Export Dynamics with Product Proximity *

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Abstract

Exporters make strategic decisions about which products to export together. Using Chinese customs data, we document that new product introductions are strongly predicted by proximity to the incumbent export basket. To quantify the aggregate consequences of these proximity effects, we develop a dynamic general equilibrium model with firm and product heterogeneity in which firms benefit from reduced export costs when adding products in close proximity to their current export portfolio. Quantitative simulations reveal that proximity effects substantially amplify welfare responses to trade policy changes, with models ignoring such effects underestimating welfare effects by up to 26%.

JEL Classification: F10, F40

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1 Introduction

Policymakers recognize that aggregate economic outcomes from trade policy changes depend critically on which specific products face tariffs, not just average protection levels.[1] This recognition reflects a broader understanding that product-level firm behavior significantly shapes macroeconomic outcomes. Understanding how firms make product-specific decisions, such as which goods they choose to export, how they respond to product-specific policy changes, and how these choices interact across firms, is therefore crucial for predicting the aggregate effects of trade policy reforms. This paper addresses this challenge by examining how firm-level product proximity, the tendency of exporters to expand into goods related to their existing portfolio, shapes firms' responses to trade policy and, in turn, aggregate dynamics. We show that proximity lowers the costs of product scope expansion, amplifying portfolio adjustments when tariffs change. As a result, models that ignore firm-level product proximity may systematically underestimate the welfare effects of trade policy changes.

Using Chinese customs data, we document that when firms introduce new products into a market, they are far more likely to add goods that are close to their existing portfolio. To capture this tendency, we construct an Export Basket Proximity (EBP) index, which measures how strongly a candidate product is linked to a firm's current exports based on co-export patterns. High-EBP candidates are relatively rare, less than six percent of the pool, but they account for nearly one-fifth of all new product introductions, with entry probabilities three to four times higher than the baseline rate. In our empirical analysis, EBP is the dominant predictor of product introductions, even after accounting for product classification and technological relatedness, indicating that realized basket proximity captures market-specific complementarities not encompassed by taxonomy or input similarity.

Motivated by these empirical findings, we develop a dynamic general equilibrium model with product and firm heterogeneity to capture the role of product proximity in shaping export dynamics and assess its welfare implications under trade policy changes. A key feature of our model is portfolio-dependent export costs: when a firm exports a new product, closer proximity to its existing export portfolio lowers the fixed export costs compared to introducing a distant product. We estimate the model parameters by matching key moments from customs and

[1] Jerome Powell's observation that "higher inflation is a possible outcome which will depend very much on specific facts of what goods are taxed and by how much" highlights the importance of product-level analysis in trade policy. See Schneider (2025).

manufacturing data. The calibrated model successfully replicates firms' tendency to introduce products based on export basket proximity, validating our empirical findings.

Unlike previous models that treat product choices as independent decisions, our modeling approach embeds proximity directly into firms' export cost functions, creating economies of scope that depend on portfolio composition. This generates endogenous product scope decisions where firms face lower barriers to entering related product markets. The model features a tractable structure where firms choose an optimal export threshold that determines their product range, reducing the dimensionally complex multiproduct choice problem to a manageable framework. Importantly, our approach generates realistic export dynamics, including the gradual expansion patterns and high persistence documented in the data, without requiring exogenous market-specific shocks, as proximity advantages alone drive portfolio evolution over time.

Next, we examine how product proximity amplifies welfare effects under different trade policy scenarios. Our analysis considers both liberalization and protection under various tariff structures. While the overall magnitude of welfare effects varies with policy design, our core finding demonstrates that product proximity substantially amplifies welfare effects across all scenarios. Eliminating proximity advantages reduces welfare gains by 23% under liberalization and welfare losses by 26% under protection. This amplification occurs because firms with proximity advantages face lower export costs when adjusting their portfolios, enabling more aggressive expansion during liberalization and more severe contraction during protection. These findings underscore the importance of considering product interconnections, not just average tariff rates, when evaluating trade policy proposals. Moreover, they suggest that models ignoring firm-level product proximity may systematically underestimate both the benefits of trade liberalization and the costs of protectionist policies.

Our paper first relates to the literature on sunk and fixed costs in shaping export dynamics. A well-established body of work shows that firms face significant sunk costs when entering export markets, generating persistence in participation (Roberts and Tybout, 1997; Das et al., 2007). Beyond entry, firms also incur fixed export costs that influence product scope. Several studies link these costs to relationships among products.[2] From a macro-trade perspective, recent work

[2]Baldwin and Harrigan (2011) and Freund and Pierola (2015) show that firms bundle related goods to minimize export costs, while Nocke and Yeaple (2014) develop a theoretical framework in which relatedness lowers the marginal

embeds product scope into dynamic general equilibrium settings.[3] Arkolakis et al. (2021) develop a model where scope economies in market access costs reduce entry costs as firms expand their range, and Alessandria et al. (2021) study export dynamics in a dynamic GE framework. Our paper builds on this line by embedding product proximity directly into export decisions.

Second, our paper relates to the literature on entry dynamics and firm expansion strategies. Exporters expand sequentially rather than all at once: Albornoz et al. (2012, 2023) show that firms gradually test destinations and products, and Ruhl and Willis (2017) highlight the volatility of new exporters. Much of this work emphasizes expansion across markets: Morales et al. (2019) and Alfaro-Urena et al. (2024) document complementarities across destinations, and related research on multinationals highlights how firms expand across countries and product lines.[4] Our contribution is to show that expansion also occurs sequentially along the product dimension *within* a market, with firms introducing goods that are proximate to their existing portfolio rather than adding products at random.

Finally, our study contributes to the literature on firm responses to trade shocks. Liberalization often triggers adjustments in product scope, with Bernard et al. (2011) documenting expansion by more productive firms.[5] From a macro-trade perspective, Eaton and Kortum (2002), Caliendo and Parro (2015), and Alessandria et al. (2021) develop general equilibrium models to measure the welfare effects of trade shocks. By embedding product proximity into a dynamic general equilibrium framework, our contribution bridges the firm-level literature on product scope adjustment with the macro-trade literature on aggregate consequences of trade reforms.

The remainder of the paper is organized as follows. Section 2 provides a detailed description of the data and presents stylized facts from our empirical analysis. Section 3 develops a dynamic general equilibrium model with portfolio-dependent export costs that incorporates product

cost of adding products. Eslava et al. (2004) document firm restructuring toward product spaces with shared efficiencies.

[3] Foundational contributions linking micro heterogeneity to aggregate welfare include Arkolakis et al. (2012) and Eaton et al. (2011).

[4] Fillat and Garetto (2015) and Garetto et al. (2024) document the dynamics of exporters and multinationals. While distinct from our focus, these studies highlight related cost complementarities across locations.

[5] Additional evidence includes Qiu and Zhou (2013) and Lopresti (2016), who find similar expansion patterns among more productive or export-oriented firms, and Goldberg et al. (2010), Pavcnik (2002), and Trefler (2004), who emphasize product switching and productivity responses to liberalization. Eckel and Neary (2009) provide a theoretical explanation via flexible manufacturing.

proximity effects. Section 4 outlines the model calibration and external validation. Section 5 presents results on firm-level decisions and dynamics in stationary equilibrium. Section 6 examines the aggregate impacts of trade liberalization and protection with product proximity. Section 7 concludes.

2 Data and Empirical Analysis

Our empirical analysis relies on the Chinese Customs Data (CCD), which provide comprehensive records of export transactions. These data contain detailed firm identifiers, including name, ownership type, and location, as well as information on export values, quantities, destinations, and product classifications at the HS6 level. This granularity allows us to track firms' product scope within and across markets and to construct proximity measures that link existing export baskets to potential new products.

Our final sample is a firm–product–destination–year panel, covering 127,856 firms exporting to 55 destinations over the 2000–2006 period. The resulting dataset contains roughly 18 million observations. To ensure meaningful variation, we restrict our attention to "thick" markets–destination–year cells with a sufficiently large number of active exporters such that our proximity measures are well defined.[6]

2.1 Candidate Set and EBP

A central feature of multiproduct exporting firms' behavior is that product additions are not random: firms tend to introduce products that are related to their existing export portfolio. To quantify this tendency, we construct a measure of firm–candidate product proximity based on observed co-export patterns across firms and destinations, which we term *Export Basket Proximity* (EBP). This measure reflects realized complementarities in firms' baskets and provides a summary of how closely a potential product is connected to a firm's existing portfolio.

Our focus on within-market product proximity complements recent evidence on cross-market complementarities. Alfaro-Urena et al. (2024) show that firms benefit when exporting to destinations that are geographically or linguistically close, or share deep trade agreements. We

[6] For a detailed description of the data cleaning procedures and sample restrictions, see the Supplementary Appendix.

shift the lens from *where* firms export to *what* they export within a given market, asking whether products that are close to a firm's current basket are more likely to be introduced next. Methodologically, our outcome-based proximity follows Hidalgo et al. (2007) in spirit, but is adapted to the firm–destination–year setting and then mapped into firm–candidate summaries.

Candidate set. For each firm f, destination d, and year t, let S_{fdt} denote the set of products exported by f to d in t, and let S_{ft} denote the set of products exported by f to any destination in t. We define the candidate set as

$$C_{fdt} = S_{ft} \setminus S_{fdt},$$

that is, products that the firm already exports somewhere in the world but not yet to destination d in year t. By construction, a candidate product $p \in C_{fdt}$ is one that the firm has the capacity to produce and export, but has not yet introduced into the particular market d at time t.[7]

Export Basket Proximity (EBP). Following the outcome-based approach of Hidalgo et al. (2007), we measure the extent to which products are jointly emphasized by exporters in a given destination and year, and then map that information into a firm–candidate index. For firm f, product p, destination d, and year t, let X_{fpdt} denote exports of p by f to d, and $X_{fdt} = \sum_j X_{fjdt}$ the firm's total exports to d. We construct an export-basket revealed comparative advantage, RCA^{mrkt}_{fpdt}, which benchmarks the share of product p in firm f's basket against the average active firm in (d, t).

$$RCA^{mrkt}_{fpdt} = \frac{\frac{X_{fpdt}}{X_{fdt}}}{\frac{1}{N_{dt}} \sum_{f'} \frac{X_{f'pdt}}{X_{f'dt}}}, \qquad N_{dt} = \left|\{f' : X_{f'dt} > 0\}\right|. \tag{1}$$

Here, N_{dt} denotes the number of active exporting firms in destination d at year t. The numerator, $\frac{X_{fpdt}}{X_{fdt}}$, captures the share of product p in firm f's total exports to destination d in year t. The denominator, $\frac{1}{N_{dt}} \sum_{f'} \frac{X_{f'pdt}}{X_{f'dt}}$, is the average share of product p across all firms exporting to (d, t). Thus, $RCA^{mrkt}_{fpdt} > 1$ indicates that product p is emphasized more in firm f's basket than in the basket of the average active exporter in that market–year.[8]

[7] For 127,856 firms across 55 destinations and 7 years, we have a total of 17,988,722 candidate observations.

[8] As robustness, we also construct an alternative measure, RCA^{exp}_{fpdt}, which benchmarks against the average p-exporter in (d, t). Summary statistics for both RCA^{mrkt} and RCA^{exp} are reported in Supplemental Appendix.

Using RCA^{mrkt}_{fpdt}, we construct a product–product proximity matrix $\varphi_{ij,dt}$ that captures co-specialization patterns across all firms active in (d,t). For two products i and j, we define

$$\varphi_{ij,dt} = \min\left\{\Pr(RCA^{mrkt}_{i,dt} > 1 \mid RCA^{mrkt}_{j,dt} > 1),\ \Pr(RCA^{mrkt}_{j,dt} > 1 \mid RCA^{mrkt}_{i,dt} > 1)\right\}. \qquad (2)$$

Here, each cell $\varphi_{ij,dt}$ represents the strength of association between products i and j: it is the probability that a firm strongly emphasizes product i given that it emphasizes product j, and vice versa, taking the smaller of the two conditional probabilities. This measure is symmetric, lies in $[0,1]$, and is universal across firms: it reflects the overall co-specialization tendencies of all exporters in destination d at time t, rather than being specific to any one firm.

Figure 1 illustrates the product–product proximity matrix $\varphi_{ij,dt}$ for U.S. exports in the year 2000, displayed at three levels of HS aggregation. The left panel shows all products within HS2 chapter 90, the middle panel zooms in to HS3 category 902, and the right panel further focuses on HS4 code 9006. The matrices are sparse: most off-diagonal elements are close to zero, indicating little or no co-export relationship. A limited set of product pairs, however, exhibit high proximity values, forming small and isolated clusters. This pattern shows that co-specialization is selective, with strong associations concentrated in a few product pairs rather than spread evenly across related categories.

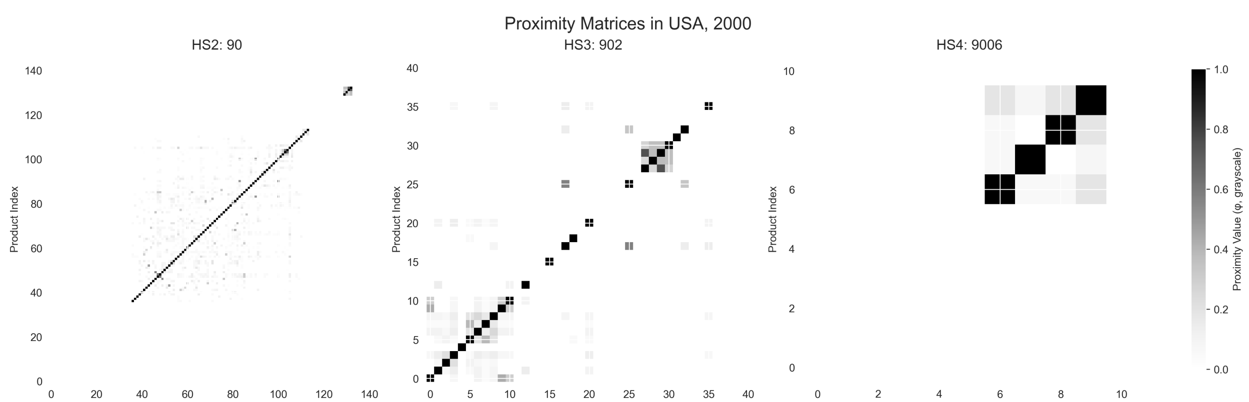


Figure 1: Proximity matrices $\varphi_{ij,dt}$ for U.S. exports in 2000 at different HS levels. The left panel shows HS2 chapter 90 (*Optical, photographic, cinematographic, measuring, medical or surgical instruments*), the middle panel zooms in to HS3 category 902 (*Instruments and apparatus for measuring or checking*), and the right panel focuses further on HS4 code 9006 (*Photographic cameras and related equipment*). Darker cells indicate stronger co-export proximity. Diagonal entries are equal to one only for products with sufficient firm support (at least five active exporters in that destination–year); products with weaker presence receive a diagonal value of zero.

To obtain a firm–candidate index, we map this universal product–product matrix into the portfolio of a particular firm. Specifically, for each candidate product $p \in C_{fdt}$, we compute its average proximity to the firm's existing basket S_{fdt}:

$$EBP_{fpdt} = \frac{1}{|S_{fdt}|} \sum_{i \in S_{fdt}} \varphi_{ip,dt}, \qquad \text{for each } p \in C_{fdt}, \tag{3}$$

Here, $|S_{fdt}|$ denotes the cardinality of the existing product set, i.e., the number of products that firm f already exports to destination d in year t. Thus, EBP_{fpdt} measures how closely the candidate product p is connected to that portfolio based on the co-specialization patterns captured by $\varphi_{ij,dt}$. The index takes values in $[0, 1]$; higher values indicate that the candidate product is more closely related to the firm's existing portfolio.

To assess the economic significance of EBP, we examine the prevalence of high-proximity candidates and their contribution to subsequent product introductions. The baseline introduction probability is 0.027, i.e. 2.7 percent of firm–candidate observations result in entry at $t+1$. Table 1 reports the share of candidates and the share of entries accounted for by products above selected EBP thresholds.

Table 1: Prevalence and entry shares by EBP threshold

Threshold τ	Share of candidates	Share of entries	Implied entry probability
$EBP > 0.1$	5.42%	17.82%	8.9%
$EBP > 0.2$	1.74%	6.65%	10.4%
$EBP > 0.3$	0.63%	2.68%	11.5%

Notes: Shares are computed over 17,988,722 firm–candidate–destination–year observations. Baseline introduction probability is 2.7%. Implied entry probability is calculated as $\Pr(\text{Intro}_{t+1} \mid EBP > \tau)$, equal to the ratio of the entry share to the candidate share times the baseline probability.

The results show that high-EBP candidates are relatively rare but disproportionately account for new product entries. For instance, only 5.4 percent of candidates have $EBP > 0.1$, yet these products represent 17.8 percent of entries, with an average entry probability of 8.9 percent—over three times the baseline rate. The concentration becomes even sharper at higher thresholds: candidates with $EBP > 0.3$ constitute only 0.6 percent of the pool but account for 2.7 percent of entries, with an average entry probability of 11.5 percent. These patterns highlight that EBP effectively sorts candidate products into a small subset with substantially higher likelihood of introduction.

2.2 Empirical Analysis

We begin by examining whether proximity in the export basket (EBP) predicts subsequent product entry into a destination. The unit of observation is firm–candidate–destination–year. For each (f, d, t) and $p \in C_{fdt}$, we define the outcome

$$\text{Introduction}_{fpdt+1} \;=\; \mathbf{1}\{\, X_{fpdt} = 0 \text{ and } X_{fpd,t+1} > 0 \,\},$$

an indicator that switches from no exports of p to d at t to positive exports at $t+1$. Figure 2 plots the mean introduction rate from t to $t+1$ by deciles of EBP. Introduction probabilities increase monotonically with proximity, with particularly steep gains in the upper deciles. This pattern suggests that products closer to a firm's existing basket are substantially more likely to be introduced in the following year.

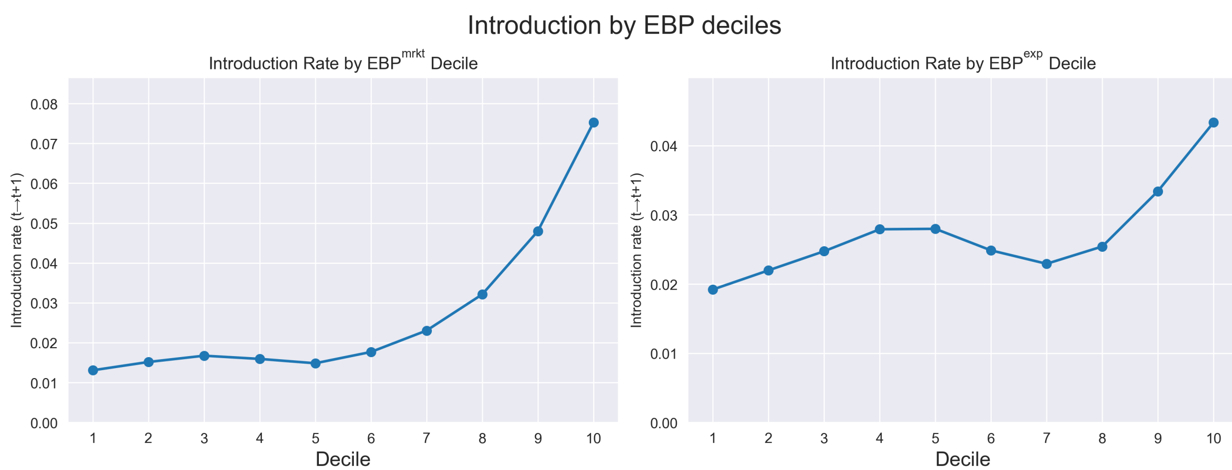


Figure 2: Mean introduction rate from t to $t+1$ by deciles of Export Basket Proximity.

To quantify the relationship, we estimate a linear probability model as following:

$$\text{Introduction}_{fpdt+1} \;=\; \beta\, EBP_{fpdt} \;+\; \gamma_{ft} \;+\; \theta_{pt} \;+\; \varepsilon_{fpdt}, \tag{4}$$

where γ_{ft} are firm–year fixed effects and θ_{pt} are product–year fixed effects. Standard errors are clustered at the firm–destination level. All proximity indices are constructed in a leave–one–out fashion at the firm level: when computing the destination–year co-specialization matrix $\varphi_{ij,dt}$ and the corresponding EBP_{fpdt} for firm f, we exclude f's observations from the (d, t) counts. This ensures that the measure is not mechanically correlated with the firm's own outcome.

The results are reported in columns (1) and (2) of Table 2. Both specifications indicate that EBP is a strong predictor of subsequent product entry. Quantitatively, a 0.1 increase in EBP raises the probability of introduction by about 3.1 percentage points, while the weighted version, EBP^w, implies an effect of 2.9 percentage points.

While these baseline results highlight the predictive role of EBP, the measure is constructed from realized export outcomes and may therefore reflect a range of factors beyond intrinsic product similarity, such as market demand conditions or firm-specific strategies. To separate these channels, we complement EBP with two additional measures that are independent of observed outcomes: HS Proximity (HSP), which captures classification-based similarity from the Harmonized System, and Input–Output Proximity (IOP), which reflects technological relatedness through production linkages. Including these measures allows us to assess whether the predictive power of EBP remains once broader taxonomy- and technology-based connections are accounted for. In this way, any residual explanatory power of EBP can be interpreted as evidence of market-specific complementarities that are not captured by product classification or technology alone.

HS Proximity (HSP). HSP measures similarity between products based on the hierarchical structure of Harmonized System (HS) codes. The objective is to capture how close two products are in classification space, in a way that respects the coding hierarchy: differences in the first two digits reflect broader distinctions than differences in later digits. The measure is continuous, bounded between zero and one.

Let c_1 and c_2 denote two HS codes. We map each code into its integer representation V_1 and V_2, and compute similarity based on their normalized distance. To magnify small differences and spread the distribution of scores, we apply an n-th root transformation. The resulting HS-based similarity measure is

$$H_{ip}(c_1, c_2) = 1 - \left(\frac{|V_1 - V_2|}{V_{\max}} \right)^{1/n},$$

where $V_{\max}$ is the maximum possible integer value at the relevant digit length (e.g., 9999 for 4-digit HS codes) and n is the parameter that governs the curvature of the similarity function.[9] Firm–candidate HS proximity is then constructed by averaging this similarity over the firm's existing

[9] As a baseline, we set $n = 5$, but we find that this parameter choice does not significantly affect our main results.

basket,

$$HSP_{fpdt} = \frac{1}{|S_{fdt}|} \sum_{i \in S_{fdt}} H_{ip}.$$

This index summarizes how close a candidate product is to the firm's current exports in classification space.[10]

Input–Output Proximity (IOP). IOP captures technology-side relatedness between products, using input–output (I–O) linkages. The idea is that two products are proximate if they rely on similar bundles of intermediate inputs. Each product p is associated with an input vector u_p that summarizes the shares of different inputs used in its production, based on concordances between HS codes and I–O industries. For two products i and j, we then define their I–O proximity as the cosine similarity of their input vectors:

$$\varphi_{ij}^{IO} = \frac{u_i^\top u_j}{\|u_i\| \, \|u_j\|}, \qquad \varphi_{ij}^{IO} \in [0,1]. \tag{5}$$

Higher values of φ_{ij}^{IO} indicate that the two products require more similar bundles of intermediate inputs. Firm–candidate IOP is the average proximity between the candidate and the products in the firm's existing basket,

$$IOP_{fpdt} = \frac{1}{|S_{fdt}|} \sum_{i \in S_{fdt}} \varphi_{ip}^{IO}.$$

This index summarizes how similar the candidate product p is to the firm's existing export basket S_{fdt} in destination d at time t, based on the similarity of their underlying input requirements.

We then augment the specification to assess whether the predictive power of EBP persists after accounting for classification-based and technology-based proximity:

$$\text{Introduction}_{fpdt+1} \;=\; \beta\, EBP_{fpdt} \;+\; \delta\, HSP_{fpdt} \;+\; \kappa\, IOP_{fpdt} \;+\; \gamma_{ft} \;+\; \theta_{pt} \;+\; \varepsilon_{fpdt}. \tag{6}$$

Columns (3) and (4) add HSP and IOP as additional controls to baseline (1) and (2). The coefficients on EBP remain large and precisely estimated, though attenuated relative to the baseline: the effect of a 0.1 increase falls to about 2.8 percentage points for EBP and 2.6 percentage points for EBP^w. By comparison, the coefficients on HSP and IOP are positive but an

[10] For example, for HS4 codes, comparing 1111 vs. 1112 yields $H_{1111,1112} \approx 0.84$, while comparing 1111 vs. 1199 yields $H_{1111,1199} \approx 0.61$. The measure therefore assigns higher similarity scores to codes that are closer in numeric space, consistent with intuitive proximity.

Table 2: Product introduction regressions

	(1) EBP	(2) EBP^w	(3) EBP+HSP+IOP	(4) EBP^w+HSP+IOP
EBP	0.3104***	0.2904***	0.2765***	0.2610***
	(0.0017)	(0.0014)	(0.0017)	(0.0015)
HSP			0.0224***	0.0224***
			(0.0003)	(0.0003)
IOP			0.0055***	0.0052***
			(0.0002)	(0.0002)
Firm–year FE	Yes	Yes	Yes	Yes
Product–year FE	Yes	Yes	Yes	Yes
Observations	17,970,020	17,970,020	17,970,020	17,970,020
R^2	0.1247	0.1257	0.1254	0.1265

Notes: The dependent variable is $\mathbf{1}\{X_{fpdt} = 0,\ X_{fpd,t+1} > 0\}$. Columns (1)–(2) report regressions using market-based proximity indices; columns (3)–(4) add HS Proximity (HSP) and Input–Output Proximity (IOP). Standard errors clustered at the firm–destination level. *** $p < 0.01$.

order of magnitude smaller, with a 0.1 increase in HSP associated with only a 0.2–0.3 percentage point higher probability of entry, and IOP with about 0.06 percentage points.[11]

The stability and magnitude of the EBP effects relative to HSP and IOP indicate that outcome-based proximity encapsulates market-specific complementarities not captured by taxonomy or input similarity—paralleling the inter-market complementarities documented by Alfaro-Urena et al. (2024), but operating at the within-market, product-scope margin and motivating our modeling focus on basket-driven product scope decisions.

[11] A natural concern with outcome-based proximity is circularity. We implement two checks. First, a placebo shifts EBP randomly within destination–year cells (d, t), preserving the (d, t) distribution while breaking the firm–basket alignment. The shuffled regressor has a small positive coefficient, 0.0085 (s.e. 0.00077), which is statistically significant in this large sample but economically negligible: a 0.1 increase in EBP_{shuf} corresponds to 0.00085 in the introduction probability (0.085 pp), and the within R^2 is effectively zero. This indicates that unconditional (d, t) composition does not drive our baseline relationship.

Second, we orthogonalize EBP with respect to HSP and IOP (and the same firm–year and product–year fixed effects) and re-estimate the introduction equation using the residualized measure. For EBP, the residual coefficient is 0.2765 (s.e. 0.00171), implying 2.77 pp per 0.1 increase. Thus, the predictive content of EBP persists after removing variation correlated with classification- and technology-based proximity and the high-dimensional fixed effects. Together with the leave–one–out construction and t vs. $t+1$ timing, these checks reduce concerns that the estimates reflect circularity rather than market-specific complementarities in export baskets.

3 Baseline Model with Product Heterogeneity

In this section, we develop a dynamic general equilibrium model that incorporates both product and firm heterogeneity. The empirical section emphasized that exporters are more likely to add products to international markets when those products exhibit strong "proximity" to their current export basket. Here, we analyze the aggregate consequences of this behavior and examine the welfare implications that arise from these empirical patterns.

Consider discrete time with infinite horizon. There are two symmetric countries: Home (H) and Foreign (F). In each country, there is a representative consumer, a representative final-goods producer, and heterogeneous intermediate-goods producers. The overall set-up of this model is similar to previous literature, such as Alessandria and Choi (2007) and Alessandria et al. (2021), but we extend their framework to include product heterogeneity through consumer preferences as in Bernard et al. (2010).

The representative household in each country derives utility from a final non-traded consumption good. They also decide how much to invest in capital and bonds. Households purchase a one-period nominal bond, denominated in units of the home-country final good, that pays one unit of the final good in the next period. A representative final-goods producer purchases different products from intermediate goods producers in both countries, and each product is made up of differentiated intermediate inputs. The nontraded final good is used for household consumption, investment, and as materials.

Intermediate-goods firms, indexed by subscript i, produce products that are differentiated by characteristics. These characteristics are represented through the relative preferences of final-goods producers over different varieties and are denoted by ω, where ω follows a standard Pareto distribution with shape parameter γ.[12] In principle, firms could produce products with arbitrarily large values of ω, since the Pareto distribution is unbounded above. In practice, however, we approximate this continuous distribution with a finite grid of discrete points, which imposes a natural upper bound on ω. As a result, ω lies within a firm-specific range $[\underline{\omega}_i, \overline{\omega}_i]$.[13] The product range of intermediate-goods firms may depend on their productivity, generating

[12] Representing product heterogeneity through preferences is equivalent to modeling products through intermediate-goods firm-specific relative productivity differences.

[13] The choice of these bounds is discussed in the Supplementary Appendix. The main results are robust to alternative bound specifications.

heterogeneity in product spaces across firms within a given period or across different periods for the same firm.[14]

While the range of product space is exogenous, firms' export decisions are endogenous. Intermediate-goods producers' export decision is determined by a threshold, which we denote by $\tilde{\omega}$, that lies within $[\underline{\omega}_i, \overline{\omega}_i]$. The product space is discretized evenly from $\underline{\omega}$ to $\overline{\omega}$, and firms' export choices are constrained to lie on this grid if they choose to export. Thus, a firm's full potential export choices for $\tilde{\omega}$ are $[0, \underline{\omega}, \omega_2, ..., \overline{\omega}]$. If a firm's export choice is $\tilde{\omega}^*$, then the firm exports all products whose attributes are lower than this threshold, i.e., $\omega \leq \tilde{\omega}^*$. Depending on the export decision, they become non-exporter ($\tilde{\omega} = 0$), single product exporter ($\tilde{\omega} = \underline{\omega}$), or multiproduct exporter ($\tilde{\omega} > \underline{\omega}$). Therefore, intermediate-goods producers in each country are characterized by their productivity (z) and export history ($\tilde{\omega}$). Exporting requires paying fixed and variable costs that depends on product portfolio, which will be formally introduced later.

Our choice to model export decisions this way was deliberate. A key challenge in modeling heterogeneous firms with multiple export products is the dimensionality of export choices: with N potential products, firms would face 2^N possible export portfolio combinations, making the problem computationally intractable. By imposing a structure where products are ordered according to their relative preferences and firms choose an optimal threshold to determine their export range, we reduce the export choice space from 2^N to $N + 1$. This approach makes the model computationally feasible while preserving the essential features of firms' export decisions.

For consistency, we index firms with subscript i and products with subscript k. In this section, we only present the equations related to the home country, but foreign country's problems are analogous. Variables chosen in the foreign country are denoted with an asterisk. Finally, firms face an exogenous industry exit rate which is dependent on their productivity, denoted by $E(z)$.

3.1 Representative Household and Final-Goods Producers

The representative household in each country derives utility from the consumption of a final good, denoted by C_t. Households maximize the expected utility of the form

$$U = \mathbb{E}_t \left[\sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma} \right], \tag{7}$$

[14]In our baseline case, we assume that firms' productivity and product spaces are independent, though we later relax this assumption and show that our main results continue to hold.

where β is the discount factor between 0 and 1, and σ denotes the parameter that relates to the household's risk aversion. The budget constraint for the household can be written as

$$P_t[C_t + K_{t+1}] + Q_t B_{t+1} = W_t \bar{L} + R_t K_t + (1-\delta) P_t K_t + B_t + \Pi_t + T_t, \tag{8}$$

where K_t and B_t denote the capital stock and bond holdings at time t. δ is the depreciation rate of capital. P_t, W_t, R_t, and Q_t are the price of the final good, wage rates, rental rates, and the price of one-period bond, respectively. $\bar{L}$ is the total amount of labor supplied by households, which we normalize to 1. Finally, Π_t and T_t are the profits from home producers and the lump-sum transfer of tariff revenue, respectively.

The nontraded final good, D_t, is a combination of different products, each with its own varieties from both countries. This can be expressed as follows:

$$D_t^{\frac{\epsilon-1}{\epsilon}} = \left(\int\int (\omega_{ki} y_{Hkit})^{\frac{\epsilon-1}{\epsilon}} dkdi + \int\int (\omega_{ki} y_{Fkit})^{\frac{\epsilon-1}{\epsilon}} dk^* di^* \right), \tag{9}$$

where, with a slight abuse of notations, $di(di^*)$ represents the distribution of Home(Foreign) producers, and ϵ is the elasticity among intermediate goods of product k. ω_{ki} is the demand parameter that determines the household's relative demand for the varieties of different firms within each product. y_{Hkit} and y_{Fkit} are the amounts of intermediate goods from firm i/i^* to produce final good k/k^* in the Home/Foreign countries.

The final-goods market is perfectly competitive. Given the price of home and foreign intermediate goods, P_{Hkit} and P_{Fkit}, the profit maximization problem for the final goods producers can be written as

$$\max_{y_{Hkit}, y_{Fkit}} \left\{ P_t D_t - \int\int P_{Hkit} y_{HKit} dkdi - \int\int (1+\tau_k) P_{Fkit} y_{FKit} dk^* di^* \right\}, \tag{10}$$

where $\tau_k \geq 0$ is the tariff rate imposed by the government for product k. Solving for the demand equation yields

$$y_{Hikt} = \left(\frac{1}{\omega_{ki}}\right)^{1-\epsilon} \left(\frac{P_{Hkit}}{P_t}\right)^{-\epsilon} D_t, \qquad y_{Fikt} = \left(\frac{1}{\omega_{ki}}\right)^{1-\epsilon} \left(\frac{(1+\tau_k)P_{Fkit}}{P_t}\right)^{-\epsilon} D_t. \tag{11}$$

The natural CES price index that follows from the optimization problem is

$$P_t^{1-\epsilon} = \left(\int\int \left(\frac{P_{Hkit}}{\omega_{ki}}\right)^{1-\epsilon} didk \right) + \left(\int\int \left(\frac{(1+\tau_k)P_{Fkit}}{\omega_{ki}}\right)^{1-\epsilon} di^* dk^* \right). \tag{12}$$

We set the final goods price as numeraire, which implies that $P_t = P_t^* = 1$.

3.2 Intermediate-Goods Producers

Intermediate-goods firms produce all products using capital, k, labor, n, and materials, m, according to a Cobb-Douglas production function at the firm-level.

$$y_{it} = z_{it}(k_{it}^{\alpha} n_{it}^{1-\alpha})^{(1-\alpha_m)} m_{it}^{\alpha_m}, \tag{13}$$

where $\alpha(1-\alpha_m)$ is the capital share, α_m is the materials share, and z_{it} is the firm-specific productivity that follows AR(1) process in logs. Intermediate-goods producers are differentiated by their productivity, z_{it}, which is persistent and stochastic, and their past export history. All intermediate-goods producers manufacture the full range of products and their decision to export is selective.

Firms' export participation varies depending on their productivity level, which not only determines export or not but also determines the subset of products they choose to export. In other words, a firm's productivity dictates the proportion of the product space, ω_i, that it will export. More productive firms will export a larger share of their product range, while less productive firms will export a smaller share or may not export at all.

The firm is subject to the feasibility constraint, which says that the total amount of output produced by the firm i equals the total amount of output produced for both home and foreign markets across the product space.

$$y_{it} = \int_{\underline{\omega}_i}^{\overline{\omega}_i} (y_{Hikt} + y^*_{Hikt}) dk, \tag{14}$$

We further assume that CES demands from final-goods producers are fully satisfied at the product level. Thus, given a firm's export choice, $\tilde{\omega}_i$, and the level of productivity, z_i, the profit maximization problem of intermediate-goods producers can be written as

$$\pi_{it} = \max_{P_{Hikt}, P^*_{Hikt}, k_{it}, n_{it}, m_{it}} \left\{ \int_{\underline{\omega}_i}^{\overline{\omega}_i} P_{Hikt} y_{Hikt} dk + \int_{\underline{\omega}_i}^{\tilde{\omega}_i} P^*_{Hikt} y^*_{Hikt} dk - W_t n_{it} - (R_t + \delta) k_{it} - P_t m_{it}, \right\}, \tag{15}$$

$$\text{subject to} \quad y_{Hikt} = \left(\frac{1}{\omega_{ki}}\right)^{1-\epsilon} \left(\frac{P_{Hkit}}{P_t}\right)^{-\epsilon} D_t, \quad y^*_{Hikt} = \left(\frac{1}{\omega_{ki}}\right)^{1-\epsilon} \left(\frac{P^*_{Hkit}}{P^*_t}\right)^{-\epsilon} D^*_t, \tag{16}$$

$$z_{it}(k_{it}^{\alpha} n_{it}^{1-\alpha})^{(1-\alpha_m)} m_{it}^{\alpha_m} = \int_{\underline{\omega}_i}^{\overline{\omega}_i} (y_{Hikt} + y^*_{Hikt}) dk. \tag{17}$$

Plugging in the first two constraints for y_{Hkit}, y_{Fkit} to the objective functions and assigning MC_{it} as the Lagrange multiplier to the third constraint above, we can find that the firm's pricing decisions are equal across products and charge a constant markup over the marginal cost for each product.

$$P_{Hikt} = P^*_{Hikt} = \frac{\epsilon}{\epsilon - 1} MC_{it}. \tag{18}$$

Next, we discuss the costs associated with exporting. For a firm's export decision in the next period to take effect, they must pay the relevant fixed costs of exporting in the current period. The total cost of exporting is the sum of two components: the cost related to the firm's export choice in the previous period and the additional export costs incurred if the firm decides to add products to their export portfolio. Given the past export history, $\tilde{\omega}$, and the export choice in the next period, $\tilde{\omega}'$, the cost of exporting can be written as

$$f(\tilde{\omega}, \tilde{\omega}') = \gamma_0 (\tilde{\omega}')^{\gamma_1} + \gamma_2 \max \left\{ 0, (\tilde{\omega}' - \tilde{\omega}) \right\}^{\gamma_3}, \tag{19}$$

where $\gamma_0, \gamma_1, \gamma_2$, and γ_3 are non-negative parameters related to the cost of exporting. The first term in the equation represents the continuation cost of exporting for the firm, which depends on the firm's export portfolio. The second term captures the cost associated with the introduction of a set of new products.

Our export cost function is a generalization of the approach used in several single-product models in the literature, such as the one formulated in Ruhl and Willis (2017). If we suppose that ω can only take a single value to collapse the case into one without multiproduct exporting firms, $\underline{\omega} = \overline{\omega} = 1$, then the possible export history can be reduced to $\tilde{\omega} \in \{0, 1\}$. In this case, the sunk cost formulation collapses to

$$f(\tilde{\omega}, \tilde{\omega}') = \gamma_0 I(\tilde{\omega}' = 1) + \gamma_2 \max\{0, (\tilde{\omega}' - \tilde{\omega})\}, \tag{20}$$

where $I(.)$ is an indicator function. In this case, $\gamma_0 + \gamma_2$ is the cost of newly entering the export market, and γ_0 is the continuation cost of exporting. Then, γ_2 is the one-time sunk cost of exporting.

Going back to the general case, the dynamic programming problem for an intermediate-goods producer with a state variable $s = (z, \tilde{\omega})$ can be written as

$$V(s) = \max_{\tilde{\omega}'} \left\{ \Pi(s) - W f(\tilde{\omega}, \tilde{\omega}') + (1 - E(z)) Q \mathbb{E} \left[V(s'|s) \right] \right\}. \tag{21}$$

As denoted before, in practice, we discretize the product space, $\omega(s) = [\underline{\omega}(s), \ldots, \overline{\omega}(s)]$. Furthermore, we constrain the export choice to lie on the discretized product grid if a firm chooses to export. Firms that choose not to export any products implies that $\tilde{\omega} = 0$. Consider a current non-exporter of a firm with some productivity level, $\bar{z}$. This firm decides to export one or more products if the following inequality holds:

$$f(0, \tilde{\omega}') < (1 - E(z))Q(\mathbb{E}\left[V((\tilde{\omega}', z')|(0, \bar{z}))\right] - \mathbb{E}\left[V((0, z')|(0, \bar{z}))\right]), \tag{22}$$

for any $\tilde{\omega}' > 0$. The left-hand side of the inequality is the cost of exporting next period that is paid the current period. The right-hand side of the inequality is the discounted expected gains from exporting compared to continuing not to export. Thus, the firm becomes a new exporter if the discounted expected benefit is greater than the export cost.

3.3 Government, Free Entry and Market Clearing Conditions

The government collects tariffs and redistributes them back to households in a lump sum fashion. The government budget constraint is

$$T_t = \int \int \tau_k P_{Fkit} y_{Fkit} di^* dk^*. \tag{23}$$

New establishments enter by paying an entry cost of γ_E units of labor in the period prior to production. They enter as non-exporters, and their productivity is drawn from an entrant-specific distribution, $G(z)$. The free-entry condition is

$$V_t^E = -W_t \gamma_E + Q_t \int_{z'} V_{t+1}(0, z') dG(z') \leq 0. \tag{24}$$

We denote the mass of entrants at time t as $N_{E,t}$ and the mass of incumbents as $N_t = \int di$. In equilibrium, labor, capital, and bond markets clear.

$$\int n_{it} di + F_t + N_{E,t}\gamma_E = \bar{L}, \qquad \int k_{it} di = K_t, \qquad B_{t+1} + B^*_{t+1} = 0, \tag{25}$$

where $F_t = \int \int f(\tilde{\omega}, \tilde{\omega}') dk di$ is the aggregate value of fixed export cost paid by intermediate-goods producers in terms of labor. Finally, combining the household budget constraint, final-goods producer profit, and intermediate-goods producer profit equations, we arrive at the final-goods market clearing condition.

$$C_t + I_t + M_t = D_t, \tag{26}$$

where $I_t = K_{t+1} - (1-\delta)K_t$ is the aggregate investment and $M_t = \int m_{it} di$ is the aggregate materials demand.

Let Λ_t be the distribution of firms over its idiosyncratic state variables at time t in the home country. We now formally define the equilibrium of our model economy. Given initial conditions $\{K_0, B_0, K_0^*, B_0^*, \Lambda_0, \Lambda_0^*\}$, and a deterministic path of tariffs, $\{\tau_{kt}, \tau_{kt}^*\}$, an equilibrium for this economy is given by sequences from $t = 0, 1, ..., \infty$ of: household choices, $\{C_t, B_{t+1}, K_{t+1}, L_t, C_t^*, B_{t+1}^*, K_{t+1}^*, L_t^*\}$, final-goods producers' decisions, $\{D_t, y_{Hkit}, y_{Fkit}, D_t^*, y_{Hkit}^*, y_{Fkit}^*\}$, decisions by intermediate-goods producers, $\{P_{Hkit}, P_{Fkit}, k_{it}, n_{it}, m_{it}\}$, mass of entrants, $\{N_{E,t}, N_{E,t}^*\}$, government transfers, $\{T_t, T_t^*\}$, real wages and rental rates, $\{W_t, R_t, W_t^*, R_t^*\}$, bond prices, $\{Q_t, Q_t^*\}$, and the distributions of firms, $\{\Lambda_t, \Lambda_t^*\}$, such that the following conditions hold:

1. Households maximize their lifetime utility by choosing consumption, bond, capital, and labor choices given prices;

2. Final-goods producers' allocations solve their profit-maximization problems;

3. Intermediate-goods producers' input choices, prices, and export decisions maximize their value functions given final goods demands and factor prices;

4. Government budget constraint is satisfied;

5. Labor market, capital market, bond market, and goods market clear;

6. The free-entry condition holds;

7. Aggregate law of motion is generated by export decisions of intermediate-goods producers.

As is standard in models with heterogeneous firms that study trade liberalizations, when $\tau_{kt} = \tau_k$ for all k, the model converges to a stationary equilibrium in which the aggregate quantities, the distribution of firms, and prices are constant. We first study the firm-level dynamics in the stationary equilibrium. Next, we study the aggregate impact from varying tariff rates. Details on methods used to solve both the stationary equilibrium and transition dynamics are provided in the Supplementary Appendix.

Table 3: **Externally Calibrated Parameters**

Parameter	Description	Value
Group 1 - Standard/Baseline Values		
σ	Risk aversion	2
ϵ	Elasticity of substitution	5
β	Discount factor	0.95
δ	Capital depreciation rate	0.08
γ_E	Entry cost	0.26
$\tau = \tau_k$	Tariff rate	0.10
Group 2 - Externally Estimated from Data		
ρ_z	Persistence of firm productivity	0.77
σ_e	Std. dev. of firm innovation	0.21
$\alpha(1-\alpha_m)$	Capital share	0.05
α_m	Materials share	0.60

4 Calibration

We categorize the model parameters into three groups. The first group consists of parameters drawn from the literature or set as baseline values. The second group includes parameters estimated externally using Chinese manufacturing data from 2000-2007. The final group comprises of parameters that we estimate internally using the Method of Simulated Moments, matching key moments of product churning and exporter dynamics. Table 3 presents parameters from the first two groups. For standard parameters from the literature, we set the risk aversion parameter σ to 2 and the elasticity of substitution ϵ to 5. We choose a discount factor β of 0.95, implying a 5% annual interest rate in steady state. The annual capital depreciation rate δ is set to 8%. The entry cost parameter γ_E is normalized to set the mass of entrants equal to 1 in the initial stationary equilibrium. Finally, we set a uniform baseline tariff rate of 10% across all products.

The second half of Table 3 presents parameters estimated using the Chinese Manufacturing Survey from 2000 to 2007. We model firm productivity as an AR(1) process in logs:

$$\ln z_{t+1} = \rho_z \ln z_t + \sigma_e \varepsilon_{z,t+1}, \tag{27}$$

where ρ_z is the persistence parameter, σ_e is the standard deviation of innovations, and ε_z follows a standard Normal distribution. We estimate factor shares and firm-level productivity following the production function estimation literature. The capital coefficient, α, and materials share, α_m, are estimated to be 0.13 and 0.60, respectively. This implies that the capital share, $\alpha(1-\alpha_m)$, is 0.05. We also estimate the persistence of firm-level productivity and the standard deviation of its innovation terms. We estimate ρ_z to be 0.77 and σ_e to be 0.21. Details on parameter estimations can be found in the Supplementary Appendix.

Table 4: **Group 3 - Internally Calibrated Parameters**

Parameter	Description	Standard	NPG
μ_E	Entrant distribution parameter	0.11	0.11*
ξ	Industry exit parameter	2.19	2.19*
γ	Pareto shape parameter	3.65	3.65*
γ_0	Fixed cost parameter 1	0.003	0.002
γ_1	Fixed cost parameter 2	2.23	3.46
γ_2	Fixed cost parameter 3	0.003	0.004
γ_3	Fixed cost parameter 4	4.85	-

Note: This table lists parameter values that are chosen to match the moments in Table 5. Standard refers to the model with proximity gains. NPG refers to an alternative model without proximity gains. Asterisks denote parameters that are not re-estimated in the alternative model.

The remaining parameters are internally calibrated to match key firm statistics with multi-product decisions and industry/exporter dynamics at the micro-level. Unless stated otherwise, we calibrate our model using time-averaged moments from the Chinese customs data and the Chinese Manufacturing Survey. There are seven parameters to estimate: the entrant distribution parameter (μ_E), the exogenous industry exit rate parameter (ξ), the tail parameter of product attributes (γ), and four parameters governing export costs (γ_0, γ_1, γ_2, γ_3). These parameters are jointly calibrated to match seven key moments: 1.) productivity gap between incumbents and entrants, 2.) long-run industry survival rates, 3.) the product addition rate (probability of MP firms adding new export products), 4.) the product drop rate (probability of MP firms discontinuing export products), 5.) exporter share in the economy, 6.) The long-run exporter survival rate, and 7.) the proportion of single-product firms among exporters.

While all parameters jointly affect all targeted moments, it is useful to highlight which parameters primarily govern specific outcomes. The mean shift parameter of the entrant productivity distribution, μ_E, is chosen to match the productivity gap between incumbents and entrants. The exogenous exit parameter, ξ, is calibrated to match long-run industry survival rates. The scale parameter of continuation costs, γ_0, is disciplined by the long-run exporter share in the economy, while the continuation cost exponent, γ_1, targets the share of single-product exporters. The sunk cost coefficient, γ_2, is used to match the long-run exporter survival rate. Finally, the Pareto shape parameter and the exponent on the sunk cost, γ and γ_3, are jointly disciplined by product churning rates, which provide two independent moments.

Let θ be a vector of parameters $[\mu_E, \xi, \gamma, \gamma_0, \gamma_1, \gamma_2, \gamma_3]$ and $M(\theta)$ be the vector of moments. We minimize the following objective function:

$$F(\theta) = (M^{data} - M^{model}(\theta))^T (M^{data} - M^{model}(\theta)). \tag{28}$$

The third column of Table 4 lists the estimated parameters. Entrants draw their initial productivity (ε_E) from the unconditional productivity distribution of incumbents $(\ln z)$, but shifted to the left by μ_E, i.e., $\varepsilon_E = \ln z - \mu_E$, where ε_E follows the distribution $G(z)$. The productivity gap between incumbents and entrants are estimated to be around 10% in the data and μ_E is estimated to be 0.11. For the exogenous industry exit rate, we assume that the exit rate is declining in productivity following a logit functional form. That is,

$$E(z) = \frac{1}{1 + \exp(\xi z)}, \tag{29}$$

where ξ governs the relationship between productivity and exit probability, which is around 11% in the data. We estimate ξ to be 2.19. The tail parameter of product characteristics, γ, is estimated to be 3.65. For the export cost function, the scale parameters (γ_0, γ_2) are of similar magnitude, both around 0.003, while the power parameters (γ_1, γ_3) are estimated at 2.23 and 4.85, respectively. These estimates imply that total export costs amount to about 44% of total export profits in the model, a substantial burden for exporters. This parameterization of the export cost function generates a key feature of our model: multiproduct exporters face lower sunk costs when introducing new products that share proximity with their existing export portfolio. This result is consistent with Qiu and Zhou (2013), which showed, using a theoretical framework, that a necessary and sufficient condition for scope expansion is that the fixed cost of introducing a new product increases rapidly with the firm's product scope.

In our model, optimal product expansions operate through export costs. To quantify the gains from accounting for product proximity, we examine a no-proximity gains (NPG) case by changing the export cost function. The alternative can be written as:

$$f(\tilde{\omega}, \tilde{\omega}') = \gamma_0 (\tilde{\omega}')^{\gamma_1} + \gamma_2 \mathbb{1}(\tilde{\omega}' > \tilde{\omega}). \tag{30}$$

In this specification, the firm pays a constant fixed cost, γ_2, to expand its portfolio regardless of its previous export status. We re-estimate γ_0, γ_1, and γ_2 to match the share of exporters, share of single-product exporters, and exporter survival rate, respectively. Estimated parameters are

Table 5: **Calibration Results**

Targeted moments	Data	Standard	NPG
Entrant/incumbent prod. difference	0.10	0.10	0.10
Industry survival rate	0.89	0.89	0.89
Product drop rate	0.31	0.31	–
Product stasis rate	0.30	0.30	–
Product add rate	0.39	0.39	–
Share of exporters	0.32	0.32	0.32
Exporter survival rate	0.85	0.85	0.85
Share of single-product exporters	0.45	0.45	0.45
Share of multi-product exporters	0.55	0.55	0.55
Untargeted Moment			
MPEF to MPEF	0.72	0.69	0.64
MPEF to SPEF	0.14	0.23	0.29
MPEF to NX	0.14	0.08	0.07

shown in the fourth column of Table 4. In the NPG case, removing gains from product proximity implies a higher coefficient for the export entry cost term. Quantitatively, γ_2 is 0.003 in the standard calibration while the parameter is 0.004 in the alternative calibration without accounting for proximity gains. Without the exponent (γ_3) in the entry cost, γ_2 requires a larger coefficient to match the observed empirical moments. Furthermore, the exponent of the continuation cost term, γ_1, is larger (3.46 in the NPG case vs. 2.23 in the Standard case), while its coefficient, γ_0, is smaller (0.002 vs. 0.003). Finally, we only re-estimate parameters related to the fixed cost without influencing other aspects of the model, as these are the only parameters affecting product proximity gains. As μ_E and ξ depend only on the firm-level productivity, these parameters are set to the same value as in the standard case. We also fix the value of γ because changing it would alter the product space, which would affect our comparative analysis. By maintaining a consistent product space, we ensure a methodologically sound comparison that isolates the aggregate effects of accounting for gains from product proximity.

Table 5 compares model-generated moments with their empirical counterparts. The model matches all targeted moments precisely. In the data, product portfolio dynamics show distinct patterns: 30% of surviving multiproduct firms maintain stable export portfolios (stasis rate), whereas 39% of firms add products and the other 31% remove products (drop rate). The extensive margin of trade is characterized by a 32% export participation rate, with 55% of the firms exporting multiple products and 45% exporting a single product. The model also matches the high persistence in export status, with an 85% long-run survival rate in the export market. Similarly, the model exactly matches the targeted moments in the NPG case.

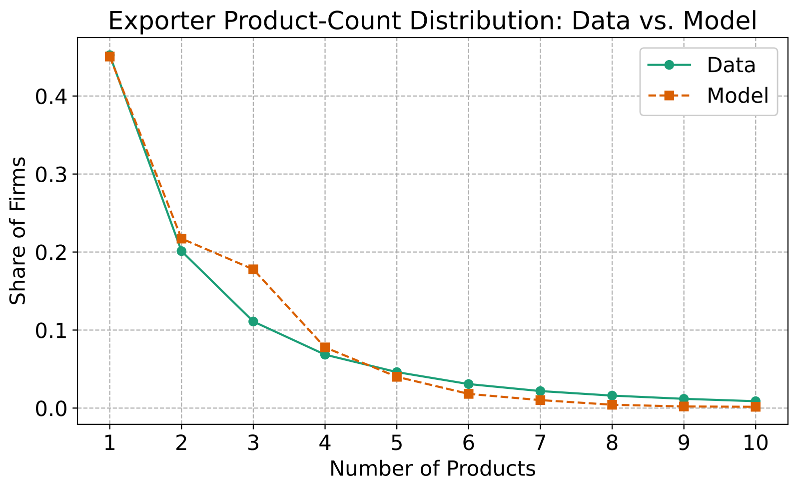


Figure 3: Product Count Distribution: Data vs. Model

We externally validate the model along three dimensions not targeted in calibration. First, we show that multi-product exporters in the model display high persistence comparable to that observed in the data. Second, we find that the product-count distribution from the model closely matches the distribution observed in the data. Finally, we replicate our empirical regression using a model-based Export Basket Proximity (EBP) and recover similar estimates.

The second panel of Table 5 compares the transition probabilities of multiproduct exporters. The model aligns reasonably well with the data along the untargeted dimension. In the data, 72% of multiproduct exporters retain their multiproduct status in the following year, while 14% switch to single-product exporters and another 14% exit the export market altogether. In the baseline calibration, the model reproduces strong persistence, though slightly below the data. Specifically, 69% of firms remain multiproduct exporters, while 23% transition to single-product exporters and 8% exit. In the NPG case, the share of multiproduct exporting firms (MPEFs) that switch to single-product exporting firms (SPEFs) is higher than in both the baseline calibration and the data. At the same time, the persistence of remaining as an MPEF is understated to an even greater degree than in the baseline calibration.

Next, we examine whether the model replicates the cross-sectional distribution of product counts. Figure 3 compares the distribution of exporters by the number of products exported, from 1 to 10. The model reproduces the data remarkably well in this dimension. By construction, the share of single-product exporters is matched exactly. More importantly, the model also closely captures the distribution among multi-product exporters, especially in the lower half of the distribution. However, the model does have some limitations. For example, the data show a thicker right tail compared to the model, and the model overstates the share of firms that export 3 products relative to the data. Despite these discrepancies, the model still successfully reproduces both the prevalence of multi-product firms and the skewed distribution of the exporter product-count distribution.

To validate our theoretical framework, we construct a model-based Export Basket Proximity (EBP) and demonstrate its consistency with our empirical findings. In our model, product proximity is captured by the distance between a firm's current export threshold, $\tilde{\omega}_{it}$, and a candidate's product's position, ω_k, in the product space. The model-based EBP for a firm i and a candidate product k is defined as:

$$EBP_{ikt} = 1 - \max\left(0, \frac{\omega_k - \tilde{\omega}_{it}}{\overline{\omega} - \underline{\omega}}\right). \tag{31}$$

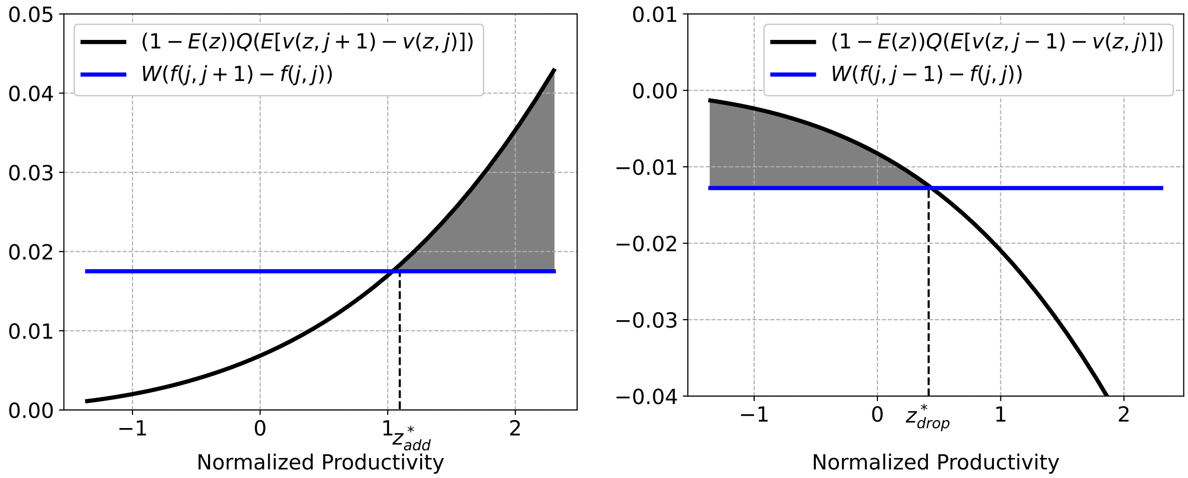
This index ranges from 0 to 1, where higher values indicate greater proximity between the candidate product and the firm's existing export portfolio. New products closer to the firm's existing portfolio generate lower fixed export costs, creating cost advantages for related product expansion. Among our empirical measures, EBP^{mrkt} most closely aligns with this theoretical definition as it focuses on a firm's export introduction behavior within a particular market. We validate this measure by running the same regression specification as our empirical analysis.

Table 6 compares the regression results using empirical versus model-generated data. The model successfully replicates the core empirical relationship: a 0.1 increase in the EBP raises the probability of product introduction by approximately 3 pp. in the model, closely matching the 3.1 pp. effect found in the data. This validates that our theoretical mechanism accurately captures the role of product proximity in firms' export decisions.

Table 6: Model-Based EBP Validation

	Data	Model
EBP Coefficient (β)	0.3104***	0.2997***
	(0.0017)	(0.0534)
Firm–year FE	Yes	Yes
Product–year FE	Yes	Yes
R^2	0.1254	0.5970

Notes: This table compares regression results from the empirical EBP analysis (Data column) with results from the same regression run on model-generated data (Model column). The regression specification is $Introduction_{ikt} = \beta EBP_{ikt} + \gamma_{it} + \theta_{kt} + \varepsilon_{ikt}$. Standard errors in parentheses. *** p<0.01.



(a) Identifying Add Region

(b) Identifying Drop Region

Figure 4: Firm-level Decisions

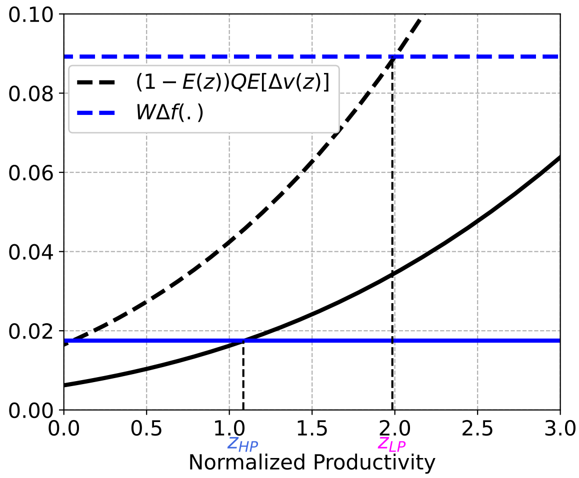
5 Firm-level Decisions and Dynamics

Having calibrated the model to match exporter and industry dynamics, we now characterize firm-level decisions and examine the gains from product proximity. Unlike standard binary export models, firms in our framework choose between expanding, shrinking, or maintaining their current export portfolio. Suppose that an exporter is deciding whether to keep its current export portfolio or choose a new portfolio, $\tilde{\omega}'$. We can identify the productivity threshold at which firms optimally chooses the new export portfolio. This threshold is determined by the productivity level z that satisfies:

$$W[f(\tilde{\omega}, \tilde{\omega}') - f(\tilde{\omega}, \tilde{\omega})] = (1 - E(z))Q\mathbb{E}[v(z', \tilde{\omega}') - v(z', \tilde{\omega})|(z, \tilde{\omega})] \tag{32}$$

At this threshold, the change in the export cost from expanding/dropping products (left-hand side) equals the discounted expected changes in profits from export expansion/reduction (right-hand side). Figure 4 illustrates these decision rules for a particular multiproduct exporter, showing how productivity levels determine optimal export choices.

In both panels of Figure 4, the blue line represents the difference in fixed costs between maintaining the current portfolio and either adding a product (left panel) or dropping a product (right panel). The black line shows the corresponding difference in discounted expected value - the potential gains from adding a product (left panel) or losses from dropping a product (right



(a) Standard

(b) No Gains from Proximity

Figure 5: Productivity Thresholds

panel). The intersection of these lines defines productivity thresholds that characterize optimal firm behavior.

Firms expand their export portfolio when their productivity z exceeds z^*_{add}, and contract their portfolio when productivity falls below z^*_{drop}. Between these thresholds ($z \in [z^*_{drop}, z^*_{add}]$), firms maintain their current portfolio, creating a region of inaction. Quantitatively, we find that the threshold for adding products (z^*_{add}) lies slightly above a standard deviation from the mean of the normalized productivity, while the threshold for dropping products (z^*_{drop}) lies below 0.5 standard deviation from the mean of the normalized productivity.

Having characterized firms' decision rules and export costs, we now examine how gains from product proximities benefit exporters through export cost reductions. Suppose an exporter is deciding whether to expand to a new product set with either high proximity, $\tilde{\omega}^{HP}$, or low proximity $\tilde{\omega}^{LP}$ to its current export portfolio, $\tilde{\omega}$. This would imply that $\tilde{\omega}^{HP} < \tilde{\omega}^{LP}$.

Figure 5a illustrates the changes in export costs (blue lines) and discounted expected benefits (black lines) for two different potential portfolios while holding the current portfolio fixed. From eq. 32, we can identify two different productivity thresholds, denoted by z^{HP} and z^{LP} respectively, that correspond to these two potential choices. Similar to the last figure, these thresholds occur at the points where the black and blue lines intersect. The dashed line represents the case of low product proximity between the current and the potential portfolios, where the difference, $\tilde{\omega}^{LP} - \tilde{\omega}$ is high. In this scenario, firms need a relatively high productivity threshold (z_{LP})—approximately

2 standard deviations above the mean-to justify expanding their export portfolio to the desired level.

In contrast, the solid lines show the case where the desired export portfolio exhibits high proximity between the current and the desired product portfolios, which implies a lower value of $\tilde{\omega}^{HP} - \tilde{\omega}$. The intersection of expected benefits (black line) and costs (blue line) occurs at a lower productivity threshold (z_{HP}). This lower threshold emerges from two effects: while the potential profit gains are somewhat reduced due to the smaller scope of expansion, the significantly lower export costs associated with introducing exporting similar products more than compensate, making portfolio expansion optimal at lower productivity levels. Quantitatively, we find that z_{HP} is approximately one standard deviation lower than z_{LP}, demonstrating that close product proximity substantially reduces the productivity threshold required for export expansion.

Figure 5b illustrates productivity thresholds in the NPG model, where firms face uniform per-product sunk export costs regardless of proximity to their existing portfolio. Without proximity advantages, the productivity thresholds for high and low proximity scenarios are much closer. The threshold z_{HP} rises to approximately 1.6 standard deviations above the mean, while z_{LP} reaches about 1.8 standard deviations above the mean. This convergence occurs because firms can no longer leverage proximity-based cost reductions when adding new products. While some cost differences remain due to continuation costs (since $\tilde{\omega}^{HP} < \tilde{\omega}^{LP}$), the elimination of proximity advantages means the potential profit gains from expansion no longer justify the export costs for most firms. Consequently, only highly productive firms find portfolio expansion profitable, raising the productivity thresholds required for export decisions. In the subsequent section, we demonstrate that the absence of proximity gains at the firm-level translate into the reduced aggregate welfare gains.

Additional Model Implications

Ruhl and Willis (2017) document that new exporters exhibit distinct dynamics compared to continuing exporters. A key empirical pattern is that both survival probability and export intensity start low but gradually increase the longer firms remain in the export market. Figure 6 illustrates two key patterns: the evolution of survival probability and export intensity for new exporters.

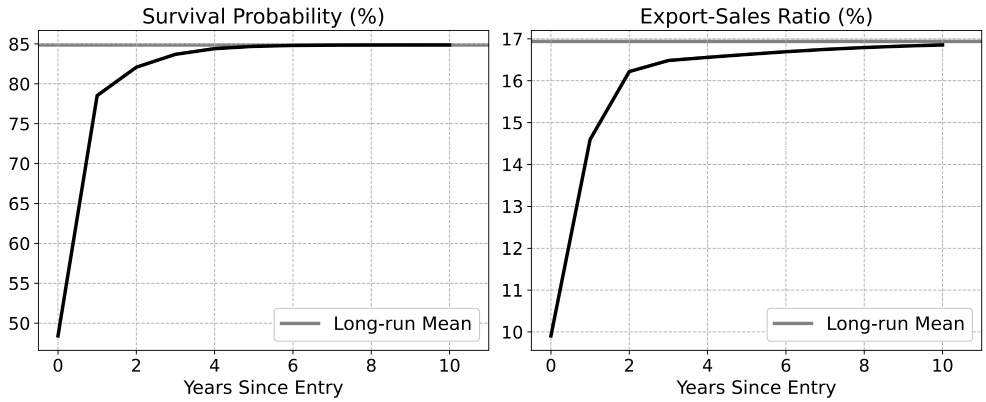


Figure 6: New Exporter Dynamics: Model

Our model successfully captures both patterns. Survival probability starts below 50% when new exporters enter and gradually increases to 85% after 5 or 6 years, eventually converging to the long-run mean. Similarly, export intensity, measured by the export-sales ratio, rises from approximately 10% when firms enter the exporter market to 17% after eight years.

The model's ability to generate rising export intensity without additional shocks is quite interesting. In a single-product framework, the export-sales ratio is given by:

$$\frac{exp_{it}}{sales_{it}} = \frac{P^*_{Hit}y^*_{Hit}}{P^*_{Hit}y^*_{Hit} + P_{Hit}y_{Hit}} = \frac{(1+\tau)^{-\epsilon}}{(1+(1+\tau)^{-\epsilon})}, \tag{33}$$

which yields a constant ratio across firms and time. In single-product models, additional heterogeneity is introduced through firm-level cost shocks, as in Alessandria et al. (2021). In contrast, our multi-product framework generates variable export intensity through the following relationship:

$$\frac{exp_{it}}{sales_{it}} = \frac{\int_{\underline{\omega}_i}^{\tilde{\omega}_i} P^*_{Hikt}y^*_{Hikt}dk}{\int_{\underline{\omega}_i}^{\tilde{\omega}_i} P^*_{Hikt}y^*_{Hikt}dk + \int_{\underline{\omega}_i}^{\overline{\omega}_i} P_{Hikt}y_{Hikt}dk}. \tag{34}$$

This ratio varies across firms and time as it depends on both the export history, $\tilde{\omega}_i$, and the product scope, $[\underline{\omega}_i, \overline{\omega}_i]$. As firms' productivity changes, they adjust their export scope, leading to changes in export intensity. This endogenous mechanism provides a novel explanation for new exporter dynamics, distinct from previous models that rely on dynamic sunk costs and exogenous shocks.

In our baseline calibration, export intensity grows exclusively through the extensive margin—firms expand their export activity by introducing new products rather than increasing export sales of existing products. This outcome is a direct consequence of our model's structure,

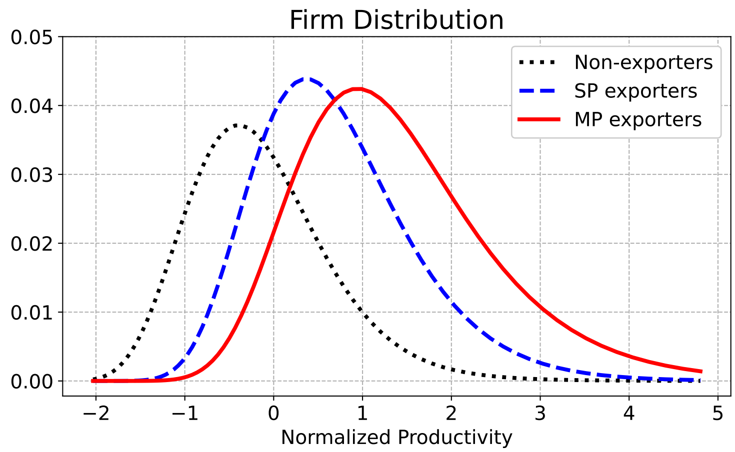


Figure 7: Stationary Distribution of Firms: Model

in which the demand for each product is independent and follows a standard CES formulation. As a result, the introduction of an additional exported product does not affect the demand for previously exported goods, eliminating the intensive margin as a channel for export intensity growth.

Regardless, our modeling of export costs reinforces the extensive-margin-driven mechanism. Since export costs are fixed rather than per-unit, firms optimize by adjusting the number of exported products rather than increasing the export volume of existing products. This is not a limitation but rather a distinguishing characteristic of our model. Traditional trade models, such as Melitz (2003), often assume firms adjust their export volumes at the intensive margin. By contrast, our framework provides a complementary mechanism where product proximity and export cost structures drive extensive-margin-based expansion. While models such as Fitzgerald et al. (2024) decompose export growth into intensive and extensive margins, our results highlight a distinct pathway through which firms expand their export activity.

Lastly, Figure 7 shows the model-implied stationary distribution of firm productivity across three types of firms: non-exporters, single-product exporters, and multi-product exporters. The productivity distribution of non-exporters is centered below zero, while single-product exporters are concentrated slightly above zero. Multi-product exporters exhibit both the highest mean productivity and the largest variance. This pattern emerges because more productive firms are better able to overcome export costs and sustain larger export portfolios, consistent with findings from Bernard et al. (2010) and Mayer et al. (2014).

6 Trade Policy Experiments

Having characterized the partial equilibrium decision rules, we now examine how these decisions impact aggregate variables following trade policy changes. We analyze both trade liberalizations and trade wars. While we focus on liberalization scenarios to align more closely with our empirical data, trade war scenarios remain of interest; thus, we present results for both types of trade policy changes. For liberalization, we reduce the average tariff rate by half from the baseline 10% to 5%, while for trade wars, we double the average tariff rate from 10% to 20%.

Our analysis reveals two key findings. First, the distribution of tariffs matters significantly, as targeted (non-uniform) tariff schedules magnify aggregate responses relative to uniform (flat) changes despite the same weighted average rate. Second, product proximity gains in export costs represent a key amplification mechanism, generating larger aggregate effects compared to models without proximity advantages.

6.1 Trade Liberalizations

We consider two scenarios of trade liberalization. First, we assume a uniform tariff reduction in which tariffs on all products decline by 5%. We refer to this as the *flat* case and use it as our baseline because it aligns with previous approaches in the trade literature that employ dynamic models to quantify gains from liberalization. In practice, however, trade liberalization rarely results in equal reductions across all products. To capture this dimension, we introduce an alternative scenario in which post-liberalization tariffs depend on pre-liberalization expenditure shares:

$$\tau_k^{post} = a \left(\frac{\bar{s}}{s_k} \right)^{\psi}, \tag{35}$$

where s_k is the pre-liberalization expenditure share of product k, and $\bar{s}$ is the upper bound of the resulting expenditure share across products. Parameter ψ controls the curvature of the tariff schedule with respect to the expenditure shares, and a is the coefficient that ensures the expenditure-weighted average of tariff rates remains at 5% post-liberalization. We refer to this as the *targeted* case.

Figure 8 illustrates the resulting post-reform tariff schedules as a function of expenditure shares. The solid blue line corresponds to the flat case, where all products face a uniform tariff reduction. The dashed orange and green lines correspond to the targeted cases, where

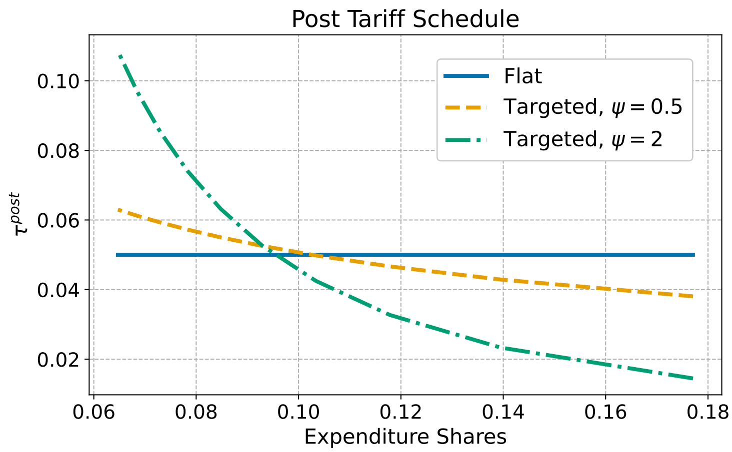


Figure 8: Post-liberalization tariff schedules under flat and targeted reductions.

post-reform tariff rates decline with expenditure shares to varying degrees, with ψ values of 0.5 and 2, respectively.

Given that expenditure shares in our model range from 6% to 18%, the targeted case with $\psi = 0.5$ yields tariff rates ranging from 6% down to 4%. For the steeper tariff schedule with $\psi = 2$, tariff rates range from higher than 10.5% down to 1%. While both targeted approaches maintain the same expenditure-weighted average tariff rate of 5% as the flat case, they create heterogeneous tariff reductions that favor products with larger expenditure shares. We view this as a more realistic representation of trade liberalization, since policymakers are more likely to prioritize tariff reductions on products that are widely consumed.

Figure 9 illustrates the dynamic responses of key aggregate variables to trade liberalization, expressed as percent deviations from pre-liberalization steady state values. Results from the uniform tariff reduction are shown as a solid blue line while the targeted tariff reduction case is plotted as a dashed orange line. In all cases, we assume that tariff reductions across all products are unexpected and occur simultaneously.

We first examine the uniform case where tariffs across all products decline by 5%. The long-run effects show notable gains: consumption increases by 1%, output by approximately 1.8%, and the capital stock by 2.5% after 30 years. Wages also rise by more than 2% as firms engage in more trade. The initial surge in consumption leads to a sharp increase in real interest rates as they are determined by the household's Euler equations. This temporarily depresses the stock of capital, though firms quickly resume capital accumulation as interest rates normalize. The transition paths exhibit substantial overshooting dynamics. Consumption peaks at 1.9%

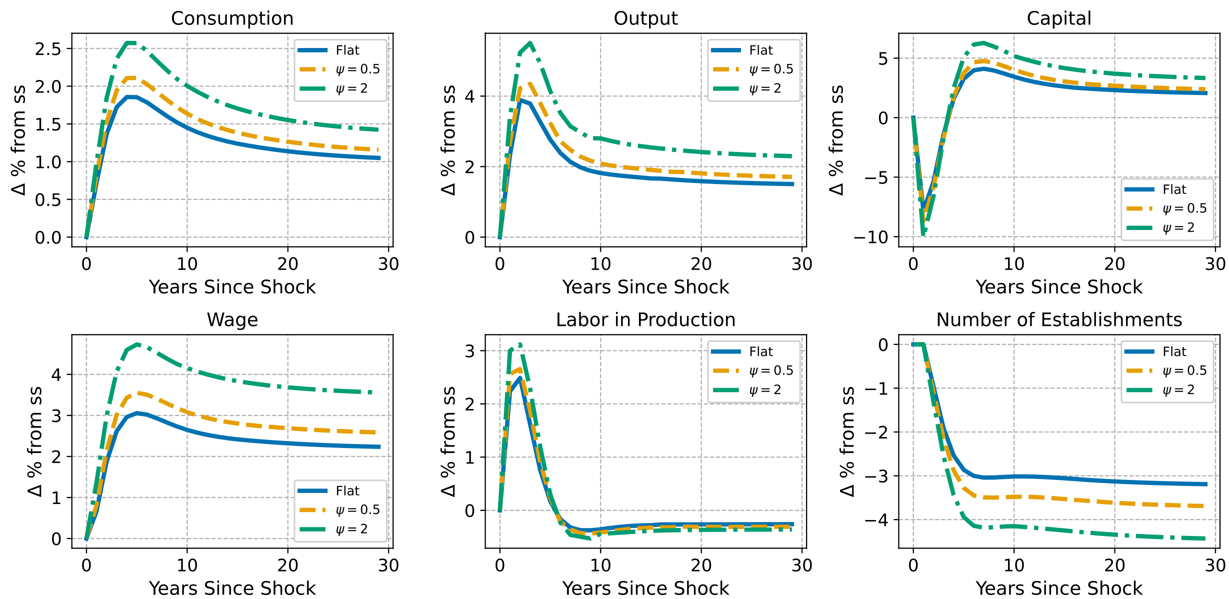


Figure 9: Trade Liberalization Dynamics - Aggregates

above steady state, output reaches almost 4%, and wages peak at nearly 3%. This overshooting is driven by industry dynamics during the adjustment period. Increased competition causes lower productivity firms to exit, reducing the number of establishments by 3%. The resulting labor market adjustments, as workers reallocate toward more productive firms, contribute to the pronounced overshooting in aggregate variables.

Targeted liberalization lowers tariffs more on high-expenditure products while cutting them less (or even raising them) on low-expenditure products. Simply changing the distribution of tariffs, while holding the average reduction fixed, amplifies aggregate effects. Quantitatively, when $\psi = 2$, long-run consumption is about 0.4 percentage points higher than under a uniform cut, and the peak is more than 0.5 points higher; long-run output rises by nearly 1%, with a peak almost 4% higher. Industry dynamics also strengthen: more firms operate, wages increase more, and production labor expands. Amplification occurs because targeting creates more marginal exporters willing to introduce high-expenditure products to international markets, which creates larger product expansions in the aggregate and results in greater gains from trade. These extensive margin expansions demonstrate the importance of tariff structures for aggregate outcomes.

Table 7 presents welfare gains from trade liberalization across various tariff schedules. In our standard calibrated model (shown in the first row), welfare gains that account for transition

Table 7: Welfare Gains from Trade for Different Tariff Schedules

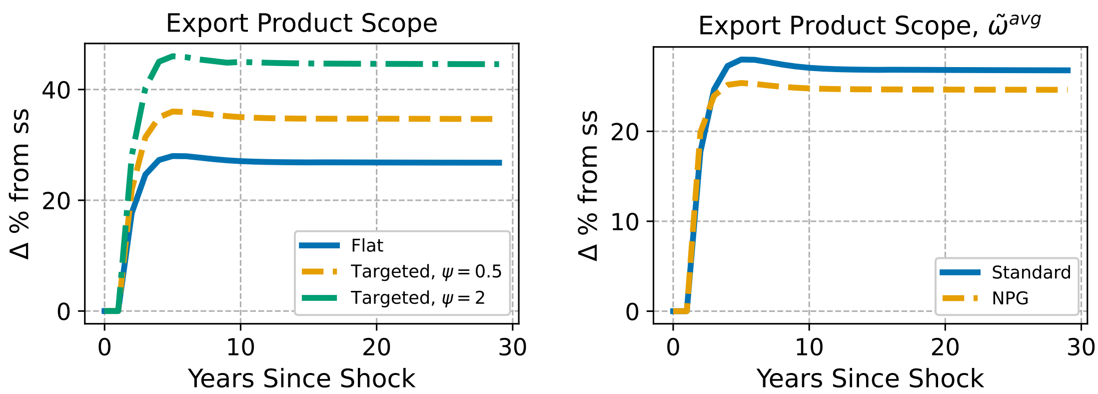
	Flat		Targeted, $\psi = 0.5$		Targeted, $\psi = 2$	
CEV(%)	SS	Trans	SS	Trans	SS	Trans
(1) Standard	1.00	1.28	1.10	1.43	1.35	1.76
(2) NPG	0.84	1.04	0.95	1.21	1.20	1.55
(1)/(2)	1.19	1.23	1.16	1.18	1.13	1.14

Note: The welfare gains are calculated as the consumption equivalent variation from trade liberalization relative to the initial equilibrium. SS compares steady-state welfare and Trans incorporates transition dynamics. NPG refers to the case where there are no gains from proximity. See text for details.

dynamics exceed those from steady-state comparisons alone, driven by industry dynamics. A uniform decline in tariffs generates welfare gains of approximately 1.28%. Heterogeneous tariff reductions yield larger gains of 1.43% when $\psi = 0.5$ and 1.76% when $\psi = 2$, which are 12% and 38% higher than the flat cases, respectively. Consistent with the aggregate outcomes and transition dynamics discussed earlier, these results confirm how targeted tariff structures can significantly increase welfare gains relative to uniform structures.

We next examine how proximity-based export cost reductions translate into aggregate welfare effects by isolating proximity cost advantages through a comparison of our Standard benchmark with the NPG model. The results in the third row show that the NPG model eliminates proximity-based export cost reductions. The Standard model generates welfare gains 23% higher than the NPG case under flat tariff liberalization. This proximity advantage narrows under steeper tariff schedules to 18% when $\psi = 0.5$ and 14% when $\psi = 2$. Despite this narrowing, the model that accounts for proximity gains consistently delivers higher welfare gains across all tariff structures. This occurs because in the Standard model, declining tariff rates mean that firms benefiting from product proximity are more likely to introduce new products, thereby incentivizing product expansion and generating higher welfare gains. In contrast, firms in the NPG economy face constant per-product costs, making portfolio expansion less attractive. In the Supplementary Appendix, we conduct sensitivity analysis varying several parameters and consistently find that proximity gains amplify welfare changes from trade liberalizations.

The aggregate effects of both tariff structure heterogeneity and export cost reductions from product proximity operate through the firms' decisions to expand their export product portfolios. To illustrate this connection, we examine the economy-wide average export product scope, which we denote as $\tilde{\omega}_t^{avg}$, as $\frac{1}{N_t}\int \tilde{\omega}_t d\Lambda_t(z_t, \tilde{\omega}_t)$. A larger value of $\tilde{\omega}^{avg}$ indicates that firms are exporting a broader range of products.



(a) Standard Under Different Tariff Schedules (b) Standard vs. NPG (Flat)

Figure 10: Export Product Scope Dynamics Following Trade Liberalization

Note: The figure shows the percentage deviation of economy-wide average export product scope ($\tilde{\omega}^{avg}$) from the initial steady state over time following trade liberalization. The left panel compares different tariff reduction schedules in the standard model. The right panel compares the standard model with product proximity to the no proximity gains (NPG) case under flat tariff reductions.

Figure 10 plots the dynamics of this variable as a percentage deviation from the initial steady state for the trade liberalization experiments considered so far. The left panel shows that under flat tariff reductions, export product scope increases by approximately 27% in the long run. However, when tariff reductions depend on expenditure shares, export product scope in the economy expands significantly more. The dashed lines demonstrate this amplification effect. This can be seen by the dashed lines in the same figure. When $\psi = 0.5$, the product scope expansion reaches around 35% compared to the 27% under flat liberalization. When $\psi = 2$, the economy-wide export scope rises to 45%. These results again confirm that deep tariff cuts on products with high expenditure shares encourage broader portfolio expansion, even when average tariff rates remain constant.

The right panel isolates the proximity cost mechanism by comparing Standard and NPG models under flat tariffs. When we eliminate proximity advantages, firms expand less aggressively: the NPG case reaches 25% expansion compared to 27% in the Standard model. This relatively small difference in product scope expansion translates into the 23% welfare gap between models documented in Table 7. Importantly, substantial welfare gains persist even in the NPG model as both models benefit from increased trade following tariff declines. However, the Standard model's proximity advantages enable more aggressive portfolio expansion by

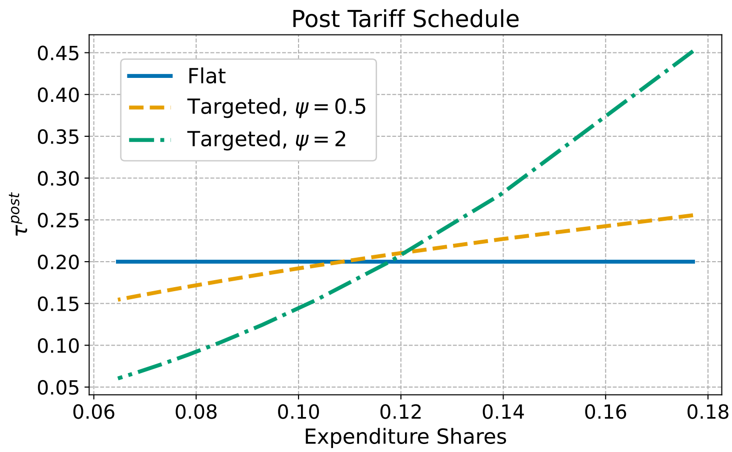


Figure 11: Tariff Schedule: Protectionism

Note: The figure shows post-tariff schedules as a function of product expenditure shares under different trade war scenarios. All schedules maintain an average tariff rate of 20%.

reducing the costs of adding related products, amplifying welfare gains beyond what the NPG model can achieve.

6.2 Trade Wars

In this section, we examine the welfare implications of protectionist policies in which both countries raise trade barriers. Similar to the trade liberalization experiments, we compare flat versus targeted tariff increases, both raising average tariffs from 10% to 20%. Under the flat policy, all products face uniform 20% tariffs. Under the targeted policy, we hold the average tariff rates at 20% while we vary tariffs across products depending on its expenditure shares. Given this, the targeted schedule is written as:

$$\tau_k^{post} = a\left(\frac{s_k}{\bar{s}}\right)^{\psi}, \tag{36}$$

where, again, a is chosen to maintain the 20% average tariff. This formula generates tariff rates that rise with expenditure shares, the opposite pattern of our liberalization analysis. The degree of targeting determines the dispersion across products: with moderate targeting ($\psi = 0.5$), tariffs range from 15% to 25%; under aggressive targeting ($\psi = 2$), they vary much more widely, from 5% to 45%. Figure 11 illustrates these schedules, with the solid blue line representing the flat tariff scenario, and the dashed orange and green lines showing targeted tariffs.

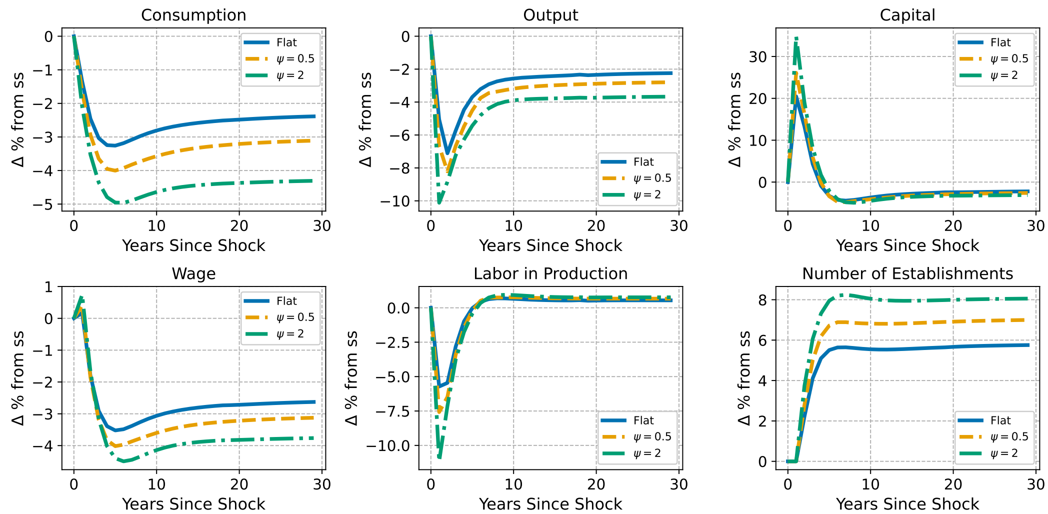


Figure 12: Aggregate Dynamics - Trade War

Figure 12 plots the dynamics of key macroeconomic variables under different tariff scenarios. These outcomes reveal consistent adjustment patterns across all policies, though with varying magnitudes. Immediately following the tariff shock, consumption, output, and labor allocation to production fall sharply due to higher trade costs. Conversely, the number of establishments rises as trade protection enables less productive firms to enter the market. Capital exhibits a distinctive pattern: it initially increases due to depressed consumption and lower interest rates, but eventually falls below its initial levels as efficiency losses accumulate. Wages decline persistently as labor reallocation away from production reduces productivity.

The quantitative impact of targeted tariffs continue to be more amplified relative to the flat case. Under flat tariffs, long-run consumption declines 2.5%, output falls 2%, capital drops 3%, and wages decrease 2.5%, while establishments increase nearly 6%. Despite identical 20% average tariff rates, targeted policies (dashed lines) generate consistently worse outcomes than flat tariffs (solid line). With aggressive targeting ($\psi = 2$), consumption falls 4.5%, output contracts nearly 10% at its trough, and long-run output declines 4%. The same extensive margins now amplify economic damage under targeted trade protection. Under the steep targeted protection ($\psi = 2$), products with high expenditure shares face tariffs up to 45% while low-share products face only 5%. This concentration triggers amplified welfare losses that exceed what average tariff rates alone would predict. These comparisons demonstrate that tariff structure, not merely average protection levels, determines the severity of economic damage from trade wars.

Table 8: Welfare Losses from Trade for Different Tariff Schedules

	Flat		Targeted, $\psi = 0.5$		Targeted, $\psi = 2$	
CEV(%)	SS	Trans	SS	Trans	SS	Trans
(1) Standard	-2.32	-2.59	-3.05	-3.29	-4.26	-4.33
(2) NPG	-1.95	-2.05	-2.67	-2.74	-4.21	-4.09
(1)/(2)	1.19	1.26	1.14	1.20	1.01	1.06

Note: The welfare losses are calculated as lifetime consumption equivalent variations relative to the initial free-trade equilibrium. SS compares steady states, and Trans incorporates transition dynamics. NPG refers to the case without gains from proximity.

Table 8 quantifies the welfare consequences from trade wars. Flat tariffs generate welfare losses of 2.59% when accounting for transition dynamics, while moderate targeting ($\psi = 0.5$) increases losses to 3.29% despite the same average tariff rates. Under aggressive targeting ($\psi = 2$), welfare losses reach 4.33%, representing a 67% increase over flat tariffs. These magnitudes are consistent with recent trade war studies: Alessandria et al. (2025) estimate welfare losses of 3.5% from a 20% global tariff increase, while our flat tariff scenario generates losses of 2.59% from a 10% to 20% tariff increase. Our higher welfare losses relative to tariff increases reflect the additional effects generated by multiproduct firm interactions in our model.

Similar to the liberalization exercise, we next turn to product proximity effects, which amplify welfare losses under all tariff structures. Comparing the standard model to the NPG case reveals that proximity interactions increase welfare losses by up to 26% across scenarios. The amplification diminishes under aggressive targeting to 6%, as direct tariff effects on major expenditure categories begin to dominate portfolio adjustment mechanisms. These findings demonstrate that models ignoring firm-level product interactions systematically underestimate the welfare costs of protectionist policies. The proximity amplification occurs independently of tariff structure design, indicating that conventional trade models miss a quantitatively important source of welfare effects. This has significant implications for policy evaluation: policymakers may choose to target specific products for political or strategic reasons, but our analysis shows that both the targeting itself and the underlying proximity mechanisms compound economic costs through firm-level portfolio adjustments that other models fail to capture.

7 Conclusion

This paper demonstrates that firms' product introduction decisions within export markets follow systematic patterns that have significant macroeconomic implications. Using Chinese customs data, we show that exporters disproportionately introduce products that are proximate to their existing export baskets, as measured by our Export Basket Proximity (EBP) index based on observed co-export patterns. This proximity effect remains robust when controlling for classification- and technology-based relatedness, indicating that it captures market-specific complementarities revealed through firms' export choices.

We develop a dynamic general equilibrium model that embeds these proximity patterns into export costs, allowing firms to expand toward products that are close to their current portfolios at lower fixed costs. The calibrated model successfully replicates key features of multiproduct exporter dynamics while matching targeted moments from the data. Importantly, the model generates realistic firm-level export patterns without directly targeting the proximity relationships we observe empirically.

Our quantitative analysis reveals that product proximity substantially amplifies the welfare effects of trade policy changes. Models that ignore proximity effects underestimate welfare changes by up to 26%, demonstrating that firm-level product complementarities have first-order importance for aggregate outcomes. This amplification operates through firms' portfolio adjustment decisions: proximity advantages enable more aggressive expansion during liberalization and more severe contraction during protection. The mechanism is robust across different policy designs, though the overall magnitude of welfare effects varies significantly with tariff structure.

These findings carry important implications for trade policy analysis and design. First, they highlight the necessity of incorporating product-level heterogeneity and firm portfolio decisions into trade models, as proximity effects represent a quantitatively significant amplification mechanism that standard models miss. Second, they demonstrate that the distribution of tariff changes across products, not just average rates, fundamentally shapes aggregate outcomes, suggesting that policymakers should consider product complementarities when designing trade reforms. Finally, our results indicate that the welfare gains from trade liberalization may be larger than previously estimated once we account for product-level interactions.

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