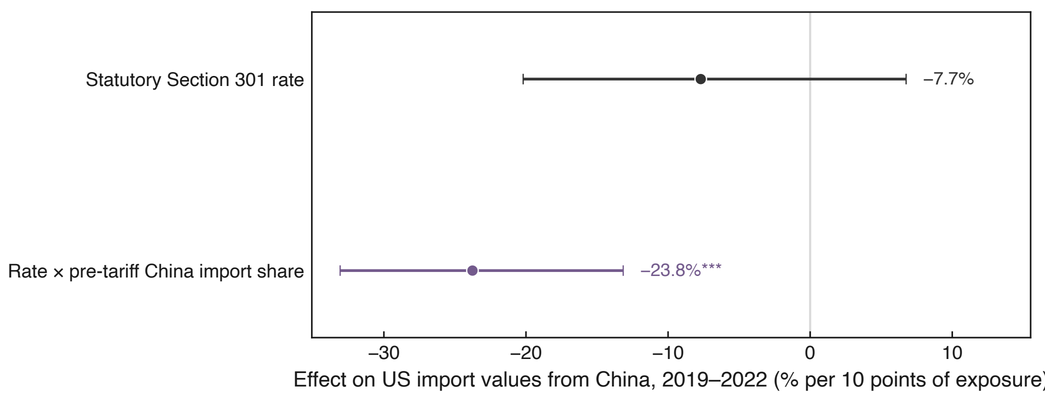
Note: U.S. R&D subsidy rate raised from 6.0 to 13.6 percent, permanently (navy) or for 10 years (red); percent deviation from the baseline path at the end of each year.

B. Additional Empirical Results

B.1. Tariff Exposure and U.S. Import Values from China

As a measurement check for the import-effective tariff exposure E_g, products with higher E_g experience larger declines in U.S. imports from China. Among products with positive pre-tariff U.S. imports from China, a 10 percentage point increase in tariff exposure is associated with 23.8 percent lower values in 2019–2022 (Figure B.1). This pattern is consistent with the fact that tariff increases matter more when China was an important pre-tariff supplier. The unscaled tariff increase has a weaker relationship with these import declines.

Figure B.1. Tariffs and U.S. import values from China.



Note: The sample is HS6 products with positive pre-tariff U.S. imports from China. The outcome is the change in log U.S. import value from China relative to 2016–2017. Each marker shows the estimated 2019–2022 effect of a 10 percentage point increase in the statutory Section 301 rate or in import-effective tariff exposure (the rate scaled by China's pre-tariff share of the product's U.S. imports). The sample has 4,293 product-years and 1,132 HS6 clusters. Horizontal lines show 90 percent confidence intervals. One, two, and three stars denote $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

B.2. Alternative Foreign-Frontier Definitions

Table B.1 varies the foreign group used to define bottom-quartile low-US-share products. The estimates in the empirical section use the eight largest foreign patentees. Using the six advanced economies that exclude China (8.7 percent, $p = 0.022$) or all non-US assignees (9.1 percent, $p = 0.019$) yields similar estimates. Using China-only assignees yields a small and imprecise estimate (3.2 percent, $p = 0.38$). China holds under a tenth of the frontier group's patents, so the U.S. share against China alone is a noisy measure of the U.S. distance to the technology frontier; the weak estimate indicates that the response is tied to being behind the frontier rather than behind the country the tariffs target.

Table B.1. Robustness to alternative foreign-frontier definitions.

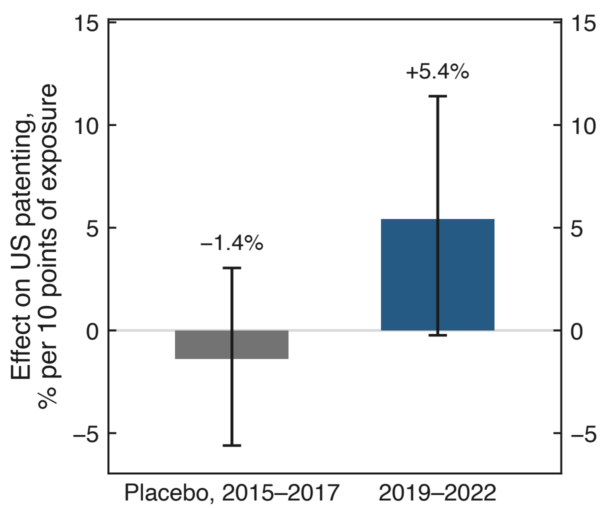
Foreign group	Annual effect (%)	Annual p-value
Eight largest foreign patentees (main)	8.74	0.036
Six advanced economies	8.68	0.022
All non-US assignees	9.15	0.019
China only	3.18	0.382

Note: Effects are percent changes for a 10 percentage point increase in tariff exposure interacted with the bottom-quartile low-US-share indicator. Annual effects use the 2019–2022 HS6 panel regression. Sample: 1,172 eligible products, 293 in the laggard quartile.

B.3. Patent-Count Initial Shares

Figure B.2 repeats the U.S. patenting regressions using unweighted pre-period patent counts to define low-US-share products. The dependent variable remains U.S. patent counts. This version provides a transparent quantity-based check, but it treats all patents equally.

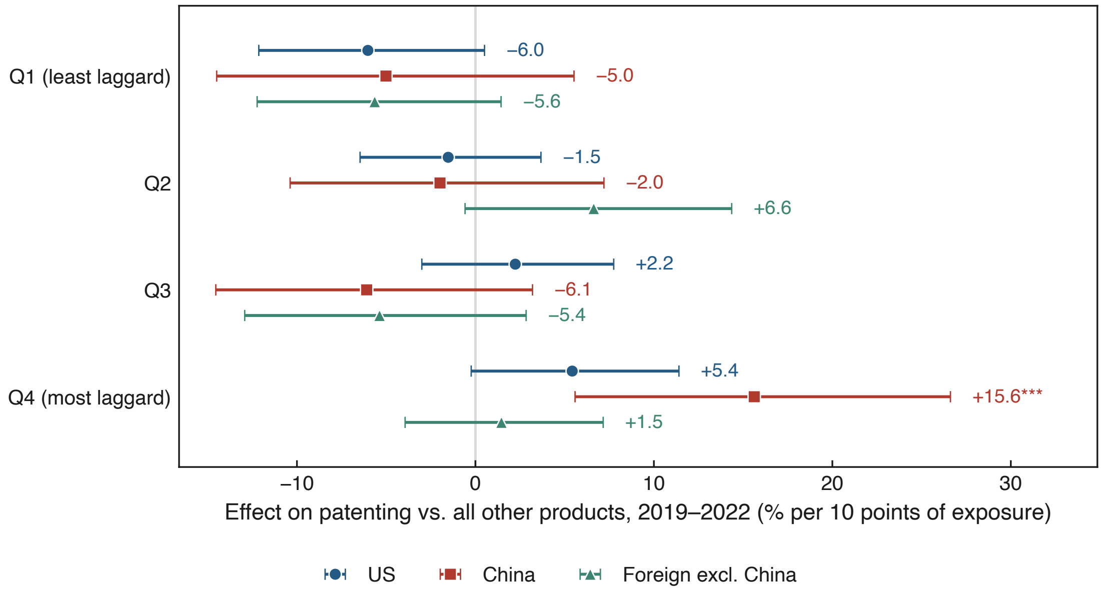
Figure B.2. Patent-count initial backwardness and U.S. patenting.



Note: Initial backwardness is defined from the bottom quartile of the unweighted U.S. patent share relative to the eight largest foreign USPTO patentees (Japan, Korea, Germany, China, Taiwan, Canada, the United Kingdom, and France). Each bar shows the estimated effect of a 10 percentage point increase in tariff exposure, from the annual specification with HS6 and HS4-by-year fixed effects and standard errors clustered on HS6. Whiskers show 90 percent confidence intervals. The gray bar is the placebo estimate, which treats 2015–2017 as the post-period against 2010–2014. One, two, and three stars denote $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

The unweighted count version obtains a similar but weaker pattern for U.S. patenting. Figure B.3 repeats the quartile analysis of Figure 11 with the count-based quartiles. In the most-laggard quartile, a 10 percentage point increase in tariff exposure is associated with additional increases of 5.4 percent in U.S. patenting ($p = 0.12$) and 15.6 percent in Chinese patenting in 2019–2022, while patenting response by other foreign producers (excluding China) is small and insignificant.

Figure B.3. Innovation response by initial patent-count share.



Note: Each marker shows a 2019–2022 annual triple-difference estimate, reported as each quartile relative to all other products, by quartile of the unweighted U.S. patent share relative to the eight largest foreign USPTO patentees (Japan, Korea, Germany, China, Taiwan, Canada, the United Kingdom, and France). Regressions include HS6 and HS4-by-year fixed effects, and standard errors are clustered on HS6. Horizontal lines show 90 percent confidence intervals. One, two, and three stars denote $p < 0.10$, $p < 0.05$, and $p < 0.01$, respectively.

B.4. Continuous Measure of Initial Technology Position

The empirical section uses a bottom-quartile low-US-share indicator because the model predicts the largest patenting response when the U.S. starts sufficiently far behind. A continuous version obtains the same qualitative result. The continuous measure uses the pre-period U.S. technology share $S_g^{\text{US,cit}}$, multiplied by -1 and standardized in the eligible sample so that higher values indicate lower initial U.S. shares. Replacing the bottom-quartile indicator with this continuous measure produces an annual effect of 5.2 percent in 2019–2022. Table B.2 reports the 2019–2022 continuous-measure estimates for U.S., Chinese, and foreign-ex-China patenting. The U.S. response is positive and significant, the Chinese response is positive and significant at the 10 percent level, while the foreign-ex-China response is small and insignificant, matching the pattern in the baseline results.

Table B.2. Continuous initial-technology-position gradient, 2019–2022.

Outcome	Effect (%)	p-value
US patenting	5.15	0.010
Chinese patenting	6.48	0.061
Foreign excluding China	2.42	0.261

Note: Effects are percent changes for a 10 percentage point increase in tariff exposure interacted with the continuous initial-laggardness measure (the pre-period U.S. technology share, multiplied by −1 and standardized so that higher values indicate lower initial U.S. shares), from the 2019–2022 annual HS6 panel regression with HS6 and HS4-by-year fixed effects and standard errors clustered on HS6.

B.5. Additional Robustness Checks

Table B.3 reports selected robustness checks for the U.S. patenting result. The 2019–2022 effect remains positive when we drop the largest pre-period US-patenting products or restrict the sample to products with positive pre-tariff U.S. imports from China. The effect is similar, at 7.5 percent ($p = 0.066$), when we restrict the post-period to 2019–2021 (dropping the truncated final year), while it is smaller and less precise, at 5.4 percent ($p = 0.12$), when initial laggardness is defined from unweighted patent counts.

Table B.3. Selected robustness checks for U.S. patenting.

Check	Effect (%)	p-value
Annual 2019–2022, full eligible sample	8.74	0.036
Drop largest 1 percent of pre-US-patent products	8.33	0.045
Positive pre-war US imports from China	8.51	0.044
Annual 2019–2021 (drops truncated 2022)	7.49	0.066
Count-based initial laggardness	5.42	0.116

Note: Effects are percent changes for a 10 percentage point increase in tariff exposure interacted with the bottom-quartile low-US-share indicator. All rows use the annual HS6 panel regression with HS6 and HS4-by-year fixed effects and standard errors clustered on HS6.