When Tariffs Disrupt Global Supply Chains*

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Abstract

We study unanticipated tariffs in a setting with firm-to-firm supply relationships. Firms that produce differentiated products conduct costly searches for potential input suppliers and negotiate bilateral prices with those that pass a reservation level of match productivity. Global supply chains are formed in anticipation of free trade. Once they are in place, the home government surprises with an input tariff. This can lead to renegotiation with initial suppliers or search for replacements. Calibrating the model's parameters to the estimated price and quantity responses to the Trump tariffs on imports from China, we find a loss of welfare of just under 0.5% of GDP, an improvement of 2% in the U.S. terms of trade with China, and a deterioration of about 0.4% in the overall U.S. terms of trade.

Keywords: global supply chains, global value chains, input tariffs, imported intermediate goods

JEL Classification: F13, F12

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1 Introduction

Global supply chains feature prominently in the landscape of modern trade. The 2020 World Development Report highlights the distinctive features of such supply chains. They derive from technological advances that make feasible the *fragmentation* of production processes. They impose non-trivial *search costs* on participants, as downstream firms hunt for suitable suppliers and upstream firms seek customers. They require *matching* of compatible partners to ensure productive exchanges. They often are governed by *incomplete contracts* that give rise to frequent *renegotiation*. And yet they typically involve *durable* relationships, because the sunk nature of search and customization costs impart "stickiness" to the pairings.[1]

A burgeoning literature examines firms' participation in global supply chains, the geography of international sourcing, the implications of these arrangements for productivity and market structure, and the persistence and economic significance of firm-to-firm networks.[2] Yet with just a few exceptions (that we discuss below), little attention has been paid to how trade policies might disrupt supply chains and with what implications for consumer prices and welfare. Perhaps this lacuna can be explained by the low and falling tariffs imposed by many high income countries on imports from low-wage economies during the period when supply chains rose to prominence. For example, the average tariff applied by the United States on imports from China—where many of its suppliers were located—amounted to only 2.7% at the end of 2017.[3]

But history changed course with the policies introduced by the Trump administration beginning in 2018, especially those imposed as "special protection" against imports from China. Using the tariff data collected by Fajgelbaum et al. (2020) for the early rounds of Trump tariffs, and the data assembled by Chad Bown for subsequent tariff hikes, we find that the weighted average tariffs on U.S. imports from China rose to 17.1% by the end of 2019. After a long period of stable trade policies, the tariff hikes came as a shock to firms that had forged relationships with suppliers in China. The disruption of supply chains and the decoupling of integrated production processes were very much a part of the administration's intention with these aggressive policies. In fact, in August 2019, President Trump advised U.S. firms to "immediately start looking for an alternative to China" (Breuninger, 2019).

Anecdotes abound that a reorganization of supply chains took place in response to the large and unanticipated U.S. tariffs. The business press reported shifts in sourcing away from China toward Vietnam, Thailand, Indonesia, Malaysia, Cambodia, and others. Relocation of import supply allegedly was undertaken by companies such as Samsonite, Cisco Systems, Macy's, Ingersoll-Rand, and the Fossil Group, and in diverse industries such as electronics, furniture, hand luggage, and

[1] See also Antràs (2020), upon which parts of the World Development Report are based.

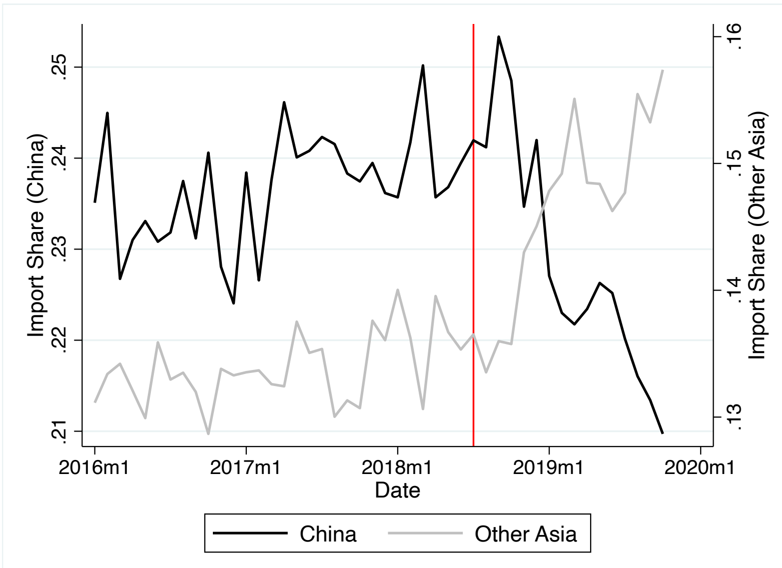
[2] See, for example, Antràs and Helpman (2004), Grossman and Rossi-Hansberg (2008), Antràs and Chor (2013), Baldwin and Venables (2013), Halpern et al. (2015), Antràs et al. (2017), Bernard and Moxnes (2018), and many others.

[3] This average is calculated by weighting the 10-digit HTS MFN tariff schedules reported for 2017 by the U.S. International Trade Commission by the value share of each category in total U.S. imports from China. If consumer goods are excluded from the calculation, the weighted average tariff on the remaining imports becomes a mere 1.0%.

auto parts.[4]

The relocation of U.S. import sourcing after the introduction of the Trump tariffs is visually clear in the aggregate data. In Figure 1, we display the shares of China and a group of 13 other low-cost Asian countries (henceforth, "Other Asia") in the total value of U.S. imports.[5] After the first wave of tariffs on China in July 2018 (marked by the red vertical line), we see a sharp decline in China's share of U.S. imports of around 3 percent (left scale), and a corresponding rise in Other Asia's share of U.S. imports of a strikingly similar magnitude (right scale).

Figure 1: Share of China and Other Asia in U.S. Imports



Note: Black solid line shows share of U.S. imports from China; gray solid line shows share of U.S. imports from Other Asia (Bangladesh, Cambodia, Hong Kong, India, Indonesia, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam); red vertical line shows the date of the first Trump tariff wave on China; both series seasonally adjusted by removing month fixed effects.

We also find evidence of supply-chain reorganization at the micro level. In Table 1, we use monthly U.S. customs data for total imports and for imports excluding consumer goods at the HTS10-country-of-origin level for the period from January 2016 through October 2019 and apply a difference-in-difference methodology similar to the one proposed by Amiti et al. (2019, 2020) in their investigations of the price and volume effects of the Trump tariffs.[6] We regress the log of

[4] See Master et al. (2018), Bloomberg News (2019), Huang (2019), Hufford and Tita (2019), Kawanami and Shiraishi (2019), Reed (2019), and Soon (2019).

[5] The thirteen LCCs include Bangladesh, Cambodia, Hong Kong, India, Indonesia, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam. These are the countries identified by Kearney (2020), in addition to China, as "traditional offshoring trade partners," when calculating their annual Reshoring Index. See Appendix B for more detail on the data sources that underlie Figure 1.

[6] See also Figure B.4 in Appendix B. There, we provide evidence that relocation of U.S. imports from China to Other Asia took place on the product extensive margin. To draw that figure, we began with the set of products that were imported from China before the first wave of Trump administration tariffs on China (from January 2017 through June 2018). We extracted the subset of these products that were not imported from Other Asia during this period before this first wave of tariffs on China. We then count how many of these products begin to be imported from Other Asia in the months following this first wave of tariffs on China. As shown in the figure, we find a sharp increase over time in the number of products that begin to be imported from Other Asia.

the value of imports from China and the log of the value of imports from Other Asia on product fixed effects, month fixed effects, and the log difference between one plus the ad valorem tariff rate on imports from China and one plus the weighted-average tariff rate on imports from these other sources. Evidently, imports from China were significantly lower for goods that experienced large tariff hikes, and imports from Other Asia were correspondingly higher, whether we include consumer goods or not.[7]

Table 1: U.S. Imports from China and Other Asia

	(1)	(2)	(3)	(4)
	Log U.S. Imports from China	Log U.S. Imports from Other Asia	Log U.S. Imports from China	Log U.S. Imports from Other Asia
	All Goods	All Goods	Excluding Consumer Goods	Excluding Consumer Goods
Log Relative Tariffs	-1.719***	0.316***	-1.566***	0.232**
	(0.087)	(0.083)	(0.114)	(0.105)
Product Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
R-squared	0.88	0.86	0.87	0.86
Observations	315,316	315,316	193,871	193,871

Note: Observations are at the source-HTS10-month level from January 2016 to October 2019, where source is either China or Other Asia. Columns (1) and (2) include all goods. Columns (3) and (4) exclude consumption goods. Regressions include only products with positive imports from both sources. Log Relative Tariffs is the log difference between one plus the ad valorem tariff rate on imports from China and one plus the weighted-average ad valorem tariff rate on imports from other Asia. The weighted-average tariffs use the annual import values in 2017 as weights. Standard errors are clustered at the HTS8 level. *, ** and *** indicate significance at the 10, 5 and 1 percent level, respectively.

Motivated by these observations, we study in this paper the effects of unanticipated but long-lasting input tariffs, such as those introduced by the Trump administration in 2018 and 2019 that continue today under President Biden. We develop a model of trade in intermediate inputs that captures many of the defining characteristics of supply chains mentioned in the 2020 World Development Report. Firms search for partners to form their chains. Search is costly. Matches vary in productivity. Relationships are governed by short-term contracts that can be renegotiated at any time. Sunk costs generate stickiness in relationships, but renewed search occurs in response to large shocks.

We introduce supply chains into an otherwise standard model of monopolistic competition and trade based on Venables (1987). There are two sectors, one that produces a homogeneous good with labor alone and another that produces differentiated products. Firms enter the latter sector in anticipation of some initial trade policy, which we take to be one of free trade. Entrants produce unique varieties by combining labor and a composite intermediate input. The latter comprises a

[7] Consumer goods may be considered part of the supply chain when imported by large retailers such as Walmart or Amazon. We are agnostic about whether these goods should be included in a discussion of supply chain disruption, so we present our evidence both ways. Appendix B uses a long-differences methodology to show that the evidence of a sourcing response to policy shock does not reflect trends that predated the tariffs.

unit continuum of differentiated inputs in fixed proportions. Each producer can manufacture the set of inputs it needs using a backstop technology, but we focus on circumstances in which they prefer to engage input suppliers in a low-wage country. The firms pay search costs that deliver draws from a known distribution of productivities for each of the inputs they require. Once they identify a potential supplier of an input, they learn the productivity of the pairing and decide whether to negotiate a renewable short-term contract or resume their search for a better match. When a match is acceptable, the buyer and supplier conduct Nash-in-Nash bargaining (i.e., pairwise Nash bargaining that takes other bargaining outcomes as given) that determines the set of input prices and thus the perceived marginal cost of the composite intermediate good. This and the wage rate govern the optimal production technique, which yields the minimum unit cost. Consumers demand the differentiated products with a love of variety and producers engage in markup pricing, as usual, under monopolistic competition with a constant elasticity of substitution between brands. The model determines the mass of varieties and the prices and quantities of each, along with the optimal search strategy and the negotiated input prices that reflect the extant trade policy and the match-specific productivities.

In Section 3, we consider the introduction of permanent input tariffs that were not anticipated at the time when entry occurred and global supply chains were formed. Small tariffs do not affect the preferred location for supplier relationships and do not instigate replacement of any of firms' original suppliers. However, such tariffs do worsen the outside options for downstream buyers and thus induce renegotiation of prices in enduring supply relationships, resulting in terms more favorable to the suppliers. Thus, small tariffs harm the terms of trade for the country that imposes them. Larger tariffs cause downstream producers to divert their new searches to a different country than where the initial searches took place, be they to another country with low wages that is exempt from the tariffs or to the home country that has imposed the tariffs. In either case, the higher are the tariffs in this range, the better is the bargaining position of the downstream producer and the lower are the input prices resulting from renegotiation with the initial suppliers. Meanwhile, for tariffs above some critical value, downstream producers sever their relationships with their least productive suppliers and conduct new searches in a country not subject to the tariffs. This relocation raises the prices of the inputs that are newly sourced, and average input prices may rise despite the renegotiation of better terms in enduring relationships.

Section 4 examines the implications of the unanticipated tariffs modeled in Section 3 for the home country's welfare. We identify several channels—some familiar and some new—through which tariffs affect home-country welfare. First, the tariffs cause a contraction of the differentiated-products sector from a scale that was already too small due to the markup pricing of these goods. Second, the tariffs lead to substitution of labor for intermediate inputs in a setting where the initial production techniques may be biased toward labor due to the wedge that exists between the social cost of inputs and the marginal cost perceived by downstream firms. This wedge reflects , in part, an inefficiency resulting from firms' independent and uncoordinated bargaining with many suppliers. Third, the tariffs alter the terms of trade, both due to the familiar effect of Vinerian trade diversion and to the novel effect of renegotiation with initial suppliers. Finally, tariffs may induce costly search for new suppliers that would not occur without the departure from free trade.

Finally, in Section 5, we apply our model to evaluate the welfare effects of the Trump administration's tariffs on imports from China that were introduced in 2018 and 2019 (henceforth, the "Trump tariffs"). We discipline the model using the reorganization of U.S. supply chains in response to these tariffs. We use demand parameters estimated for the Trump tariffs by Fajgelbaum et al. (2020) and cost parameters from U.S. data prior to the imposition of the tariffs. We choose the bargaining weights to match the observed share of profits in the U.S. manufacturing sector in 2017. Finally, and most importantly, we calibrate the Pareto shape parameter for the distribution of match productivities and the cost disadvantage of the next best supply option relative to China's so as to match event-study estimates of the impact of the Trump tariffs on U.S. China import values (32 percent) and Chinese exporter prices (2 percent).

The weighted average of new tariffs introduced during the sample period amounted to about 14% on imports from China. Although Chinese export prices fell by 2 percent, our model implies an overall deterioration in the U.S. terms of trade of 0.42 percent, after taking into account the relocation of import sourcing to higher cost locations. We find an overall reduction in U.S. welfare of just under 0.5 percent of GDP, or around 3 percent of differentiated sector expenditure. We also use our calibrated model to evaluate the welfare effects of tariffs smaller and larger than those that were actually implemented and simulate a counterfactual in which all relocated supply relationships are reshored to the United States.

As we noted at the outset, our paper contributes to a small literature on the effects of tariffs that are applied to intermediate inputs and an even smaller literature that considers trade policy in the context of global supply chains. The earliest papers on input tariffs focused on effective rates of protection; see, for example, the various papers collected in Grubel and Johnson (1971). The effective rate of protection adjusts the nominal tariff on a final good for the cost of tariffs levied on the imported inputs used to produce that good. Ruffin (1969) and Casas (1973) study second-best tariffs on intermediate goods in small countries that protect their final producers, while Das (1983) considered optimal tariffs on intermediate and final goods in a large country, all in neoclassical settings with perfect competition and constant returns to scale. Blanchard et al. (2021) represents a more recent contribution in this same vein. Using an approach that emphasizes the national origin of the value-added content of traded goods, they relate the structure of optimal protection to the sources of value added. Caliendo and Parro (2015) is a well-known paper that brings input tariffs and input-output linkages to quantitative modeling of multi-country trade so as to conduct welfare analysis of trade liberalization.

The papers most closely related to ours are by Ornelas and Turner (2008, 2012) and Antràs and Staiger (2012). These authors focus on the hold-up problems that arise when relationship-specific investments occur with incomplete contracts. Ornelas and Turner (2008) study bilateral relationships in which a foreign supplier must make a relationship-specific investment to sell an input to a downstream, home producer. Tariffs dampen the foreign firm's incentive to do so, thereby exacerbating the underinvestment problem that results from the incomplete contracting. The endogenous investment responses make trade flows more sensitive to trade policy than they would be with conventional, anonymous trade. In Ornelas and Turner (2012), in contrast, specialized inputs are provided by domestic suppliers, whereas imports offer a more generic alternative. In such a setting, tariffs reduce the attractiveness of the outside option to the downstream firm and thereby enhance incentives for relationship-specific investment by the domestic upstream firm. Tariffs on cheap but generic inputs can improve home welfare by mitigating the hold-up problem.

Antràs and Staiger (2012) study a setting with two small countries and a single, homogeneous good sold at a fixed world price. The producer of the final good is located in the home country, whereas the input supplier is located abroad. The input must be customized for the buyer, so that it has no value outside the relationship. Due to incomplete contracting, the terms of exchange are negotiated after the inputs have been customized and produced. In this setting, the authors identify the optimal input and output taxes and subsidies and the policies that result from non-cooperative policy setting in the two countries. Efficiency can be achieved by an input subsidy that resolves the hold-up problem together with free trade in the final good. But the governments have unilateral incentives to invoke sub-optimal policies, because the benefits of any subsidy paid by the home country are shared by firms in the foreign country. As in our model below, trade policy influences the bilateral negotiations between suppliers and buyers, and thereby impacts the terms of trade. But their focus is on relationship-specific investments, as opposed to search, and the very different market environment makes the two papers complements rather than substitutes.[8]

A recent paper by Ornelas et al. (2021) examines the reorganization of supply chains induced by preferential trading arrangements. As in their earlier work, they focus on relationship-specific investment in a world of incomplete contracts. Like us, they consider discriminatory trade policies that can divert trade away from the lowest-cost sources. They allow for matching of buyers with heterogeneous suppliers, albeit in a frictionless setting that yields globally-efficient pairings and lacks any stickiness from sunk costs. Their welfare analysis has a second-best flavor similar to ours, although the inefficiencies they highlight arise from a different source, namely the insufficiency of investment owing to the hold-up problem. Interestingly, a preferential trade agreement might generate welfare gains in their setting even in the absence of any trade creation.

2 Foreign Sourcing with Search and Bargaining

In this section, we develop a simple model of global supply chains. Firms in a monopolistically competitive industry combine labor and a composite intermediate good to produce differentiated products. The intermediate good requires a continuum of inputs in fixed proportions. Each firm can produce any input it needs using a "backstop" technology or it can search for an external supplier of that input at home or in its choice of foreign markets. When a firm locates a supplier,

[8] In an appendix, Antràs and Staiger (2012) introduce search costs. But they focus on whether search yields a match or not, and optimal search determines how many buyers search in each of several foreign markets, not the intensity of search or the productivity of the resulting matches.

it learns the productivity of the potential match. Then it can bargain with the supplier over a short-term (but renewable) contract, or it can choose to resume its search. Time is continuous and the interest rate is equal to the subjective discount rate.

We characterize below an initial, long-run equilibrium. We assume that entry takes place in anticipation of free trade, although we could just as easily use any fixed tariff rate as the starting point. In Section 3, we introduce tariff shocks and study how they impact the original supply-chain relationships.

2.1 Preferences and Demands

To isolate the role of the reorganization of supply chains, we focus on an otherwise standard model of trade under monopolistic competition, following Venables (1987). A unit mass of consumers demands a homogeneous good and an array of differentiated products. Preferences are characterized by

$$\Omega\left(X,Y\right)=Y+U\left(X\right),$$

where $\Omega\left(X,Y\right)$ is the quasi-linear utility of the representative individual, Y is her consumption of the homogeneous good, and X is an index of consumption of differentiated varieties. We assume the subutility $U\left(\cdot\right)$ has a constant elasticity ε greater than one, so that[9]

$$U\left(X\right)=\frac{\varepsilon}{\varepsilon-1}\left(X^{\frac{\varepsilon-1}{\varepsilon}}-1\right),\quad \varepsilon>1. \tag{1}$$

The consumption index takes the familiar form,

$$X=\left[\int_0^n x\left(\omega\right)^{\frac{\sigma-1}{\sigma}}d\omega\right]^{\frac{\sigma}{\sigma-1}},\ \sigma>1,$$

where $x\left(\omega\right)$ is consumption of variety ω, n is the measure of varieties available in the home country, and σ is the constant elasticity of substitution between any pair of brands. The corresponding real price index is

$$P=\left[\int_0^n p\left(\omega\right)^{1-\sigma}d\omega\right]^{\frac{1}{1-\sigma}}, \tag{2}$$

where $p\left(\omega\right)$ denotes the per-unit price of brand ω.

In order to focus most sharply on supply chains, we assume that the differentiated final goods are not tradable; this allows us to ignore the determinants of foreign demand for home brands.[10] The representative home consumer purchases differentiated products up to the point where $U'\left(X\right)=P$ or $X=\mathcal{X}\left(P\right)=P^{-\varepsilon}$. Each individual demands variety ω as a function of its price and the

[9] Estimates of demand across categories of differentiated products in the recent literature justify this assumption, as we discuss further below.

[10] We could, alternatively, consider a home country that is small in the market for differentiated products, as in, for example, Demidova and Rodriguez-Clare (2009). They assume that the prices and variety of home products have no effect on either foreign expenditures on these products nor on the foreign price index. Introducing such fixed export demand would have little effect on our analysis.

aggregate price index according to

$$x\left[p\left(\omega\right),P\right]=\mathcal{X}\left(P\right)\left[\frac{p\left(\omega\right)}{P}\right]^{-\sigma}. \tag{3}$$

This is also the aggregate demand for variety ω, in view of the unit mass of consumers.

The demand for brand ω declines with its own price and increases with the price index for competitor brands, under our empirically-motivated assumption that the demand elasticity within the differentiated sector exceeds that across sectors, i.e., $\sigma > \varepsilon$.

2.2 Production

The homogeneous good is produced competitively with labor alone and is freely tradable. By choices of units and numeraire, one unit of good Y requires one unit of labor and bears a normalized price of one. This fixes the home wage rate at one in units of the homogeneous good.

The introduction of an outside good allows us to abstract from income effects on demand and general-equilibrium effects on the wage, which do not seem pertinent to the trade policies of interest here. By fixing the wage, we eliminate the aggregate terms of trade effect that is familiar from conventional trade models in order to focus on new mechanisms for adjustments in the terms of trade that arise from renegotiation within existing relationships and searches for new suppliers. We show below that our calibrated model is able to match the estimated price and quantity response to the Trump tariffs using our mechanisms of renegotiation and search, without requiring changes in relative wages that generate a conventional terms-of-trade effect.

Firms in the monopolistically-competitive sector produce unique varieties of the differentiated final good using labor, ℓ, and bundles of a composite intermediate good, m, subject to a constant-returns-to scale production function $z\left(\ell,m\right)$. The composite intermediate good comprises a unit continuum of inputs indexed by j in fixed proportions, with one unit of each input needed for each unit of the composite.[11]

In addition to variable costs, a firm producing any variety ω bears a one-time entry cost of F_e units of home labor, as well as a recurring fixed operating cost of f_o. Moreover, it bears a cost of finding partners for its global supply chain, which we describe next.

2.3 Search

The creation of supply chains requires that producers locate suppliers. The cost of search can be an important component in the response to changes in trade policy. We suppose that firms can search for potential suppliers in one or more of several countries, $i \in \{1,\ldots,I\}$. One value of i represents the home country, so that producers of differentiated products might seek out domestic outsourcing relationships. With the symmetry that we impose across inputs, it is always optimal for a firm

[11] Inasmuch as the input suppliers must be identified through search and they provide match-specific productivity at a negotiated price, it is immaterial whether the inputs used by different final producers are physically the same or not, so long as all aspects of the search, matching and bargaining are symmetric across producers.

to search for all of its suppliers in a single country, although that target country might change following the imposition of a tariff. With free trade and the other assumptions described below, the optimal location for any supply chain is the country that has the lowest (efficiency-adjusted) wage. For now, we take the foreign Country A to have the lowest wage, i.e., $w_A = \min \{w_1 \ldots, w_I\}$. All home producers conduct their searches in Country A, so we describe the search process without reference to the i index and write w instead of w_A. However, once the home country introduces a discriminatory tariff on inputs imported from Country A, producers might seek out new suppliers at home or in some other country that is exempt from the tariff.

Search requires home labor. A firm ω seeking a supplier for input j can take a draw from a cumulative distribution $G(\cdot)$ at a capital cost of F. The realization of this draw, a, reveals the quality of the match between the producer and the particular supplier. Specifically, a potential supplier with match-specific (inverse) productivity a can produce a unit of input j for brand ω at a cost of aw. The firm producing ω decides whether to negotiate a short-term but renewable contract to buy input j from the potential supplier or whether to continue its search by taking another, independent draw from $G(\cdot)$ at an additional cost of F. For simplicity, we abstract from the time that may elapse between draws and assume, instead, that all search takes place in an instant. We assume that $g(a) \equiv G'(a) > 0$ for all $a \in (0, 1]$ and $g(a) = 0$ for all $a > 1$. The firm producing brand ω also has access to an inferior but viable backstop technology for producing every input j that requires one unit of labor per unit of output. As we shall see, this option—that might be a fallback in case of a sequence of failed negotiations—proves to be irrelevant to the equilibrium outcome whenever supply chains form.

The optimal search strategy, as usual, involves a reservation stopping rule.[12] Let $\bar{a}$ be the reservation level, which the firms choose optimally. Then a firm takes another draw for the input j if and only if all of its prior draws for that input had inverse match productivities that exceed $\bar{a}$. Ultimately, all of a firm's suppliers will have inverse productivities in the range $[0, \bar{a}]$, with densities given by $g(a)/G(\bar{a})$. Given the continuum of inputs and the independence across them, the search process (plus bargaining) leads to a deterministic cost for a given quantity of the composite intermediate.

We can readily calculate the total cost of a firm's search effort, $S(\bar{a})$, as a function of the stringency of its stopping rule. When a firm takes its first draw, it pays F. Then, with probability $G(\bar{a})$ it achieves at least its reservation level of match productivity, in which case there are no further search costs. With the remaining probability, $1-G(\bar{a})$, it encounters a supplier with $a > \bar{a}$, in which case it finds itself facing again a search cost of $S(\bar{a})$. It follows that $S(\bar{a}) = F + [1 - G(\bar{a})] S(\bar{a})$, or

$$S(\bar{a}) = \frac{F}{G(\bar{a})}.$$

This is the expected cost of search for any one input as well as the aggregate cost of search for the measure one of inputs in the bundle.

[12] See, for example, Benkert et al. (2018) for proof that a reservation stopping rule is optimal in this environment.

2.4 Bargaining

In principle, a downstream firm might bargain with its suppliers over both prices and quantities. However, full efficiency would require a joint negotiation of quantities with all suppliers and this would be quite impractical with many of them. Instead, we invoke simultaneous but separate ("Nash-in-Nash") bargaining; i.e., each negotiation between a buyer and a potential supplier takes all other bargaining outcomes as given.[13] In our setting with a Leontief technology, this takes bargaining over quantities off the table; once a firm has decided to purchase m units of every input from its many other suppliers, it has no use for any more than this amount from the individual supplier with whom it is bargaining, nor can it manage with less without wasting the purchase of other inputs. Inasmuch as the price of a single input has a negligible effect on the cost of the bundle, the buyer and each of its suppliers have no conflict over quantity given the outcome of the other negotiations. Instead, each pair takes m as given and the parties haggle over price. We assume Nash bargaining with exogenous weights β for the buyer and $1-\beta$ for the seller and denote the agreed price per unit of an input produced with inverse productivity a by $\rho(a)$.[14]

An individual seller may have multiple sources of income, but earns nothing from the relationship in question if the negotiation with the buyer breaks down. Therefore a seller with match productivity a earns a surplus from the relationship equal to the difference between its revenues $\rho(a)\,m$ and its production costs, wam, considering that the m units of the composite require m units of each of its components. The buyer, in contrast, has two options should the negotiation break down. It can produce input j using its backstop technology, with a labor coefficient of one and a wage of one. Or it can resume its search for an alternative supplier. Clearly, the latter option dominates, or else it would not have begun to search in the first place. Therefore, the outside option for the buyer is the expected cost of finding a new supplier plus the payment it would expect to make to that supplier. Continued search engenders an expected capital cost of $S(\bar{a})$, or a flow cost of $rS(\bar{a})$, where r is the constant interest rate, equal to the representative individual's subjective discount rate. The expected payment to an alternative supplier is $\mu_\rho(\bar{a})\,m$, where

$$\mu_\rho(\bar{a}) = \frac{1}{G(\bar{a})}\int_0^{\bar{a}} \rho(a)\,g(a)\,da$$

is the expected price of an input drawn randomly from the truncated distribution with domain $[0,\bar{a}]$. Thus,

$$\rho(a) = \arg\max_q \,(qm - wam)^{1-\beta}\left[\mu_\rho(\bar{a})\,m + rS(\bar{a}) - qm\right]^\beta.$$

[13] For a discussion of the game-theoretic foundations of Nash-in-Nash bargaining, see Collard-Wexler et al. (2019). Neither the Stole and Zwiebel (1996) protocol nor Brügemann et al.'s (2019) "Rolodex game" would yield different results in our setting, because with every input j essential to production, a failed negotiation would result in a potential supplier being replaced by another, with negligible impact on the other bargains.

[14] Technically speaking, there exist many Nash-in-Nash equilibria, because once all other negotiations have generated a quantity of some $\tilde{m}$, an individual pair of buyer and supplier has every incentive to agree to this same quantity. Among the Nash-in-Nash equilibria, we focus on the one most preferred by the buyer, who is the only party engaged in multiple negotiations. This amounts to the same as allowing the buyer to specify the quantity of each input in advance of the individual, bilateral negotiations.

The Nash bargaining solution implies

$$\rho\left(a\right)=\beta wa+\left(1-\beta\right)w\mu_{a}\left(\bar{a}\right)+\frac{1-\beta}{\beta}\frac{f}{mG\left(\bar{a}\right)} \tag{4}$$

and that

$$\mu_{\rho}\left(\bar{a}\right)=w\mu_{a}\left(\bar{a}\right)+\frac{1-\beta}{\beta}\frac{f}{mG\left(\bar{a}\right)}\ ,$$

where $\mu_a\left(\bar{a}\right)$ is the conditional mean of a for $a\leq\bar{a}$ and $f=rF$ is the debt service on the fixed cost of entry F. When the producer follows the same search strategy and bargaining process for all of its inputs, it pays $\mu_{\rho}\left(\bar{a}\right)$ per unit for its composite intermediate good plus the fixed cost of search, $f/G\left(\bar{a}\right)$. Thus, the total cost of m units of the intermediate good runs to $\left[w\mu_a\left(\bar{a}\right)+\frac{1-\beta}{\beta}\frac{f}{mG(\bar{a})}\right]m+f/G\left(\bar{a}\right)=w\mu_a\left(\bar{a}\right)m+f/\beta G\left(\bar{a}\right)$.[15] Note that each firm perceives a constant marginal cost of $\phi=w\mu_a\left(\bar{a}\right)$ for each unit of the composite intermediate good.

2.5 Cost Minimization

To minimize cost, the firm chooses the optimal search strategy $\bar{a}$ for producing m units of the intermediate, and the optimal factor mix, m and ℓ, for producing x units of its brand. The factor mix minimizes $\ell+w\mu_a\left(\bar{a}\right)m+f/\beta G\left(\bar{a}\right)$, subject to $z\left(\ell,m\right)\geq x$. Notice that the third term in the minimand is independent of ℓ and m. Evidently, the firm perceives a fixed search cost (including the fact that the search costs weaken the buyer's bargaining position) of $f/\beta G\left(\bar{a}\right)$ and a constant marginal cost of $c\left[1,w\mu_a\left(\bar{a}\right)\right]$, where $c\left(\cdot\right)$ is the unit cost function dual to $z\left(\cdot\right)$. We shall henceforth suppress the first argument in $c\left(\cdot\right)$—which is the constant, unitary home wage—and write the unit cost more compactly as $c\left(\phi\right)$, where $\phi=w\mu_a\left(\bar{a}\right)$ is the perceived marginal cost of a unit of m. Shephard's Lemma then gives us the factor demands, so that $m=xc'$ and $\ell=x\left(c-w\mu_a c'\right)$.

Turning to the optimal search strategy, the total (flow) cost of m units of the composite intermediate comprises the aggregate payment to suppliers, $m\mu_{\rho}\left(\bar{a}\right)=mw\mu_a\left(\bar{a}\right)+\left(1-\beta\right)f/\left[\beta G\left(\bar{a}\right)\right]$, and the debt service on the up-front cost of search, $f/G\left(\bar{a}\right)$. The tradeoff facing each firm is clear. On the one hand, a more exacting strategy generates a better average match productivity and thus a lower variable component in the payment to suppliers. On the other hand, a more stringent search strategy spells higher fixed costs of search and a larger fixed component in the payment to suppliers. Each firm chooses $\bar{a}$ to minimize the sum, i.e., $\bar{a}=\arg\min_a\left[mw\mu_a\left(a\right)+f/\beta G\left(a\right)\right]$. Then, if an interior solution exists, the first-order condition implies

$$mw\mu_a'\left(\bar{a}\right)=\frac{fg\left(\bar{a}\right)}{\beta G\left(\bar{a}\right)^2}. \tag{5}$$

Noting that $\mu_a'\left(\bar{a}\right)=g\left(\bar{a}\right)\left[\bar{a}-\mu_a\left(\bar{a}\right)\right]/G\left(\bar{a}\right)$, and substituting (5) into (4), we can write the nego-

[15] Inasmuch as the firm can produce the inputs in-house at a cost of m, outsourcing proceeds if and only if there exists an $\bar{a}$ for which $w\mu_a\left(\bar{a}\right)+\frac{1}{\beta}\frac{f}{mG(\bar{a})}<1$.

tiated price of an input with inverse productivity a as

$$\rho(a) = \beta w a + (1-\beta) w \bar{a} \ , \tag{6}$$

a weighted average of the supplier's production cost and the cost of producing the input with the reservation match productivity.

2.6 Profit Maximization and Monopolistically-Competitive Equilibrium

The firms in the differentiated-product sector face a constant elasticity of demand, per (3). They maximize profits, as usual, by charging a proportional markup over marginal cost,

$$p = \frac{\sigma}{\sigma-1} c(\phi) . \tag{7}$$

These prices yield operating profits of

$$\pi_o = \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} \mathcal{X}(P) P^\sigma c(\phi)^{1-\sigma} - \frac{(1-\beta) f}{\beta G(\bar{a})} - f_o. \tag{8}$$

The first term in (8) is the difference between revenues and variable costs when the marginal cost of production is $c(\phi)$, $\phi = w\mu_a(\bar{a})$, and firms practice the pricing rule in (7) subject to the demands in (3). The second term represents the sum of ongoing fixed payments to suppliers that result from the Nash bargains prescribed by (4). The last term in (8) is the recurring, fixed operating cost.

In a symmetric equilibrium, all firms charge the same price, p. Then (2) implies

$$P = n^{-\frac{1}{\sigma-1}} p.$$

As usual, the index increases linearly with the price of a typical brand, but decreases with the number of brands. This reflects the "love of variety" inherent in the Dixit-Stiglitz formulation.

Finally, in a monopolistically-competitive equilibrium with free entry, the present value of operating profits matches the fixed costs of entry and of search, or

$$\pi_o = f_e + \frac{f}{G(\bar{a})} \ , \tag{9}$$

where $f_e = rF_e$ denotes the debt service on the one-time entry cost and $f/G(\bar{a})$ represents the debt service on the sunk search costs.

2.7 Solving for the Free-Trade Equilibrium

The exogenous primitives of the model are the parameters $\{\varepsilon, \sigma, \theta, f, f_o, f_e, \beta\}$, the supplier productivity distribution $(G(\cdot))$, and the wages in Country A (w_A). Given these primitives, the general equilibrium is referenced by a quadruple consisting of the optimal stopping rule for supplier search $(\overline{a})$, the price for differentiated sector varieties (p), output per variety (x), and the mass of varieties (n). This equilibrium quadruple is determined by utility maximization, cost minimization, the optimal pricing rule, and free entry; see the Appendix A for details. All other endogenous variables, such as operating profits per brand, the average price of inputs, and the price index for differentiated products, can be calculated using the equilibrium values of $\bar{a}$, p, x, and n.

2.8 Properties of the Initial Equilibrium

To elucidate some of the properties of the free-trade equilibrium, we invoke two conventional assumptions about the functional forms of the production function and the distribution of match productivities. We will use these same functional forms in Section 5 to calibrate the model to the observed U.S. experience with the Trump tariffs.

In particular, regarding the technology for producing final goods, we assume

Assumption 1 *The marginal cost of any differentiated product takes the form* $c(\phi) = \phi^{\alpha}$*, with* $0 < \alpha < 1$*.*

Here, ϕ represents the cost to the producer of a marginal unit of m. Clearly, $c(\phi) = \phi^{\alpha}$ is dual to a Cobb-Douglas production function with exponents $1 - \alpha$ and α on ℓ and m, respectively, when the wage rate is one.

Additionally, and in keeping with the literature on heterogenous firms in international trade, we adopt a Pareto distribution for supplier productivity, namely

Assumption 2 *The distribution function* $G(a)$ *takes the form* $G(a) = a^{\theta}$*,* $\theta > 1$*,*

where θ captures (inversely) the spread of productivities.

The Pareto distribution implies $\mu_a(\bar{a}) = \frac{\theta}{\theta+1}\bar{a}$ and $g(\bar{a})/G(\bar{a})^2 = \theta/\bar{a}^{\theta+1}$. Then, the first-order condition (5) can be written as

$$\bar{a}^{\theta+1} = \frac{f(\theta+1)}{\beta m w}.$$

Intuitively, the stopping rule is more tolerant (higher $\bar{a}$) when search draws are more costly or the distribution of productivities is tighter. Search effort is greater (lower $\bar{a}$) when the foreign wage is higher, the scale of production is larger, or the buyers have more bargaining power; in these situations, the producers have more at stake in the search process. The greater is the search effort, the lower are the resulting transaction prices of all inputs, per (6). Of course, the scale of production and the demand for intermediates are endogenous in the full equilibrium, so the total effect of the parameters f, θ, β, and w must include the indirect effects that operate through m.

We next ask, under what conditions does there exist an interior optimal stopping rule in the free-trade equilibrium, i.e., when is $0 < \bar{a} < 1$? For this, we need the second-order condition also to be satisfied at the $\bar{a}$ that satisfies (5) and we need the solution for $\bar{a}$ to be less than one when m takes on its equilibrium value. In Appendix A, we prove that the second-order condition is satisfied at $\bar{a}$ under Assumptions 1 and 2 if and only if $\theta > \alpha(\sigma - 1)$. This condition is more likely to be satisfied if the dispersion of productivities is relatively low (θ high), if output is relatively unresponsive to the volume of intermediates (α low) and if the differentiated varieties are relatively poor substitutes for one another. Otherwise, costs may be monotonically increasing with $\bar{a}$ and it may be optimal to search indefinitely despite the prohibitive fixed cost of doing so, because operating profits rise even faster than fixed costs as production costs go to zero. To abstract from such an unrealistic situation, we label for future reference

Assumption 3 *When the production function satisfies Assumption 1 and the productivity distribution satisfies Assumption 2, $\theta > \alpha(\sigma - 1)$.*

Now we can use Assumptions 1 and 2 to solve explicitly for $\bar{a}$. We find

$$\bar{a}^{\theta} = \frac{f}{f_o + f_e} \frac{\theta - \alpha(\sigma - 1)}{\beta\alpha(\sigma - 1)}. \tag{10}$$

The right-hand side of (10) is positive under Assumption 3. It is less than one if the cost of search is not too large compared to the one-time cost of entry and the fixed cost of operation and if the buyers' bargaining power is not too low. We also require that the spread of productivities not be too small. This makes sense, inasmuch as a less dispersed distribution of productivities implies a smaller return to search. For θ sufficiently large, firms take only a single draw from $G(a)$ and accept any outcome; i.e., $\bar{a} = 1$. An interior value for $\bar{a}$ thus requires that θ should be neither too small nor too large. We henceforth assume parameter values that ensure $\bar{a} < 1$.

Using the value of $\bar{a}$ in (10), we can solve in closed form for the price index P, the number of varieties n, and all other endogenous variables, as shown in Appendix A. As in other models of monopolistic competition, variety is abundant and the price index of differentiated products is low when the one-time cost of entry and the fixed cost of operation are small. A lower value of the price index P corresponds to a higher level of welfare. As for the search costs, a lower value of f also implies a lower equilibrium price index and greater welfare. The equilibrium number of firms decreases with f.

3 Unanticipated Tariffs

We are now ready to introduce tariffs on imported inputs. We will study discriminatory tariffs on imports from Country A that come as a surprise to downstream producers that have already formed their supply chains there. Once the tariffs have been implemented, firms expect them to persist indefinitely. Let τ denote one plus the *ad valorem* tariff rate. We assume that τ is not so large as to induce exit by any of the original producers. These firms have already borne the sunk costs of entry and search, so they need only cover their fixed and variable operating costs to remain active. Since $\pi_o = f_e + f/G(\bar{a}) > 0$ in the initial equilibrium, there is room for input costs to rise without this causing exit.[16]

[16] It is not difficult to extend the analysis to a range of large tariffs that induce exit from the industry. Exit can happen only when demand for the final good is elastic. In such circumstances, the decline in variety represents an additional channel for welfare loss that is absent from our analysis; see Appendix A for details.

We distinguish two sizes of tariffs. If the tariff is small enough, i.e., $\tau < w_i/w_A$, for all $i \neq A$, then producers of differentiated products will find it optimal to continue to form their new supply relationships in Country A despite the burden the tariff. In this case, they will conduct their searches in Country A, should they decide to replace any of their original suppliers. If, on the other hand, the tariff is large enough, i.e., $\tau > w_B/w_A$ for some Country B (including, possibly, the home country), then the tariff-inclusive price of an import from A would exceed the tariff-free price of an import from B, and so any and all new searches take place in Country B. The evidence that we presented above that some U.S. imports were deflected from China to Other Asia suggests that the Trump tariffs are large in this sense. However, it is easier to understand the impact of tariffs in our model when they are small, and we will anyway need these results when we consider welfare, because we derive the total welfare effects by integrating a range of incremental tariff changes. So, we begin there.

3.1 Small Tariffs

Even when tariffs are not so large as to disturb the competitive advantage of Country A as a source of input supply for producers in the home country, they might disrupt existing supply chains in two ways. First, in the absence of long-term contracts, one side or the other in an enduring relationship might insist on renegotiating the terms. Second, the home producer might choose to replace its least productive suppliers in view of the added costs imposed by the tariffs. We consider each of these possibilities in turn.

3.1.1 Renegotiation in Enduring Relationships

In an enduring relationship, the tariff imposes a fiscal burden that must be shared by the two parties. The tariff might also alter the optimal search strategy for the buyer and thereby revise its outside option. If the outside option for the buyer improves, it will insist on better terms. If the outside option deteriorates, the supplier will demand a higher price. The new f.o.b. price is the Nash outcome when the buyer pays the tariff and each side shares in the surplus from the relationship relative to the buyer's new outside option.

Let $\rho(a, \tau)$ denote the renegotiated price that a producer pays to its ongoing supplier of some input j when the inverse match productivity is a and the *ad valorem* tariff rate is $\tau - 1$. Upon importing the input, the producer incurs a customs charge of $(\tau - 1)\rho(a, \tau)$. The outside option for the producer is to conduct a new search in Country A—with optimal stopping rule $\bar{a}(\tau)$—and to pay an expected tariff-inclusive price to a new supplier of $\tau\mu_\rho[\bar{a}(\tau), \tau]$, where $\mu_\rho[\bar{a}(\tau), \tau]$ is the mean of $\rho(a, \tau)$ conditional on $a \leq \bar{a}(\tau)$. The producer's net benefit from remaining with its original supplier amounts to $\tau\mu_\rho[\bar{a}(\tau), \tau] m(\tau) + f/G[\bar{a}(\tau)] - \tau\rho(a, \tau) m(\tau)$, where $m(\tau)$ is the quantity of the composite intermediate good that the firm assembles with the tariff in place. For the supplier, the surplus is simply the difference between revenue and production cost, or

$[\rho(a,\tau) - wa]\, m(\tau)$, as before. Therefore, renewed Nash bargaining yields

$$\rho(a,\tau) = \arg\max_q \left[\tau\mu_\rho[\bar{a}(\tau),\tau] + \frac{f}{m(\tau)\, G[\bar{a}(\tau)]} - \tau q\right]^\beta (q - wa)^{1-\beta}$$

which implies that

$$\rho(a,\tau) = \beta wa + (1-\beta)\, w\mu_a[\bar{a}(\tau)] + \frac{1-\beta}{\beta}\frac{f}{\tau m(\tau)\, G[\bar{a}(\tau)]} \tag{11}$$

and

$$\mu_\rho[\bar{a}(\tau),\tau] = w\mu_a[\bar{a}(\tau)] + \frac{1-\beta}{\beta}\frac{f}{\tau m(\tau)\, G[\bar{a}(\tau)]}.$$

We can find the optimal search strategy as before. A firm that conducts new searches after the small tariff has been introduced will choose $\bar{a}(\tau)$ to minimize $\tau m(\tau)\,\mu_\rho[\bar{a}(\tau),\tau] + f/G[\bar{a}(\tau)]$, the sum of procurement costs and the debt burden imposed by search costs. The new first-order condition becomes

$$\tau m(\tau)\, w\mu_a'[\bar{a}(\tau)] = \frac{fg[\bar{a}(\tau)]}{\beta G[\bar{a}(\tau)]^2} \tag{12}$$

which, after rearranging terms, can be written as

$$w\{\bar{a}(\tau) - \mu_a[\bar{a}(\tau)]\}\, G[\bar{a}(\tau)] = \frac{f}{\beta\tau m(\tau)}. \tag{13}$$

Note that left-hand side of (13) is increasing in $\bar{a}(\tau)$; the derivative is $G[\bar{a}(t)] > 0$. It follows that $\bar{a}(\tau) > \bar{a}$ if and only if $\tau m(\tau) < m$; more on the conditions for this below.

Now we can substitute (13) into (11) to derive

$$\rho(a,\tau) = \beta wa + (1-\beta)\, w\bar{a}(\tau). \tag{14}$$

Evidently, if $\beta < 1$, all input prices rise in enduring relationships if $\bar{a}(\tau) > \bar{a}$ and all prices fall if $\bar{a}(\tau) < \bar{a}$. Only if the bargaining power rests entirely with the buyer are the negotiated prices immune to changes in the outside option. Adjustments in the negotiated prices amount to changes in the terms of trade, much as in Antràs and Staiger (2010) and Ornelas and Turner (2012).

3.1.2 Replacing the Least Productive Suppliers

Now consider whether a typical producer will choose to replace some of its original suppliers by renewing search for better matches in Country A. If the firm does so, then certainly it will terminate the least productive among its initial matches. With this strategy in mind, we denote by a_c the inverse productivity of the marginal match, such that a typical producer retains its supply relationships for all inputs with $a \in [0, a_c]$, while replacing suppliers with $a \in (a_c, \bar{a}]$. Of course, if $a_c = \bar{a}$, firms preserve their original supply chains in their entirety.

As we noted above, there are two possibilities for the new, optimal search strategy should a firm choose to re-engage in search. First, $\bar{a}(\tau)$ might be (weakly) greater than $\bar{a}$, as it will be if $\tau m(\tau) \leq m$. Alternatively, $\bar{a}(\tau)$ might be smaller than $\bar{a}$, as it will be if $\tau m(\tau) > m$. In the first scenario, all existing supply relationships already meet or surpass the reservation level of match productivity; there is nothing to be gained by resuming search for any of them. In the second scenario, there exists a set of inputs for which $a \in (a_c, \bar{a}]$. For all of these, the firms opt to renew searches until they achieve match productivities at least as good as $\bar{a}(\tau)$. In short, each producer minimizes the cost of procuring $m(\tau)$ units of every input by setting $a_c = \min\{\bar{a}(\tau), \bar{a}\}$.

To identify circumstances in which supply chains are reorganized after the introduction of a small tariff, we must examine whether $\bar{a}(\tau)$ is ever strictly less than $\bar{a}$. To this end, we consider the marginal cost of a composite intermediate good in the tariff equilibrium. For the fraction of inputs $G(a_c)/G(\bar{a})$, the producers retain their initial suppliers. For these inputs, they perceive an average marginal cost of $\beta\tau w\mu_a(a_c) + (1-\beta)\tau w\mu_a[\bar{a}(\tau)]$, according to (11). For the remaining inputs (if any), they perceive an average marginal cost of $\tau w\mu_a[\bar{a}(\tau)]$. The weighted average gives the marginal cost of m that firms use in making their decisions about production techniques and consumer prices, which we denote by $\phi^\tau = \phi(\tau)$.[17] After collecting terms, we have

$$\phi^\tau = \beta\frac{G(a_c)}{G(\bar{a})}\tau w\mu_a(a_c) + \left[1 - \beta\frac{G(a_c)}{G(\bar{a})}\right]\tau w\mu_a(\bar{a}^\tau) \tag{15}$$

and then optimal pricing implies

$$p^\tau = \frac{\sigma}{\sigma - 1}c(\phi^\tau). \tag{16}$$

In Figure 2, the kinked curve labeled MM depicts the relationship between ϕ^τ and $\bar{a}^\tau$ implied by (15) for a particular value of τ, when $a_c = \min\{\bar{a}^\tau, \bar{a}\}$. We illustrate for the case of a Pareto distribution, namely[18]

$$\phi^\tau = \begin{cases} \frac{\theta}{\theta+1}\tau w\bar{a}^\tau & \text{for } \bar{a}^\tau < \bar{a} \\ \beta\frac{\theta}{\theta+1}\tau w\bar{a} + (1-\beta)\frac{\theta}{\theta+1}\tau w\bar{a}^\tau & \text{for } \bar{a}^\tau \geq \bar{a} \end{cases}. \tag{17}$$

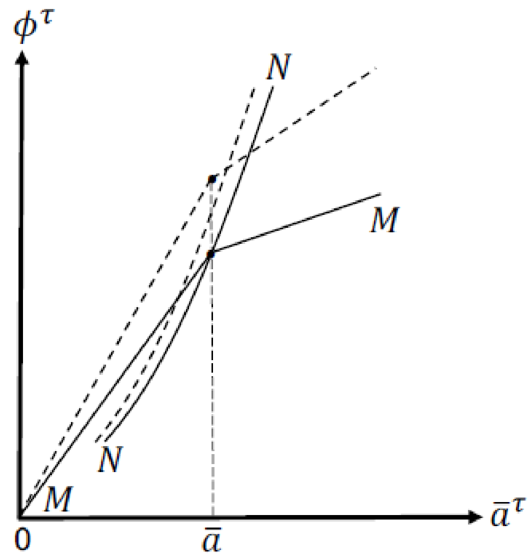
Here, we have drawn the curve associated with $\tau = 1$ (i.e., a tariff rate of zero). Evidently, the MM curve is piecewise linear with a kink at $\bar{a}$.

We can derive a second relationship between ϕ^τ and $\bar{a}^\tau$ by using the first-order condition for $\bar{a}^\tau$ in (13), the first-order condition for $m^\tau = x^\tau c'(\phi^\tau)$, the expression for demand for variety ω in (3), and the expression for the price index, $P^\tau = p^\tau(n^\tau)^{-1/(\sigma-1)}$. Combining these equations, using $c'(\tau) = \alpha(\phi^\tau)^{\alpha-1}$ and $p^\tau = \frac{\sigma}{\sigma-1}(\phi^\tau)^\alpha$, and hypothesizing that there is no induced entry of

[17] To reduce notational clutter, we will sometimes write the value of a variable y in the tariff equilibrium as y^τ. For example, $\phi^\tau = \phi(\tau)$ and $\bar{a}^\tau = \bar{a}(\tau)$.

[18] In Appendix A, we show that the qualitative properties of Figure 2 are the same for a general distribution function, provided that the second-order conditions for the choice of stopping rule are satisfied.

Figure 2: Small Tariff Equilibrium



final producers (i.e., $n^\tau = n$), we have under Assumptions 1 and 2,

$$\frac{(\theta+1) f}{w\beta (\bar{a}^\tau)^{\theta+1}} = \tau n^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} \alpha (\phi^\tau)^{\alpha(1-\varepsilon)-1} \ , \tag{18}$$

which we have depicted by the curve NN in Figure 2. The left-hand side of (18) is a decreasing function of $\bar{a}^\tau$, while the right-hand side is a decreasing function of ϕ^τ. Thus, the NN curve is upward sloping. Under Assumptions 1 and 2, it has a constant elasticity of $(\theta+1) / [1-\alpha(1-\varepsilon)]$. For $\tau = 1$, the two curves intersect at $\bar{a}(1) = \bar{a}$ and $\phi(1) = [\theta/(\theta+1)] w\bar{a}$. When the second-order condition for $\bar{a}^\tau$ is satisfied, the slope of NN must be steeper than that of MM at the point of intersection, as drawn.[19]

Now suppose that a positive tariff is introduced, so that τ rises proportionately by $d\tau/\tau = \hat{\tau} > 0$ from an initial value of $\tau = 1$. The figure illustrates the resulting shift in the curves. The MM curve shifts upward at every point in proportion to $\hat{\tau}$, with a kink still at $\bar{a}$. The NN curve also shifts upward, but in proportion to $[1+\alpha(\varepsilon-1)]^{-1} \hat{\tau} < \hat{\tau}$. Therefore, the intersection of the new MM curve and the new NN curve must come to the right of the kink in the former, which implies that $\bar{a}^\tau > \bar{a}$.[20]

Why does the stopping rule became less stringent after the introduction of a small tariff? We have seen that the benefit from search is proportional to the tariff-inclusive cost of the input bundle, τm^τ. When the demand for final goods is elastic and the production function has constant returns to scale, the derived demand for inputs is elastic as well. Then a tariff that raises the cost of imports

[19] The elasticity of the NN curve at $\bar{a}$ is $(\theta+1) / [1-\alpha(1-\varepsilon)]$, while that of the steeper branch of the MM curve is 1. But $(\theta+1) / [1-\alpha(1-\varepsilon)] > 1$ when $\sigma > \varepsilon$ and Assumption 3 holds.

[20] In Appendix A, we provide conditions on the cost function $c(\phi)$ under which the same result applies for a general (inverse) productivity distribution, $G(a)$.

reduces spending on intermediate inputs. Less spending implies less marginal benefit from search, and so producers become more tolerant of mediocre matches. This in turn improves the bargaining position of enduring suppliers. A small tariff raises all input prices and harms the home country's terms of trade.

Note that operating profits fall for all producers of differentiated products, but they remain positive for small enough τ. The fall in profits validates our hypothesis of no induced entry.

3.1.3 Effect of Small Tariffs on Average Input Prices, Perceived Marginal Costs, and Output Prices

The average price paid to foreign suppliers can be computed using (11) and the fact that a is distributed on $[0, \bar{a}]$ according to the truncated distribution, $G(a)/G(\bar{a})$. This gives

$$\rho^{\tau} = \beta w \mu_a(\bar{a}) + (1-\beta) w \bar{a}^{\tau} \tag{19}$$

or

$$d\rho^{\tau} = (1-\beta) w d\bar{a}^{\tau} > 0.$$

We can use (12), (13), and (18) to calculate the effect of a small tariff on the perceived marginal cost of the composite intermediate good. We find

$$\hat{\phi}^{\tau} = \left[\frac{\theta + 1 - \gamma^{\tau}}{\theta + 1 - \gamma^{\tau} - \gamma^{\tau}\alpha(\varepsilon - 1)}\right]\hat{\tau} \geq \hat{\tau}, \tag{20}$$

where $\gamma^{\tau} = \frac{(1-\beta)\bar{a}^{\tau}}{\beta\bar{a} + (1-\beta)\bar{a}^{\tau}}$ and thus $0 \leq \gamma^{\tau} \leq 1$. Finally, markup pricing according to (16), the expression for the price index (2), and a fixed number of producers imply

$$\hat{p}^{\tau} = \alpha\hat{\phi}^{\tau} = \hat{P}^{\tau} = \left[\frac{\theta + 1 - \gamma^{\tau}}{\theta + 1 - \gamma^{\tau} - \gamma^{\tau}\alpha(\varepsilon - 1)}\right]\alpha\hat{\tau} > 0. \tag{21}$$

We record our findings about small tariffs in

Proposition 1 *Suppose Assumptions 1-3 hold. Then a small tariff generates no new searches and no entry, but renegotiation with the original suppliers leads to higher input prices and thus a deterioration of the terms of trade. Consumer prices rise and the price index rises.*

3.2 Large Tariffs

Now suppose that $\tau w_A > w_B$ for some Country B that is exempt from the new tariff. For the case of the Trump tariffs, Country B might represent, for example, Other Asia, Mexico, or the United States. In any case, the tariff is large enough such that Country B replaces Country A (e.g., China) as the preferred destination for new searches.

3.2.1 Renegotiation and Relocation

Once the large tariffs come into effect, producers may renegotiate terms with some of their original suppliers in Country A, while searching to replace others with new partners in the exempt Country B. When new searches do take place, the buyers draw match-specific (inverse) productivities from the distribution $G(\cdot)$. We let b denote the realization of such a draw and $\bar{b}^\tau = \bar{b}(\tau)$ denote the optimal stopping rule in the large-tariff equilibrium, analogous to a and $\bar{a}^\tau$, respectively. For relationships that endure, $\bar{b}^\tau$ is the reservation productivity that figures in the buyer's outside option. Let a_B be the inverse productivity of the marginal supplier that is retained after the tariff comes into effect, so that firms renegotiate with their initial suppliers that have match productivities $a \in (0, a_B]$ and replace those that have $a \in (a_B, \bar{a}]$. Of course, it may be that $a_B = \bar{a}$, in which case no new searches occur.

We can calculate the optimal stopping rule as we have done before, to derive an equation that relates $\bar{b}^\tau$ to the derived demand for the composite intermediate good, analogous to that for $\bar{a}$ in (5); see the Appendix A for details. Then we substitute this first-order condition for $\bar{b}^\tau$ into the Nash bargaining solution to obtain negotiated prices for inputs imported from countries A and B, respectively, as functions of the inverse match productivities, a and b.[21] This gives

$$\rho_A(a,\tau) = \beta w_A a + (1-\beta)\frac{w_B \bar{b}^\tau}{\tau} \tag{22}$$

and

$$\rho_B(b,\tau) = \beta w_B b + (1-\beta) w_B \bar{b}^\tau. \tag{23}$$

These bargaining outcomes imply that tariff-inclusive prices, $\tau\rho_A(a,\tau)$ and $\rho_B(b,\tau)$, are weighted averages of the unit cost of production-cum-delivery and the unit cost of an input that could be produced by a supplier in Country B with the reservation level of productivity. In this sense, (22) and (23) are analogous to (14). Moreover, these price equations imply that two inputs with the same unit cost of production-cum-delivery but different countries of origin carry the same delivered price. Notice that, if $w_B\bar{b}^\tau/\tau < w_A\bar{a}$, suppliers in Country A bear some of the burden of the tariff.

Facing these potential input prices, producers can make their optimal sourcing decisions. By definition, the stopping rule identifies the worst match that a buyer would accept conditional on searching in Country B and recognizing the costliness of further search. This worst match yields an opportunity to purchase an input at delivered price $\rho_B\left(\bar{b}^\tau,\tau\right) = w_B\bar{b}^\tau$. However, even before

[21] The Nash bargain with a supplier in country A with inverse match productivity a yields a price

$$\rho(a,\tau) = \arg\max_q \left[w_B\mu_b\left(\bar{b}^\tau\right) + \frac{f}{\beta m(\tau) G\left(\bar{b}^\tau\right)} - \tau q\right]^\beta (q - w_A a)^{1-\beta}.$$

The Nash bargain with a supplier in country B with inverse match productivity b yields a price

$$\rho(b,\tau) = \arg\max_q \left[w_B\mu_b\left(\bar{b}^\tau\right) + \frac{f}{\beta m(\tau) G\left(\bar{b}^\tau\right)} - q\right]^\beta (q - w_B b)^{1-\beta}.$$

commencing a new search, the buyer has access to its original supplier from whom it can buy at delivered price $\tau\rho_A(a,\tau) = \beta\tau w_A a + (1-\beta) w_B \bar{b}^\tau$ for a match with productivity a. If $\tau w_A a < w_B \bar{b}^\tau$, the original supplier offers a better deal than the reservation match. Conversely, if $\tau w_A a > w_B \bar{b}^\tau$, search in Country B yields a cost saving even if the firm realizes the worst possible match among those it will accept. It follows that $a_B = \min\left\{w_B \bar{b}^\tau / \tau w_A, \bar{a}\right\}$ and that producers retain suppliers with $a \leq \frac{w_B}{\tau w_A}\bar{b}^\tau$ while replacing those (if any) with $a > \frac{w_B}{\tau w_A}\bar{b}^\tau$.

We are ready to examine the equilibrium effects of large tariffs. Again, we invoke Assumptions 1 and 2. We use ϕ^τ, as before, to denote the tariff-inclusive marginal cost of the composite intermediate good for the original producers of final goods. Recall that these producers perceive a lower marginal cost of inputs than the average price that they pay for them, because they recognize that price per unit falls with the volume m^τ. For a fraction $G(a_B)/G(\bar{a})$ of inputs, the original producers continue to buy from their existing suppliers in Country A and perceive an average marginal cost of $\beta\tau w\mu_a(a_B) + (1-\beta) w_B \mu_b\left(\bar{b}^\tau\right)$. For the remaining fraction $1 - G(a_B)/G(\bar{a})$ of inputs (if any), they source from Country B and perceive an average marginal cost of $w_B\mu_b\left(\bar{b}^\tau\right)$. After collecting terms, the weighted average becomes

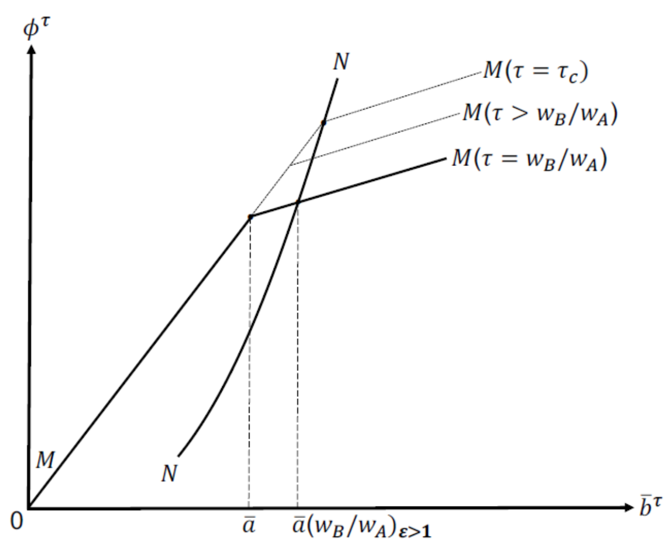
$$\phi^\tau = \beta\frac{G(a_B)}{G(\bar{a})}\tau w_A \mu_a(a_B) + \left[1 - \beta\frac{G(a_B)}{G(\bar{a})}\right] w_B \mu_b\left(\bar{b}^\tau\right) \ .$$

In Figure 3, the solid curve MM depicts the relationship between ϕ^τ and $\bar{b}^\tau$ for $\tau = w_B/w_A$. Under Assumption 2 of a Pareto distribution for match productivities, the curve is piecewise linear, with

$$\phi^\tau = \begin{cases} \frac{\theta}{\theta+1} w_B \bar{b}^\tau & \text{for } \bar{b}^\tau < \tau w_A \bar{a}/w_B \\ \frac{\theta}{\theta+1}\left[\beta\tau w_A \bar{a} + (1-\beta) w_B \bar{b}^\tau\right] & \text{for } \bar{b}^\tau > \tau w_A \bar{a}/w_B \end{cases} . \tag{24}$$

For $\bar{b}^\tau < \tau w_A \bar{a}/w_B$, it has a slope of $\frac{\theta}{\theta+1} w_B$, whereas for $\bar{b}^\tau > \tau w_A \bar{a}/w_B$, it has the shallower slope of $(1-\beta)\frac{\theta}{\theta+1} w_B$. With $\tau = w_B/w_A$, the curve kinks at $\bar{b}^\tau = \bar{a}$.

Figure 3: Large Tariff Equilibrium with Elastic Demand



As before, we need a second relationship between ϕ^τ and $\bar{b}^\tau$ to locate the equilibrium. Recall that $n(w_B/w_A) = n$, because operating profits per firm are smaller when $\tau = w_B/w_A > 1$ than when $\tau = 1$, and thus there is no entry beyond the free-entry level. We use the first-order condition for $m^\tau = x^\tau c'(\phi^\tau)$, the expression for the demand for variety ω in (3), and the expression for the price index, $P^\tau = p^\tau n^{-1/(\sigma-1)}$, much as we did in constructing the NN curve in Figure 2. Combining these equations, and applying Assumption 1 of a Cobb-Douglas technology and Assumption 2 of a Pareto distribution of match productivities, we find the new NN curve,

$$\frac{(\theta+1) f}{w_B \beta \left(\bar{b}^\tau\right)^{\theta+1}} = n^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} \alpha \left(\phi^\tau\right)^{\alpha(1-\varepsilon)-1} . \tag{25}$$

We have seen that the stopping rule with a large tariff $\tau = w_B/w_A$ is the same as the stopping rule with a small tariff of this size, and that both are less stringent than under free trade; i.e., $\bar{b}(w_B/w_A) = \bar{a}(w_B/w_A) > \bar{a}$. It follows that the intersection of the MM curve and the new NN curve in Figure 3 takes place to the right of the kink in the former curve, as drawn. Now let τ be something larger than w_B/w_A. The tariff rate does not appear in (25), except insofar as it influences the variables on the axes or the number of active firms. But as we raise τ above w_B/w_A, the portion of the MM curve to the right of the kink shifts upward, as can be seen from (24). For τ somewhat greater than w_B/w_A, the equilibrium occurs at the intersection of NN and the lowermost dashed curve in the figure. Here, $\bar{b}^\tau > \bar{a}$, but $\tau w_A \bar{a} < w_B \bar{b}^\tau$, so the original producers preserve the entirety of their supply chains. The parties renegotiate the terms of their exchange against the new outside option of search in Country B. Moreover, since operating profits are a declining function of τ in this range, no entry takes place.

For some still-higher tariff rate, the original producers of differentiated products are indifferent between relocating their worst matches to Country B and continuing on with their original suppliers. This tariff, which we denote by τ_c in the figure, is defined implicitly by $\tau_c w_A \bar{a} = w_B \bar{b}(\tau_c)$. Tariffs larger than τ_c disrupt the supply chains. For $\tau \geq \tau_c$, $a_B = \frac{w_B}{\tau w_A} \bar{b}(\tau_c) = \tau_c \bar{a}/\tau$ and so $\phi^\tau = \frac{\theta}{\theta+1} \tau_c w_A \bar{a}$. Further tariff hikes do not generate any further shifts in the MM curve at the equilibrium point. Rather, the stopping rule remains $\bar{b}^\tau = \bar{b}(\tau_c)$ and a_B declines with the size of the tariff. In other words, the higher the tariff for $\tau > \tau_c$, the more extensive is the reorganization of the supply chain. In this range, operating profits remain constant but profits net of additional search costs fall.[22]

We recap the effects of larger tariffs on the number and organization of supply chains in

Proposition 2 *Suppose Assumptions 1-3 hold and that $\tau > w_B/w_A$ for some Country B that is exempt from the tariff (possibly the home country). Then there is no new entry and the original producers preserve their entire supply chains in Country A for all $\tau < \tau_c$ defined by $\tau_c w_A \bar{a} = w_B \bar{b}(\tau_c)$; for $\tau > \tau_c$, these producers retain their initial suppliers in Country A for $a \leq \frac{\tau_c}{\tau} \bar{a}$, while replacing those with $\bar{a} \geq a > \frac{\tau_c}{\tau} \bar{a}$. The number of active firms is $n^\tau = n(1)$ for all $\tau > w_B/w_A$.*

[22] In Appendix A, we derive an explicit expression for τ_c, namely $\tau_c = (w_B/w_A)^{\frac{\theta}{\theta - \alpha(\varepsilon-1)}}$.

3.2.2 Effects of Large Tariffs on Average Input Prices, Perceived Marginal Cost, and Output Prices

Before closing this section, we note the effects of large tariffs on average input prices, perceived marginal cost, and output prices. For tariffs in the range $\tau \in [w_B/w_A, \tau_c]$, there is no entry of new brands. The original producers continue to procure all of their inputs in Country A, paying the prices recorded in (22). We see here the offsetting forces at work on the negotiated price. On the one hand, a higher tariff directly raises the value of a buyer's outside option to search in a tariff-free location. On the other hand, a higher tariff means that buyers would have less incentive to search intensely in Country B, were they to undertake such searches. In Appendix A we show that $\bar{b}^\tau$ rises less than in proportion to τ, so $\bar{b}^\tau/\tau$ declines with τ. It follows that higher tariffs improve the buyers' bargaining position vis-à-vis all of their suppliers and so reduce net-of-tariff input prices. The average input price becomes

$$\rho^\tau = \beta w_A \mu_a(\bar{a}) + (1-\beta)\frac{w_B \bar{b}^\tau}{\tau},$$

which is a declining function of τ.

Next consider tariffs large enough to induce partial relocation of supply chains to Country B. We have seen that search intensity is not affected by the size of the tariff in such circumstances; rather $\bar{b}^\tau = \bar{b}(\tau_c)$ for all $\tau > \tau_c$. From (22), we find that the prices of all inputs that continue to be imported from Country A fall with the tariff, as the option to shift production to a tariff-free source strengthens the buyers' bargaining position. Meanwhile, parts of the supply chain move from a relatively low-cost source to one with higher wages. We write the (net of tariff) weighted average cost of inputs from the alternative sources as

$$\rho^\tau = \frac{G(a_B)}{G(\bar{a})}\left[\beta w_A \mu_a(a_B) + (1-\beta)\frac{w_B \bar{b}^\tau}{\tau}\right] + \left[1 - \frac{G(a_B)}{G(\bar{a})}\right]\left[\beta w_B \mu_b\left(\bar{b}^\tau\right) + (1-\beta) w_B \bar{b}^\tau\right], \quad (26)$$

where $a_B = \frac{w_B}{\tau w_A}\bar{b}(\tau_c)$ in these circumstances. In Appendix A, we show that the fall in prices from Country A outweighs the shift in production to the higher-cost Country B if and only if $\tau < (\theta+1)/\theta$. If $\tau_c < (\theta+1)/\theta$, then there exists a range of tariffs above τ_c in which higher tariffs imply lower average input costs. Moreover, $\rho(\tau_c) = \rho$; i.e., at τ_c the average price of inputs are the same as when $\tau = 1$.[23] So, when $\tau_c < (\theta+1)/\theta$, there also exists a range of tariffs for which the net-of-tariff average price of inputs is less than with zero tariffs. For sufficiently high tariffs, however, most imports are sourced from Country B, where ex-factory prices are higher than those in Country A, so the average input price must be higher than that under free trade.

Producers of differentiated varieties set their prices, as before, at a fixed markup over their perceived marginal costs. As we have seen in Figure 3, ϕ^τ is an increasing function of τ for all

[23] At τ_c, $a_B = \bar{a}$ and $\bar{b}^\tau = \tau_c w_A \bar{a}/w_B$. Therefore, (22) implies

$$\rho(\tau_c) = \beta w_A \mu_a(\bar{a}) + (1-\beta) w_A \bar{a} = \rho.$$

$\tau \in (w_B/w_A, \tau_c)$. So, higher input tariffs give rise to higher perceived marginal costs and higher output prices throughout this range. For still higher tariffs such that $\tau > \tau_c$, producers perceive the marginal costs of the composite intermediate to be independent of the tariff rate. Consumer prices also are independent of the level of the tariff for $\tau > \tau_c$. But since $\phi^\tau > \phi$ and the markup is constant, prices are higher when $\tau > \tau_c$ than when $\tau = 1$ (i.e., free trade).

4 Welfare Effects of Unanticipated Tariffs

In this section, we derive expressions that relate changes in welfare in the importing country to changes in the tariff rate, for tariffs of different sizes. We identify several channels through which a surprise tariff affects welfare in a setting with extant supply chains that are subject to renegotiation and reorganization. We use these expressions in the next section to evaluate the tariffs introduced by the Trump administration during 2018 and 2019 on imports from China.

Welfare in the home country comprises total income (the sum of labor income, dividends paid by firms from their operating profits net of interest payments, and rebated tariff revenue) plus consumer surplus. We let $V(\tau) = \Pi(\tau) + T(\tau) + \Gamma(\tau)$ represent the sum of the three components of aggregate welfare that might vary with a tariff, where $\Pi(\tau)$ denotes aggregate variable profits net of the amortized value of any new search costs induced by the tariff τ, $T(\tau)$ denotes tariff revenue, and $\Gamma(\tau)$ represents the aggregate consumer surplus from purchases of differentiated products. In this section, we invoke Assumptions 1 and 2 to derive explicit expressions for each component of $V(\tau)$ and to calculate how aggregate welfare responds to a small tariff hike in the presence of global supply chains. Then, we can evaluate the total welfare effect of any tariff τ, $V(\tau) - V(1)$, using $V(\tau) = \Pi(1) + \Gamma(1) + \int_1^\tau V'(t)\,dt$, and we can decompose the change in welfare into components that capture the various distortions present in our model.

4.1 Increase in a Small Tariff

A marginal increase in a small tariff causes operating profits of the initial producers to fall. These firms undertake no novel searches and so bear no new fixed costs. Aggregate variable profits amount to $\Pi(\tau) = n(p^\tau x^\tau - \tau\rho^\tau m^\tau - \ell^\tau)$, the difference between revenues and the input costs for active firms. The government collects and rebates tariff revenue of $T(\tau) = n(\tau - 1)\rho^\tau m^\tau$ on the nm^τ units of imports by downstream producers at an average price of ρ^τ. Consumer surplus is given by $\Gamma(\tau) = U(X^\tau) - np^\tau x^\tau$. Summing these components, we have

$$V(\tau) = U(X^\tau) - n\rho^\tau m^\tau - n\ell^\tau, \tag{27}$$

the difference between aggregate utility from consuming differentiated products and the real resource cost of producing them.

Differentiating (27), we find

$$\frac{1}{n}\frac{dV^{\tau}}{d\tau}=\left(\frac{\sigma}{\sigma-1}-1\right)\frac{d\ell^{\tau}}{d\tau}+\left(\frac{\sigma}{\sigma-1}\phi^{\tau}-\rho^{\tau}\right)\frac{dm^{\tau}}{d\tau}-m^{\tau}\frac{d\rho^{\tau}}{d\tau}, \tag{28}$$

where we have used the fact that firms hire labor and purchase intermediate goods up to the point at which the marginal revenue product of each factor equals its marginal cost.

The first term on the right-hand side of (28) represents the net social benefit that results from a change in labor input in the differentiated-products sector. Since $\sigma/(\sigma-1)>1$, the wedge between the private and social marginal cost of labor is positive, and thus an increase in employment raises welfare, for given input usage and terms of trade. The positive wedge reflects the monopoly pricing of differentiated varieties. A tariff that induces a reduction in employment and output (for given m^{τ} and ρ^{τ}) contributes to a decline in aggregate welfare, much as in other settings with markup pricing.[24]

The second term represents the welfare effect of the change in input usage, for given employment and terms of trade. Here, the wedge between private and social marginal costs is $\zeta^{\tau}\equiv\frac{\sigma}{\sigma-1}\phi^{\tau}-\rho^{\tau}$. Three factors determine its sign and magnitude. First, $\sigma/(\sigma-1)>1$ contributes to a positive sign, suggesting underutilitization of intermediate goods, for much the same reason that market-generated employment is suboptimally low with markup pricing. Second, a tariff contributes directly to a higher private marginal cost of inputs, ϕ^{τ}, for given $\bar{a}^{\tau}$, as can be seen from the second row of (17). Since the tariff revenues accrue to the home government, the tariff does not figure directly in the social cost of inputs, ρ^{τ}. For this standard reason, a tariff raises the private cost of imports relative to the social cost, again suggesting underuse of inputs in the tariff equilibrium.

But a third, and novel, effect of a tariff pushes in the opposite direction when input prices are settled by negotiation. If buyers could negotiate collectively with all of their suppliers, they would agree on a jointly-optimal choice of m and would share the gains from productive efficiency. But joint negotiations are impractical with large numbers of suppliers. Instead, we have assumed "Nash-in-Nash" bargaining whereby firms negotiate individually with each of their suppliers, taking the outcome of their other negotiations as given. Buyers cannot discuss separately with each supplier the choice of m, because the technology requires that all inputs be used in fixed proportions. Instead, the buyer chooses m unilaterally and negotiates a price for this quantity of each of its inputs. In such circumstances, the downstream firm has an incentive to "overuse" intermediates in order to enhance its bargaining position vis-à-vis each of its suppliers. From (14) we see that the price falls with m; therefore, each buyer adjusts its input use to exploit its monopsony power.

Comparing (17) with (19), we see that any increase in $\bar{a}^{\tau}$ induced by a tariff hike raises the perceived private marginal cost ϕ^{τ} in proportion to $\tau(1-\beta)\frac{\sigma}{\sigma-1}\frac{\theta}{\theta+1}d\bar{a}^{\tau}$ while raising the social marginal cost ρ^{τ} in proportion to $1-\beta$. For $\tau\sigma/(1-\sigma)$ close to one, the first effect is smaller, which means that an increase in $\bar{a}^{\tau}$ contributes to a less positive, or possibly even a negative wedge. If the wedge ζ^{τ} happens to be negative, a decline in input use such as results from a tariff contributes

[24] See, for example, Helpman and Krugman (1989, pp. 137-145) or Campolmi et al. (2021).

positively to home welfare, for given employment ℓ^τ and terms of trade ρ^τ.

Finally, the third term on the right-hand side of (28) manifests yet another consideration that arises in supply chain relationships but is absent with arms-length purchase of intermediate goods. As in other settings with imperfect competition, trade policy redistributes profits from one party to the other.[25] Here, this works through the bilateral negotiations. As we have seen, any tariff that reduces τm^τ also dampens the incentives for search. But a less stringent stopping rule $\bar{a}^\tau$ carries with it a less imposing threat if a negotiation collapses, so a tariff tilts the table in favor of the suppliers. In short, any positive tariff delivers higher ex-factory prices for all inputs than under free trade, which imposes a terms-of-trade loss on the home country.

We can combine the three terms on the right-hand side of (28) to derive a necessary and sufficient condition for welfare to be declining in τ at $\tau = 1$. This requires some algebra, which we relegate to Appendix A.[26] There, we prove

Proposition 3 *Suppose Assumptions 1-3 hold. Then $dV/d\tau < 0$ locally at $\tau = 1$ if and only if*

$$\frac{\theta\varepsilon\left(\theta+\beta\right)}{\theta+\beta-\alpha\left(\varepsilon-1\right)\left(1-\beta\right)} > \left(1-\beta\right)\left(\sigma-1\right). \tag{29}$$

Clearly, (29) is satisfied if $\beta = 1$; indeed, if all bargaining power resides with the home producers, then any positive tariff reduces home welfare. The condition also is satisfied if $\theta/\left(\sigma-1\right) > \left(1-\beta\right)$, which is equivalent to $\left[\sigma/\left(\sigma-1\right)\right]\phi\left(1\right) > \rho\left(1\right)$; i.e., the middle term in (28) is negative when evaluated at $\tau = 1$. Another sufficient condition is $\alpha\varepsilon > \left(1-\beta\right)$.[27]

A point worth emphasizing, however, is that the usual welfare cost of an input tariff that reflects the underproduction of differentiated varieties in a setting of monopolistic competition is augmented by two additional considerations when producers create supply chains via costly search. First, a tariff alleviates misallocation associated with inefficient overuse of intermediates relative to labor in the production of final goods. This inefficiency results from a process of piecemeal negotiations with multiple suppliers. Second, a tariff worsens the terms of trade when producers negotiate with suppliers over input prices and resuming search becomes less attractive. The overall welfare cost may be larger or smaller than with competitive input markets and a small tariff might even increase home welfare.

4.2 Increase in a Large Tariff

When $\tau > w_B/w_A$, firms conduct any new searches in the tariff-exempt Country B, in place of the now-costlier Country A. Based on our earlier findings, there are two ranges of large tariffs to

[25] See the seminal papers on the use of tariffs to extract monopoly rents by Katrak (1977) and Svedberg (1979), and subsequent work by Brander and Spencer (1984), Helpman and Krugman (1989), and many others.

[26] In Appendix A, we also provide sufficient conditions for welfare to be declining in τ for all $\tau \geq 1$.

[27] Inequality (29) is equivalent to

$$\frac{\theta\varepsilon}{\sigma-1} > \left(1-\beta\right) - \frac{\alpha\left(\varepsilon-1\right)\left(1-\beta\right)^2}{\theta+\beta}$$

and Assumption 3 ensures that $\theta\varepsilon/\left(\sigma-1\right) > \alpha\varepsilon$.

consider. For $\tau \in (w_B/w_A, \tau_c)$, a tariff hike induces no new searches. For $\tau > \tau_c$, an increase in the tariff rate causes parts of the supply chain relocate to Country B after firms bear the cost of new searches. In these latter circumstances, we need to distinguish for welfare purposes whether Country B represents a foreign country or the country that implements the tariffs. If foreign, then home welfare includes as a negative component the full amount of the payments by producers of differentiated products to their input suppliers. If, instead, Country B denotes the home country, so that producers begin to reshore some of their inputs once the tariff is introduced, the deduction from home welfare comprises only the resource cost of these inputs, because the difference between price and cost accrues as profits to home suppliers.

Consider a marginal increase in τ when $\tau \in (w_B/w_A, \tau_c)$. Recognizing that supply chains remain in Country A and thus tariffs are applied to all imports in this case, we can write $V(\tau)$ as in (27). Then, differentiating this expression gives the same result as in (28). It is not necessary to repeat the arguments from Section 4.1, except to note that the first term again is negative, the second can be negative or positive according to the sign of the expression in parenthesis, and the last term is *positive* now, because higher tariffs in this range *improve* the terms of trade.

Turning to still larger tariffs with $\tau > \tau_c$, we find several new considerations in the welfare calculus. First, tariffs apply only to imports from Country A and thus only for inputs with $a \in (0, a_B]$. Second, ϕ^τ is independent of τ in this range, so that $d\ell^\tau/d\tau = dm^\tau/d\tau = 0$ and $dX^\tau/d\tau = dP^\tau/d\tau = 0$. Third, if the label B identifies the home country, then the final producers' payments to suppliers net of production costs contribute to home welfare. Finally, fresh searches in Country B generate additional fixed costs.

Suppose first that B denotes a foreign country. New searches are conducted by all n original producers for a fraction $1 - G(a_B)/G(\bar{a})$ of their inputs. These searches each have an expected flow cost of $f/G\left[\bar{b}(\tau_c)\right]$. Tariff revenues collected by the home government exactly offset the tariffs payments made by home producers. So, using Assumption 2, we can write

$$V(\tau) = U(X^\tau) - n\rho^\tau m^\tau - n\ell^\tau - nf\left[\left(\frac{\tau w_A}{w_B}\right)^\theta - \frac{1}{\bar{a}^\theta}\right]. \tag{30}$$

Since the tariff revenues collected by the home government exactly offset the tariffs payments made by home producers, we can write $\Pi(\tau) + T(\tau) = P^\tau X^\tau - n\rho^\tau m^\tau - n\ell^\tau$. With $\bar{b}^\tau = \bar{b}(\tau_c)$ for all $\tau > \tau_c$, perceived marginal costs, prices and factor demands are independent of τ. Only the terms of trade and the search costs vary with the tariff rate. Substituting $m^\tau = m/\tau$, we have

$$\frac{\tau}{n}\frac{dV^\tau}{d\tau} = -m^\tau \frac{d\rho^\tau}{d\tau} - \theta f\left(\frac{w_A}{w_B}\right)^\theta \tau^\theta, \text{ for } \tau > \tau_c. \tag{31}$$

The first term on the right-hand side of (31) represents the welfare effect of the change in the terms of trade. We calculated this term in (26). The second term represents the cost of new searches in Country B to replace the least-productive suppliers in Country A. Of course, higher tariffs induce more new searches, so the search costs grow with τ, which detracts from profits and welfare. Combining the two terms, we show in Appendix A that, if sourcing shifts from Country A to another foreign country, aggregate welfare increases with the tariff rate for $\tau > \tau_c$ if and only if

$$\tau < \frac{\theta + 1 - \beta}{\theta} \ . \tag{32}$$

Now suppose that B denotes the home country, so that the reorganization of the supply chain involves the reshoring of some inputs. In such circumstances, home welfare should include the profits earned by home input suppliers. The social cost of inputs then becomes

$$\rho^{\tau} = \frac{G(a_B)}{G(\bar{a})}\left[\beta w_A \mu_a(a_B) + (1-\beta)\frac{\bar{b}^{\tau}}{\tau}\right] + \left[1 - \frac{G(a_B)}{G(\bar{a})}\right] w_B \mu_b\left(\bar{b}^{\tau}\right),$$

where the second term now represents the cost of producing inputs at home rather than the prices that buyers pay for them. Using this expression for ρ^{τ}, we find that $d\rho^{\tau}/d\tau > 0$ if and only if $\tau > \left(\frac{\theta+1}{\theta}\right)\left(\frac{\theta+1-\beta}{\theta}\right)$. Since $(\theta + 1 - \beta)/\theta > 1$, this condition leaves more room for the real cost of inputs to fall when profits are shared domestically rather than with foreign suppliers. The calculations in Appendix A prove that aggregate welfare increases with the tariff rate in this case if and only if

$$\tau < \left(\frac{\theta+1}{\theta}\right)\frac{\theta + 1 - \beta}{\theta + \beta} \ .$$

We summarize our findings in

Proposition 4 *Suppose Assumptions 1-3 hold. (Terms of trade) For all $\tau_c > \tau > \frac{w_B}{w_A}$ and for $\tau > \max\{\tau_c, \frac{\theta+1}{\theta}\}$, $\rho(\tau)$ is increasing in τ. (Welfare) For $\tau > \tau_c$, (i) if Country B is a foreign country, welfare increases with τ if and only if $\tau < \frac{\theta+1-\beta}{\theta}$; (ii) if Country B is the home country, welfare increases with τ if and only if $\tau < \left(\frac{\theta+1}{\theta}\right)\frac{\theta+1-\beta}{\theta+\beta}$.*

5 Application to the Trump Tariffs

In this section, we apply our model to the tariffs introduced by the Trump administration. Arguably, these tariffs came as a surprise to American producers, in the sense that they were not anticipated when the firms formed their initial supply chains. Early waves of the tariffs were concentrated on intermediate and capital goods. Later waves expanded to include consumer goods, as the administration began to "run out" of intermediate and capital goods to target. In our baseline specification, we calibrate our model using all imports, recognizing that some supply chains include consumer goods. In Appendix B, we report a robustness check in which we exclude consumer goods from the calibration, and demonstrate a similar pattern of results.

We begin in Section 5.1 by calibrating the model's parameters using the schedule of tariffs introduced by the Trump administration between January 2018 and October 2019, the price and quantity responses revealed by an event-study analysis of this period, and other empirical moments pertaining to the United States. In Section 5.2, we report the model's predictions for the terms of trade and welfare, and compare our estimates to those from conventional quantitative trade models. We also consider the welfare effects of tariffs smaller and larger than the ones that were actually implemented. Section 5.3 examines the robustness of our predictions to alternative parameter values and model specifications, including a counterfactual in which we assume that all supply relationships displaced by the tariffs are relocated to the United States rather than to other Asian countries.

5.1 Parameter Calibration

We discipline the predictions of our model by calibrating its parameters to match empirical estimates of the price and quantity response to the Trump tariffs. We interpret Country A in the model as corresponding to China in the data. Motivated by our empirical findings of a relocation of U.S. imports to other Asian countries, we designate Other Asia as Country B in the model.

The parameters of the model include the tariff rate τ, the demand elasticities σ and ε, the cost share of intermediate inputs α, the Nash bargaining parameter β, the fixed operating, entry and search costs f_o, f_e, and f, the effective wages w_A and w_B in Countries A and B, and the Pareto shape parameter θ that captures dispersion of supplier productivity. In Table 2, we list these parameters, their calibrated values, and the source for each one. We now discuss these entries in turn.

In our baseline specification, we set the tariff τ equal to the import-weighted average of the tariffs imposed by the Trump administration on China across all goods, using 2017 import shares as weights. This yields $\tau = 1.14$. Given our other calibrated model parameters, we show below that $\tau > \tau_c$, such that firms undertake new searches in Country B, consistent with the relocation of import sourcing in the data.

We take demand parameters from earlier studies of the Trump tariffs. In particular, we use for the elasticity of substitution across varieties and the elasticity of demand for the group of differentiated products, respectively, the estimates from Fajgelbaum et al. (2020) across 10-digit HTS products within industries and across 4-digit North American Industry Classification Systems (NAICS) categories. This gives $\sigma = 2.53$ and $\varepsilon = 1.19$, which satisfy our assumptions of elastic demand across sectors ($\varepsilon > 1$), and a higher elasticity across varieties than across sectors ($\sigma > \varepsilon$). The value of σ that we use is close to the median estimate of 3.1 in Broda and Weinstein (2006) across 10-digit HTS products for U.S. imports from 1990-2011. The value of ε is close to the estimate of 1.36 across NAICS 4-digit industries in Redding and Weinstein (2021).

We turn next to the variable cost and bargaining parameters. We set the cost share of intermediate inputs to match the aggregate share of intermediates in U.S. firms' costs, which yields $\alpha = 0.45$. We choose the Nash bargaining weight so that the share of profits in differentiated sector expenditure in the model matches the observed 5% profit share in U.S. manufacturing in 2017, which yields $\beta = 0.8$.

As for the fixed costs of search, operation and entry, our estimates are rough, but not essential

Table 2: Calibration of Model Parameters

Parameter	Notation	Calibrated Value	Source
Sector elasticity	ε	1.19	Fajgelbaum et al. (2020)
Variety elasticity	σ	2.53	Fajgelbaum et al. (2020)
Intermediate costs	α	0.45	Input cost share U.S. manufacturing
Bargaining weight	β	0.80	Profit share U.S. manufacturing
Home wage		1	Numeraire
Labor supply	L	19.48	U.S. Gross Domestic Product (GDP) in 2017
Fixed operating cost	f_o	0.0025	Share of Manufacturing in GDP
Fixed search cost	f	f_o / 100	Institute of Management (2018)
Fixed entry cost	f_e	Such that $\tau_c < \tau < \tau_{ex}$	Relocation of import sourcing in response to the Trump tariffs
Country A wage	w_A	0.20	Relative China-U.S. GDP per capita (purchasing power parity)
Relative Country B wage	w_B / w_A	1.12	Estimated declines of U.S.-China imports
and productivity dispersion	θ	9.26	(34.23%) and of Chinese export prices (2.14%)

Note: The first column lists each parameter; the second column contains the corresponding notation; the third column gives its calibrated value; the fourth column summarizes the source for this calibrated value.

for our conclusions.[28] The Institute of Supply Managements (2018) reports that procurement accounts for an average of about 1.2% of total spending in the U.S. private sector. Based on this rough estimate, we set $f/f_o = 0.01$. We calibrate the level of the fixed operating cost f_o so that the share of the differentiated sector in gross domestic product (GDP) in our model matches the 11% share of manufacturing in 2017 U.S. GDP. Finally, we calibrate the ratio of the fixed entry cost to the fixed operating cost, f_e/f_o, so that a tariff of 14% induces a relocation of input sourcing but does not induce exit from the differentiated products sector; this requires

$$\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} < \frac{f_o}{f_e+f_o} < \frac{\theta-(1-\beta)\,\alpha\,(\sigma-1)}{\theta-\alpha\,(\sigma-1)}\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}.$$

Given any finite positive value for f_o, we can find a finite positive value for f_e such that the two inequalities are satisfied. We choose the fixed entry cost (f_e) such that $f_o/\left(f_e+f_o\right)$ lies mid-way between the above lower bound of $\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}$ and its upper bound of one.

We set w_A to generate an income per capita in Country A equal to one fifth of that in the home country, which is line with relative per capita GDP in purchasing power parity (PPP) terms in China versus the United States in 2017.

The remaining two parameters, θ and w_B/w_A, representing the dispersion of match productivities and the relative cost disadvantage of Country B, play central roles in determining the terms of trade and welfare impact of tariffs in our model. We choose these key parameters to match the event-study estimates of the impact of the Trump tariffs on U.S.-China import values and Chinese export prices in Amiti et al. (2020).[29] In line with a range of other empirical studies, these

[28] We show in Appendix A that the welfare effect of a tariff, normalized by total spending on differentiated products (such as we estimate below) does not depend on f, f_o, or f_e under Assumptions 1 and 2. Therefore, the calibrated values of these parameters are not consequential for the variables of interest to us.

[29] An advantage of the estimates in Amiti et al. (2020) is that the sample period includes the two waves of U.S. tariffs on China in June and September 2019. In contrast, the sample periods in Amiti et al. (2019) and Fajgelbaum et al. (2020) end in December 2018 and April 2019, respectively.

event-study estimates imply a sharp decline in U.S.-China import values and almost complete pass-through of the tariffs into U.S. consumer prices. Twelve months after a tariff wave, the estimated elasticity of U.S. import values with respect to the tariff is 2.15, while the estimated elasticity of U.S. import prices is 0.96, implying a corresponding elasticity of Chinese exporter prices with respect to the tariff of -0.04, as discussed further in Appendix B.[30] Multiplying these estimated elasticities by the changes in U.S. tariffs on China, we obtain an estimated decline by October 2019 of 34 percent in U.S.-China import values and 2 percent in Chinese export prices.[31]

With the other calibrated parameters described above, our model exactly matches the observed value and price responses when $\theta = 9.26$ and $w_B/w_A = 1.12$. A Pareto shape parameter of $\theta = 9.26$ is towards the high end of the range of values considered in the trade literature. However, in our model, this parameter governs productivity dispersion across input suppliers, where intermediate inputs account for only 45 percent of total production costs. A relative cost disadvantage of Country B of $w_B/w_A = 1.12$ is larger than observed differences in income per capita in purchasing power parity terms between other Asian countries and China. However, w_B/w_A in the model corresponds to the relative wage per efficiency unit of labor in Country B, which can differ systematically from the relative observed wages. By construction, relative production costs in Other Asia must have been higher than in China before the tariff, otherwise these imports would not have been sourced from China. More broadly, if labor is less productive in other Asian countries than in China, relative production costs in Other Asia will be larger than relative observed wages.

5.2 Effects of the Trump Tariffs on U.S. Terms of Trade and Welfare

Using the calibrated parameters described in the previous section, we now evaluate our model's predictions for the impact of the Trump tariffs on U.S. terms of trade and welfare.

5.2.1 Terms of Trade

In Figure 4, we show our model's predictions for changes in the terms of trade as a function of the level of the tariff. The black solid line depicts the relative change in the home country's average input prices (ρ^{τ}/ρ), which corresponds to an inverse measure of its overall terms of trade. The broken gray line illustrates the relative change in the price of imports from Country A (ρ^{τ}_A/ρ).

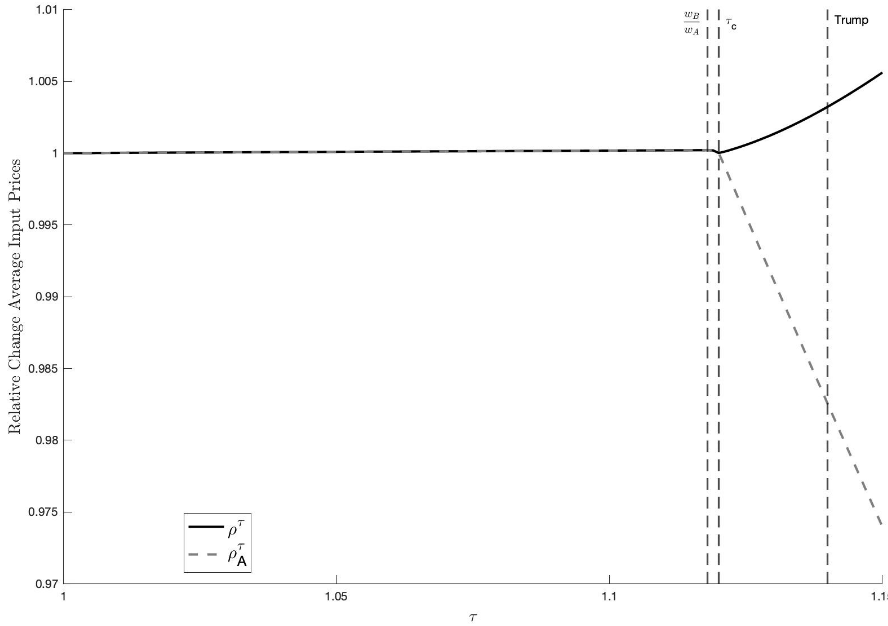
For small tariffs in the range $\tau \in (1, w_B/w_A)$, the model predicts an upward-sloping relationship between ρ^{τ}_A and τ due to renegotiation with extant suppliers under the shadow of the tariff. However, for our calibrated parameter values that give most of the bargaining power to the buyer, this effect is quite muted. We find that $\rho^{\tau}/\rho = 1.0002$ for $\tau = w_B/w_A = 1.12$, a tiny deterioration in the terms of trade. Throughout the range of small tariffs, all imports are sourced from Country

[30] These estimated elasticities for import values and prices are close to the estimate of -1.42 in Amiti et al. (2019) and the estimate of -2.53 in Fajgelbaum et al. (2020, 2021).

[31] In comparison, the observed share of China in U.S. imports declined from 21.6 percent in 2017 to 17.0 percent by the end of 2022, which reflects not only the change in U.S.-China tariffs, but the combined impact of all other shocks in the data.

A, so the gray dashed line for home's average input prices from that country coincides with the black solid line representing its overall average input prices.

Figure 4: Effects of Tariffs on Average Input Prices (Inverse Terms of Trade)



Note: Black solid line shows the relative change in overall average input prices under the tariff (ρ^τ/ρ); gray dashed line shows the relative change in average input prices from Country A (ρ^τ_A/ρ); vertical black dashed lines show w_B/w_A, $\tau_c = 1.12$ and our calibrated Trump tariff of $\tau = 1.14$.

Next comes a range of larger tariffs with $\tau \in (w_B/w_A, \tau_c)$ wherein an increase in the tariff strengthens the bargaining power of the *buyers* without inducing any relocation away from Country A. Here, a higher tariff improves the home country's terms of trade. For our parameter values, the range of tariffs that generate a downward-sloping black curve is quite narrow, as can be seen in the figure. The analysis predicts that the overall terms of trade when $\tau = \tau_c$ matches that under free trade; i.e. $\rho(\tau_c)/\rho = 1$.

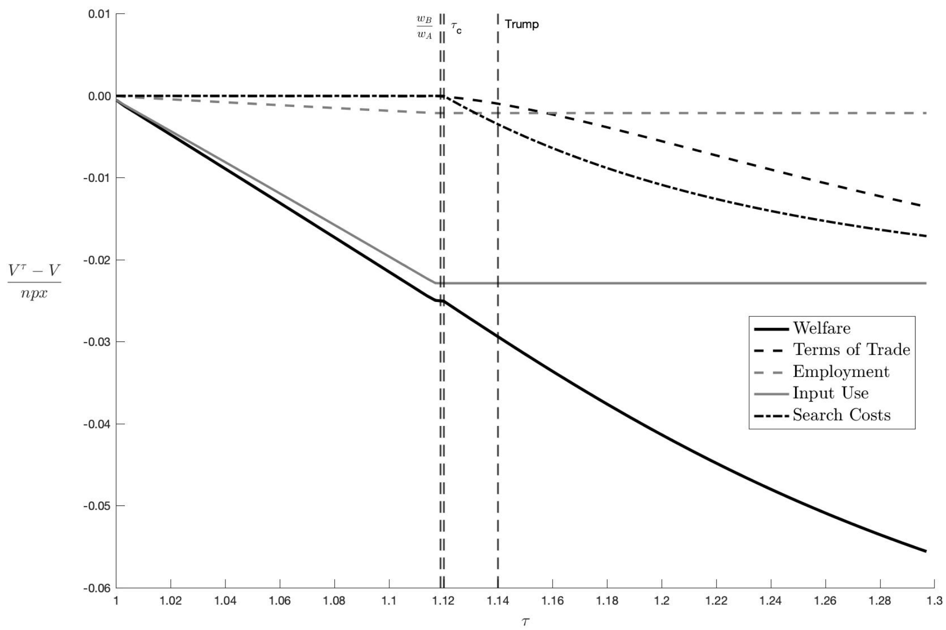
For still larger tariffs with $\tau > \tau_c$, there are two offsetting effects of further tariff hikes. On the one hand, higher tariffs continue to strengthen the buyers' bargaining positions vis-à-vis their suppliers in Country A. This strengthening bargaining position leads to a further improvement in the terms of trade with Country A, as shown by the downward-sloping gray dashed line. On the other hand, increases in the tariff rate beyond τ_c cause parts of the supply chain to relocate from a relatively low-cost to a relatively high-cost country. When this relatively high-cost country is a foreign nation, as in our baseline specification, this amounts to Vinerian trade diversion, and it contributes towards an overall deterioration in the terms of trade.

Proposition 4 states that the Vinerian effect dominates the renegotiation effect if and only if $\tau > \max\{\tau_c, \frac{\theta+1}{\theta}\}$. Our calibrated value of $\theta = 9.26$ implies $(\theta+1)/\theta = 1.11$, whereas $\tau_c = 1.12$. Therefore, throughout the entire range of tariffs $\tau > \tau_c$, further increases in tariffs raise average input prices and worsen the terms of trade in the home country, as reflected in the upward slope of the black curve to the right of τ_c. Although the cost of Vinerian trade diversion to Other Asia dominates, we find the renegotiation of import prices with Chinese suppliers to be quantitatively significant in this range.

Finally, our model generates a prediction about the overall terms-of-trade impact of the Trump tariffs of $\tau = 1.14$. Overall, we find a small terms-of-trade deterioration of 0.42% despite a 2% fall in the price of imports from China.

5.2.2 Welfare

The black solid curve in Figure 5 depicts our model's predictions about the change in home welfare relative to initial spending on differentiated products, for different values of the tariff. The necessary and sufficient condition for $dV/d\tau < 0$ at $\tau = 1$—as provided in Proposition 3—is satisfied for our calibrated parameters. Moreover, the requirement for an increase in a large tariff to enhance home welfare (see (32)) is violated with our parameters for all $\tau > \tau_c = 1.12$. In short, we find that the calibrated parameters imply a monotonically decreasing relationship between home welfare and the size of the tariff, except in the narrow range between w_B/w_A and τ_c.



Note: Changes in welfare and its components are scaled by differentiated sector expenditure (npx) to ensure that they are invariant to the choice of units in which to measure home income; black solid line shows the overall change in welfare ($\left(V^\tau - V\right)/npx$); black dashed line shows the change in the terms of trade ($\left(\rho^\tau - \rho\right)/npx$); gray dashed line shows the change in employment ($\left(l^\tau - l\right)/npx$); gray solid line shows the change in input use ($\left(m^\tau - m\right)/npx$); black dashed-dotted line shows the additional fixed costs for new searches (Σ/npx); vertical black dashed lines show w_B/w_A, τ_c and our calibrated Trump tariff of $\tau = 1.14$.

The figure also shows a decomposition of the welfare change into four components representing the welfare effects of changes in employment, changes in input usage, changes in the terms of trade, and the cost of new searches, all relative to initial spending on differentiated products,

PX; see Appendix B for details.[32] For the range of small tariffs, most of the welfare cost can be associated with the depressed use of imported intermediate goods. Although, theoretically, the wedge $\zeta^\tau \equiv \frac{\sigma}{\sigma-1}\phi^\tau - \rho^\tau$ in (28) might be positive or negative, Figure B.8 in Appendix B shows that it is always positive for our calibrated parameter values. Therefore, the reduction in input use induced by a tariff contributes to an aggregate welfare loss. Reductions in industry employment account for a small further loss, but for small tariffs the worsening of the terms of trade contributes hardly at all. For the range of large tariffs ($\tau > \tau_c$), employment and input use remain constant, so their contributions to the welfare cost do not grow further. In this range of large tariffs, deterioration of the terms of trade grows as a source of welfare loss, as does the cost of new searches. At $\tau = 1.14$, search costs account for roughly 10% of the total welfare loss from the tariff. For larger tariffs than this, their share can be substantially higher.

Our model's predictions of the total welfare loss from the Trump tariffs are broadly in line with the results from other quantitative trade models. Amiti et al. (2019) and Fajgelbaum et al. (2020) estimate welfare costs of the Trump tariffs of \$8.2 billion and \$7.2 billion, respectively, which amounts to about 0.04 percent of GDP. These welfare losses are small relative to GDP, in part because much of national spending is devoted to services that are not directly affected by the tariffs. In comparison, Figure 5 shows a welfare loss of 3.03 percent of spending on differentiated products for $\tau = 1.14$. If we associate the differentiated-products sector with U.S. manufacturing, then our estimate translates into a welfare loss of about 0.3 percent of GDP.

5.3 Robustness

We next probe the robustness of our quantitative conclusions to variations in our assumptions, as discussed in further detail in Appendix B.

First, we examine the sensitivity of our welfare estimates to alternative parameter values. As we vary the productivity dispersion parameter from $\theta = 2$ to $\theta = 12$, holding other parameters constant, the predicted declines in U.S.-China import values and Chinese export prices vary from -40.42 to -17.97 percent and from -2.17 to -1.74 percent, respectively. Nevertheless, we continue to find welfare losses from the tariff, with the percentage change in welfare relative to spending on differentiated products ranging narrowly from -3.19 to -2.38 percent, compared to -3.03 percent in our baseline specification. Evidently, our welfare estimates are not too sensitive to the value of θ within the range of values considered in the trade literature.

Second, we re-calibrate the model after excluding consumer goods from the set of imports that we consider to be part of the U.S. supply chains. For this narrower set of imports that includes only capital and intermediate goods, we find a somewhat larger fall in Chinese export prices of 4.26 percent. When calibrated to this larger fall in Chinese export prices, our model implies an improvement in the overall terms of trade of 1.91 percent, compared to a small deterioration of 0.42 percent in our baseline specification. Nevertheless, since the terms-of-trade component in the

[32] These four terms represent the cumulative welfare effects of the three terms on the right-hand side of (28) combined with the total search costs, given by the integral of the fourth term in (31) over $\tau > \tau_c$.

welfare decomposition is relatively small, the estimated total welfare loss of -2.44 percent is not too different from our baseline estimate of -3.03 percent.

Third, we undertake a counterfactual in which we assume that new supplier relationships are formed in the United States, rather than in other Asian countries. For this exercise, we hold all other parameters constant to see the significance of continued offshoring versus onshoring. While the inclusion in home welfare of the profits earned by domestic input suppliers reduces the welfare loss from the tariff, this offset is relatively modest. When the new suppliers are assumed to be U.S. firms, the welfare loss of the tariff is estimated to be 2.92 percent of domestic spending on differentiated products, compared to the 3.03 percent loss that we found in our baseline specification.

Across a range of specifications, we find that our calibrated model predicts welfare losses from the Trump tariffs and from tariffs larger and smaller than those actually applied. The novel mechanisms highlighted in this paper account for a non-negligible portion of these losses.

6 Conclusions

Traditional tariff analysis focuses on supply and demand elasticities and Harberger triangles. Of course, subsequent literature has addressed many types of market imperfections, including those arising from monopoly power and from factor-market distortions. Yet, the rise of global supply chains introduces some novel considerations to the evaluation of trade barriers, especially when tariffs are applied to imports of intermediate goods.

In this paper, we have stressed the relational aspects of supply chains, as highlighted in the 2020 World Development Report. The formation of supply chains often requires costly search. Partnerships may vary in productivity. Supply relationships might be governed by imperfectly-enforceable contracts that can be renegotiated when circumstances change. Bargaining might take place separately between a buyer and many, independent suppliers.

We have identified several new mechanisms by which unanticipated tariffs may impact prices and welfare. First, negotiations with suppliers may be conducted in the shadow of renewed search. When the outside option for a buyer is to find an alternative supplier, the negotiated price depends upon the factors that govern the intensity of search and its eventual prospects. If a tariff weakens the incentives for search, the bargaining table tilts in favor of suppliers. In contrast, if a tariff makes search in some different destination relatively more attractive, the negotiations may result in shared incidence of the levy.

Second, bargaining can drive a wedge between the marginal cost of inputs as perceived by final-good producers and their true social cost. When a downstream firm bargains independently with many suppliers, it becomes impractical to negotiate levels of input demands that are jointly efficient. If, instead, the downstream firm decides its factor demands unilaterally, it will recognize a connection between that choice and the eventual per-unit price. The firm will perceive a marginal cost of inputs different from their average cost, which generates an inefficient (but privately profitable) choice of production technique.

Third, large tariffs can induce firms to replace their least efficient suppliers with alternatives at home or in countries that are exempt from the tariff. In the latter case, the relocation of portions of the supply chain amounts to Vinerian trade diversion. In both cases, the additional search costs become a hidden component of the welfare calculus.

We have analyzed tariffs that are introduced after global supply chains are already in place. With original search and entry costs sunk, firms remain active as long as they can cover their operating costs and supply relationships endure in the face of shocks. We consider tariffs that are small enough to leave the location of the supply chain as originally situated and larger tariffs that make a new destination more attractive.

In our second-best setting, input tariffs can generate either positive or negative effects on the terms of trade and welfare. To gauge which outcomes might be most empirically relevant, we calibrated our model's parameters using the price and quantity response to the Trump administration's tariffs and other empirical moments for the U.S. economy. We treated China as the original location of sourcing by American producers and Other Asian countries, such as Vietnam and the Philippines, as the place where they shifted the least productive parts of their supply chains after the discriminatory tariffs were introduced. In our baseline calibration, we found that the Trump tariffs improved the U.S. terms of trade vis-à-vis China by 2%, but worsened its overall terms of trade by 0.5%. We estimated a welfare loss for the U.S. economy of 0.3% of GDP or 3% of initial spending on differentiated products.

More broadly, our paper contributes a tractable analytic framework for studying the complex adjustments that occur when various unanticipated shocks disrupt global supply chains. Our framework can be extended to allow for heterogeneous suppliers who enjoy comparative advantage in different parts of the production process. Comparative advantage would provide a ready explanation for multi-country sourcing, as in Blaum et al. (2017) and Antràs et al. (2017). And whereas we have set aside the holdup problems emphasized by Ornelas and Turner (2008) and Antràs and Staiger (2012) in order to focus on costly search, it should be possible to combine these features in a future analysis.

References

[1] Amiti, Mary, Redding, Stephen J., and David E. Weinstein, 2019. “The Impact of the 2018 Tariffs on Prices and Welfare,” *Journal of Economic Perspectives 33:4*, 187-210.

[2] Amiti, Mary, Redding, Stephen J., and David E. Weinstein, 2020. “Who’s Paying for the US Tariffs? A Longer-Term Perspective,” *AEA Papers and Proceedings 110*, 541-546..

[3] Antràs, Pol, 2020, “Conceptual Aspects of Global Value Chains,” *The World Bank Economic Review 34:3*, 551-574.

[4] Antràs, Pol and Davin Chor, 2013. "Organizing the Global Value Chain,” *Econometrica 81:6*, 2127-2204.

[5] Antràs, Pol, Fort, Theresa, and C. and Felix Tintelnot, 2017. “The Margins of Global Sourcing: Theory and Evidence,” *American Economic Review 107:9*, 2514-2564.

[6] Antràs, Pol and Elhanan Helpman, 2004. “Global Sourcing,” *Journal of Political Economy 112:3*, 552-580.

[7] Antràs, Pol and Robert W. Staiger, 2012. “Offshoring and the Role of Trade Agreements,” *American Economic Review 102:7*, 3140-3183.

[8] Baldwin, Richard E. and Anthony J. Venables, 2011. “Spiders and Snakes: Offshoring and Agglomeration in the Global Economy,” *Journal of International Economics 90:2*, 245-254.

[9] Benkert, Jean-Michel, Letina, Igor, and Georg Nödeke, 2018. “Optimal Search from Multiple Distributions with Infinite Horizon,” *Economic Letters 164*, 15-18.

[10] Bernard, Andrew B. and Andreas Moxnes, 2018. “Networks and Trade,” *Annual Review of Economics 10*, 65-85.

[11] Blanchard, Emily J., Bown, Chad P and Robert C. Johnson, 2021. “Global Value Chains and Trade Policy,” Dartmouth College, mimeo.

[12] Blaum, Joaquin, Lelarge, Clair and Michael Peters, 2018. “The Gains from Input Trade with Heterogeneous Importers,” *American Economic Journal: Macroeconomics 10:4*, 77-127.

[13] Bloomberg News, 2019.“Trump Tariffs Seal the Deal for Companies Looking to Quit China,” *Bloomberg News* May 16, 2019,
https://www.bloomberg.com/news/articles/2019-05-16/trump-tariffs-seal-the-deal-for-companies-looking-to-quit-china.

[14] Brander, James A. and Barbara Spencer, J. “Trade Warfare: Tariffs and Cartels,” *Journal of International Economics 16:3*, 227-242.

[15] Breuninger, Kevin, 2019. “Trump says He’s Ordering American Companies to Immediately Start Looking for an Alternative to China,” *CNBC*, August 23, 2019, https://www.cnbc.com/2019/08/23/trump-says-hes-ordering-american-companies-to-immediately-start-looking-for-an-alternative-to-china.html.

[16] Brügemann, Bjorn, Gautier, Pieter and Guido Menzio, 2019. “Intra Firm Bargaining and Shapley Values,” *Review of Economic Studies 82:2,* 564-592.

[17] Caliendo, Lorenzo and Fernando Parro, 2015. "Estimates of the Trade and Welfare Effects of NAFTA,” *Review of Economic Studies 82:1*, 1-44.

[18] Campolmi, Alessia, Fadinger, Harald, and Chiata Forlati, 2018. “Trade and Domestic Policies in Models with Monopolistic Competition,” http://fadinger.vwl.uni-mannheim.de/Research_. . . les/CFF_2018_1004.pdf.

[19] Casas, Francisco R., 1973. “Optimal Effective Protection in General Equilibrium,” *American Economic Review 64:3*, 714-716.

[20] Collard-Wexler, Allan, Gowrisankaran, Gautam, and Robin S. Lee, 2019. “‘Nash-in-Nash’ Bargaining: A Microfoundation for Applied Work,” *Journal of Political Economy 127:1*, 163-195.

[21] Das, Satya, 1983. “Optimal Tariffs on Final and Intermediate Goods,” *International Economic Review 24:2*, 493-508.

[22] Demidova and Andrés Rodríguez-Clare, 2013. “The Simple Analytics of the Melitz Model in a Small Open Economy,” *Journal of International Economics 90:2*, 266-272.

[23] Fajgelbaum, Pablo D., Goldberg, Pinelopi K., Kennedy, Patrick J. and Amit K. Khandelwal, 2020. “The Return to Protectionism,” *Quarterly Journal of Economics 135:1*, 1-55.

[24] Fajgelbaum, Pablo D., Goldberg, Pinelopi K., Kennedy, Patrick, Khandelwal, Amit and Daria Taglioni, 2021. “The U.S.-China Trade War and Global Reallocations,” NBER Working Paper No. 29562.

[25] Grossman, Gene M. and Esteban Rossi-Hansberg, 2008. “Trading Tasks: A Simple Theory of Offshoring,” *American Economic Review 98:5*, 1978-1997.

[26] Grubel, Herbert G. and Harry G. Johnson, eds., 1971. *Effective Tariff Protection*, Geneva: GATT and the Graduate Institute of Economics Studies.

[27] Halpern, László, Koren, László, and Adam Szeidl, 2015. “Imported Inputs and Productivity,” *American Economic Review 105:12*, 3660-3703.

[28] Helpman, Elhanan and Paul R. Krugman, 1989. *Trade Policy and Market Structure*, Cambridge, MA: The MIT Press.

[29] Huang, Eustance, 2019. "Thailand is a 'Leading Beneficiary' of the Trade War, says Standard Chartered", *CNBC* Nov 4, 2019, https://www.cnbc.com/2019/11/05/thailand-is-a-leading-beneficiary-of-the-us-china-trade-war-stanchart.html.

[30] Hufford, Austen and Bob Tita, 2019. "Manufacturers Move Supply Chains Out of China," *The Wall Street Journal* July 14, 2019, https://www.wsj.com/articles/manufacturers-move-supply-chains-out-of-china-11563096601.

[31] Katrak, Homi, 1977. "Multi-National Monopolies and Commercial Policy," *Oxford Economic Papers 29:2*, 283-291.

[32] Kawanami, Takeshi and Takeshi Shiraishi, 2019. "Trump's Latest China Tariffs to Shock Global Supply Chains," *Nikei Asian Review* May 12, 2019, https://asia.nikkei.com/Economy/Trade-war/Trump-s-latest-China-tariffs-to-shock-global-supply-chains.

[33] Kearney, 2020. *Trade War Spurs Sharp Reversal in 2019 Reshoring Index, Foreshadowing COVID-19 Test of Supply Chain Resilience*, Washington DC: Kearney.

[34] Master, Farah, Sriring, Orathai, and Anne Marie Roantree, 2018. "Supply Chain Reaction: Trade War Refugees Race to Relocate to Vietnam, Thailand," *Reuters* November 28, 2018, https://www.reuters.com/article/us-usa-trade-china-vietnam/supply-chain-reaction-trade-war-refugees-race-to-relocate-to-vietnam-thailand-idUSKCN1NX2XZ.

[35] Ornelas, Emanuel and John L. Turner, 2008. "Trade Liberalization, Outsourcing, and the Hold-up Problem," *Journal of International Economics 74:1*, 225-241.

[36] Ornelas, Emanuel and John L. Turner, 2012. "Protection and International Sourcing," *The Economic Journal 122:559*, 26-63.

[37] Ornelas, Emanuel, Turner, John L. and Grant Bickwit, 2021. "Preferential Trade Agreements and Global Sourcing," *Journal of International Economics 128*, doi: 10.1016/j.jinteco.2020.103395.

[38] Reed, J.R., 2019. "President Trump Order Firms to Ditch China, but Many Already Have and More are on the Way," *CNBC* September 1, 2019, https://www.cnbc.com/2019/09/01/trump-ordered-us-firms-to-ditch-china-but-many-already-have.html.

[39] Ruffin, Roy J., 1969. "Tariffs, Intermediate Goods and Domestic Protection," *American Economic Review 59:3*, 261-269.

[40] Soon, Stella, 2019. "Investors Have Set Their Eyes on Thailand as the Trade War Deepens, says CEO," *CNBC* August 27, 2019, https://www.cnbc.com/2019/08/27/us-china-trade-war-companies-looking-to-invest-in-thailand-vietnam.html.

[41] Stole, Lars A. and Jeffrey Zwiebel, 1996. "Infor-firm Bargaining under Non-Binding Contracts," *Review of Economic Studies 63,* 375-410.

[42] Svedberg, Peter, 1979. “Optimal Tariff Policy on Imports from Multinationals,” *Economic Record 55,148*, 64-67.

[43] Venables, Anthony J., 1987. “Trade and Trade Policy with Differentiated Products: A Chamberlinian-Ricardian Model,” *The Economic Journal 97:387*, 700-717.

[44] World Bank, 2020. *World Development Report 2020: Trading for Development in the Age of Global Value Chains*, Washington DC: The World Bank.

Appendix A: Analytical Appendix

When Tariffs Disturb Global Supply Chains

by

Gene M. Grossman, Elhanan Helpman and Stephen J. Redding

Table of Contents

Section 1 Introduction

This appendix provides proofs and derivations for the Propositions and analytical expressions in the main text. Section numbers in the appendix correspond to those in the main text. We also derive the analytical expressions used in the calibration exercise.

Section 2 Foreign Sourcing with Search and Bargaining

We start from the bargaining game, which determines the payment to a supplier with inverse match productivity a for one unit of the intermediate input. The Nash bargaining solution solves

$$\rho(a) = \arg\max_{q} (qm - wam)^{1-\beta} \left[\mu_\rho(\bar{a})\, m + \frac{f}{G(\bar{a})} - qm\right]^{\beta}.$$

The first-order condition for the maximization on the right-hand side yields

$$\frac{1-\beta}{\rho(a) - wa} = \frac{\beta}{\mu_\rho(\bar{a}) + \frac{f}{mG(\bar{a})} - \rho(a)}$$

and therefore

$$\rho(a) = \beta wa + (1-\beta)\,\mu_\rho(\bar{a}) + (1-\beta)\frac{f}{mG(\bar{a})}.$$

Taking the conditional mean of both sides of this equation for $a \leq \bar{a}$, we have

$$\mu_\rho(\bar{a}) = w\mu_a(\bar{a}) + \frac{1-\beta}{\beta}\frac{f}{mG(\bar{a})}. \tag{A.1}$$

Substituting this result back into the $\rho(a)$ function then gives

$$\rho(a) = \beta wa + (1-\beta)\,w\mu_a(\bar{a}) + \frac{1-\beta}{\beta}\frac{f}{mG(\bar{a})}, \tag{A.2}$$

which is equation (4) in the main text. Next we use (5), the first-order condition for $\bar{a}$. This states

$$mw\mu_a'(\bar{a}) = \frac{fg(\bar{a})}{\beta G(\bar{a})^2}. \tag{A.3}$$

Note, however, that

$$\mu_a(\bar{a}) = \frac{1}{G(\bar{a})}\int_0^{\bar{a}} ag(a)da$$

and therefore

$$\mu_a'(\bar{a})\,G(\bar{a}) = g(\bar{a})\left[\bar{a} - \mu_a(\bar{a})\right]. \tag{A.4}$$

Substituting this into (A.3), we obtain

$$w\left[\bar{a} - \mu_a(\bar{a})\right] = \frac{f}{\beta mG(\bar{a})}. \tag{A.5}$$

Substituting (A.5) into (A.2) then yields equation (6),

$$\begin{aligned}\rho(a) &= \beta w\left[a-\mu_a(\bar{a})\right]+\beta w\mu_a(\bar{a})+(1-\beta)\,w\bar{a} \\ &= \beta wa+(1-\beta)\,w\bar{a}.\end{aligned}$$

We next use the demand equation (3), the pricing equation (7), and (A.1) to compute operating profits. These profits are

$$\pi_o = x\,(p-c)-\frac{1-\beta}{\beta}\frac{f}{G(\bar{a})}-f_o,$$

where

$$p=\frac{\sigma}{\sigma-1}c,$$

$$x = X\left(\frac{p}{P}\right)^{-\sigma} = XP^{\sigma}\left(\frac{\sigma}{\sigma-1}c\right)^{-\sigma}, \tag{A.6}$$

and the aggregate cost of m units of the intermediate input is

$$w\mu_a(\bar{a})\,m+\frac{1-\beta}{\beta}\frac{f}{G(\bar{a})}.$$

Therefore,

$$\pi_o = XP^{\sigma}\frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}}c^{1-\sigma}-\frac{1-\beta}{\beta}\frac{f}{G(\bar{a})}-f_o, \tag{A.7}$$

where

$$c=c\left[w\mu_a(\bar{a})\right],$$

as stated in equation (8). By Shephard's Lemma, m is given by

$$m = XP^{\sigma}\frac{(\sigma-1)^{\sigma}}{\sigma^{\sigma}}c^{-\sigma}c'. \tag{A.8}$$

A firm chooses $\bar{a}$ to maximize profits net of search costs, taking P and X as given. That is,

$$\begin{aligned}\bar{a} &= \arg\max_a XP^{\sigma}\frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}}c\left[w\mu_a(a)\right]^{1-\sigma}-\frac{1-\beta}{\beta}\frac{f}{G(a)}-\frac{f}{G(a)}-f_o \\ &= \arg\max_a XP^{\sigma}\frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}}c\left[w\mu_a(a)\right]^{1-\sigma}-\frac{f}{\beta G(a)}-f_o.\end{aligned}$$

For an interior solution, the first-order condition is

$$-XP^{\sigma}\frac{(\sigma-1)^{\sigma}}{\sigma^{\sigma}}c\left[w\mu_a(\bar{a})\right]^{-\sigma}c'\left[w\mu_a(\bar{a})\right]w\mu_a'(\bar{a})+\frac{fg(\bar{a})}{\beta G(\bar{a})^2}=0,$$

which is the same as (5) in view of (A.8). Using Assumptions 1 and 2, this condition can be written as

$$-\alpha X P^{\sigma} \frac{(\sigma-1)^{\sigma}}{\sigma^{\sigma}} \left(w \frac{\theta}{\theta+1} \bar{a}\right)^{-\alpha(\sigma-1)-1} \left(w \frac{\theta}{\theta+1}\right) + \theta \frac{f}{\beta \bar{a}^{\theta+1}} = 0.$$

Therefore the second-order condition for profit maximization is satisfied at the optimal choice of $\bar{a}$ if and only if $\theta > \alpha(\sigma-1)$, as stipulated in Assumption 3. This first-order condition can be expressed as

$$\bar{a}^{\theta-\alpha(\sigma-1)} X P^{\sigma} = \frac{\theta f}{\alpha\beta} \left(\frac{w\theta}{\theta+1}\right)^{\alpha(\sigma-1)} \left(\frac{\sigma}{\sigma-1}\right)^{\sigma}. \tag{A.9}$$

Substituting this expression into (A.7) yields

$$\pi_o - \frac{f}{G(\bar{a})} = \frac{\theta-\alpha(\sigma-1)}{\beta\alpha(\sigma-1)} f \bar{a}^{-\theta} - f_o.$$

The free entry condition is

$$\pi_o - \frac{f}{G(\bar{a})} = f_e,$$

which, together with the previous equation, yields equation (10):

$$\bar{a}^{\theta} = \frac{f}{f_o+f_e} \frac{\theta-\alpha(\sigma-1)}{\beta\alpha(\sigma-1)}. \tag{A.10}$$

The solution to this cutoff is interior if and only if

$$\frac{f}{f_o+f_e} \frac{\theta-\alpha(\sigma-1)}{\beta\alpha(\sigma-1)} < 1.$$

Substituting (A.10) and $XP^{\sigma} = P^{\sigma-\varepsilon}$ into (A.9) provides a solution for P. And substituting this equation into

$$P = \frac{\sigma}{\sigma-1} \left(w \frac{\theta}{\theta+1} \bar{a}\right)^{\alpha} n^{-\frac{1}{\sigma-1}} \tag{A.11}$$

provides a solution for n. Note that

$$\hat{n} = (\sigma-1)\left(\alpha\hat{\bar{a}} - \hat{P}\right),$$

where a hat over a variable represents a proportional rate of change, e.g., $\hat{y} = dy/y$. For an increase in the search cost f we have, from (A.9),

$$\hat{P} = \frac{\hat{f} - [\theta-\alpha(\sigma-1)]\hat{\bar{a}}}{\sigma-\varepsilon}$$

and from (A.10),

$$\hat{\bar{a}} = \frac{1}{\theta}\hat{f}.$$

Therefore,

$$\hat{P} = \frac{\alpha(\sigma-1)}{\theta(\sigma-\varepsilon)}\hat{f},$$

$$\hat{n} = \frac{\alpha(\sigma-1)}{\theta}\frac{1-\varepsilon}{\sigma-\varepsilon}\hat{f}.$$

These results are summarized in

Lemma A.1 *Suppose Assumptions 1-3 hold and*

$$\frac{f}{f_o+f_e}\frac{\theta-\alpha(\sigma-1)}{\beta\alpha(\sigma-1)} < 1.$$

Then lower search costs f lead to a lower cutoff $\bar{a}$ and a lower price index P. They also generate more variety n for $\sigma > \varepsilon > 1$.

Section 3 Unanticipated Tariffs

Section 3.1 Small Tariffs

In this case, the ex-factory price paid to a foreign supplier with inverse match productivity a is $\rho(a,\tau)$, which is the solution to

$$\rho(a,\tau) = \arg\max_q \left[\tau\mu_\rho[\bar{a}(\tau),\tau] + \frac{f}{m(\tau)G[\bar{a}(\tau)]} - \tau q\right]^\beta (q-wa)^{1-\beta}.$$

This f.o.b. price excludes the tariff levy. The first-order condition for this maximization problem is

$$\frac{1-\beta}{\rho(a,\tau)-wa} = \frac{\beta}{\mu_\rho[\bar{a}(\tau),\tau] + \frac{f}{\tau m(\tau)G[\bar{a}(\tau)]} - \rho(a,\tau)},$$

which yields

$$\rho(a,\tau) = \beta wa + (1-\beta)\mu_\rho[\bar{a}(\tau),\tau] + (1-\beta)\frac{f}{\tau m(\tau)G[\bar{a}(\tau)]}. \tag{A.12}$$

Taking conditional expectations on both sides of this equation for $a \leq \bar{a}(\tau)$, we find

$$\mu_\rho[\bar{a}(\tau),\tau] = w\mu_a[\bar{a}(\tau)] + \frac{1-\beta}{\beta}\frac{f}{\tau m(\tau)G[\bar{a}(\tau)]}. \tag{A.13}$$

Next, substituting this expression into (A.12), we obtain

$$\rho(a,\tau) = \beta wa + (1-\beta)w\mu_a[\bar{a}(\tau)] + \frac{1-\beta}{\beta}\frac{f}{\tau m(\tau)G[\bar{a}(\tau)]}, \tag{A.14}$$

which is equation (11) in the main text. As explained in the text, using the optimal search cutoff $\bar{a}(\tau)$ yields

$$w\{\bar{a}(\tau) - \mu_a[\bar{a}(\tau)]\} = \frac{f}{\beta\tau m(\tau)G[\bar{a}(\tau)]}. \tag{A.15}$$

Now substitute this equation into (A.14) to obtain

$$\rho(a,\tau) = \beta wa + (1-\beta)\, w\bar{a}(\tau). \tag{A.16}$$

Next note that it is cheaper to sources inputs from the original supplier a whenever

$$\tau\rho(a,\tau) \leq \tau\mu_\rho[\bar{a}(\tau),\tau] + \frac{f}{m(\tau)\, G[\bar{a}(\tau)]}.$$

Using (A.13) and (A.15), the right-hand side of this inequality equals $\tau w_A \bar{a}(\tau)$. Therefore this inequality can be expressed as

$$a \leq \bar{a}(\tau).$$

From this result, we have

Lemma A.2 *For a given $\bar{a}(\tau)$ the cost minimizing cutoff a_c is*

$$a_c = \min\{\bar{a}(\tau), \bar{a}\}.$$

As explained in the main text, the marginal cost of m is given by equation (15),

$$\phi^\tau = \beta \frac{G(a_c)}{G(\bar{a})} \tau w \mu_a(a_c) + \left[1 - \beta \frac{G(a_c)}{G(\bar{a})}\right] \tau w \mu_a(\bar{a}^\tau)$$

and then optimal (mark-up) pricing implies

$$p^\tau = \frac{\sigma}{\sigma-1} c(\phi^\tau).$$

Using Assumption 2 and Lemma A.2, the marginal cost can be expressed as

$$\phi^\tau = \begin{cases} \frac{\theta}{\theta+1}\tau w \bar{a}^\tau & \text{for } \bar{a}^\tau < \bar{a} \\ \beta\frac{\theta}{\theta+1}\tau w\bar{a} + (1-\beta)\frac{\theta}{\theta+1}\tau w \bar{a}^\tau & \text{for } \bar{a}^\tau > \bar{a} \end{cases}. \tag{A.17}$$

This is the MM curve in Figure 2.

We next derive the NN curve, using the first-order condition for $\bar{a}^\tau$ in (A.15), Shephard's Lemma $m^\tau = x^\tau c'(\phi^\tau)$, the expression for the demand for variety ω in (A.6), and the expression for the price index, $P^\tau = p^\tau (n^\tau)^{-1/(\sigma-1)}$. This expression of the price index assumes that all firms, new and old, charge the same price p^τ, which we verify below. First, in the Pareto case (A.15) becomes

$$w\bar{a}(\tau)^{\theta+1} = \frac{f(\theta+1)}{\beta\tau m(\tau)}. \tag{A.18}$$

Second,

$$m^{\tau} = X^{\tau} \left(\frac{p^{\tau}}{P^{\tau}} \right)^{-\sigma} c' \left(\phi^{\tau} \right) \tag{A.19}$$
$$= X^{\tau} \left(n^{\tau} \right)^{-\frac{\sigma}{\sigma-1}} c' \left(\phi^{\tau} \right) = \left(P^{\tau} \right)^{-\varepsilon} \left(n^{\tau} \right)^{-\frac{\sigma}{\sigma-1}} c' \left(\phi^{\tau} \right)$$
$$= \left(p^{\tau} \right)^{-\varepsilon} \left(n^{\tau} \right)^{-\frac{\sigma-\varepsilon}{\sigma-1}} c' \left(\phi^{\tau} \right)$$

Combining these equations, we obtain

$$\frac{(\theta+1) f}{w\beta \left(\bar{a}^{\tau} \right)^{\theta+1}} = \tau \left(n^{\tau} \right)^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(p^{\tau} \right)^{-\varepsilon} c' \left(\phi^{\tau} \right) \ ,$$

which is equation (18) in the main text. Using $p^{\tau} = c\left(\phi^{\tau}\right)\sigma / \left(\sigma - 1\right)$ and $c\left(\phi^{\tau}\right) = \left(\phi^{\tau}\right)^{\alpha}$, this equation becomes

$$\frac{(\theta+1) f}{w\beta \left(\bar{a}^{\tau} \right)^{\theta+1}} = \tau \left(n^{\tau} \right)^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1} \right)^{-\varepsilon} \alpha \left(\phi^{\tau} \right)^{\alpha(1-\varepsilon)-1} \ . \tag{A.20}$$

This implies that the NN curve is higher the greater is the tariff rate and that all along this curve,

$$\hat{\phi}^{\tau} = \frac{\theta+1}{1-\alpha\left(1-\varepsilon\right)} \hat{\bar{a}}^{\tau}.$$

The denominator is positive for all $\varepsilon > 0$, and since $\varepsilon < \sigma$ and $\theta > \alpha\left(\sigma - 1\right)$, $\theta + 1 > 1 + \alpha\left(\varepsilon - 1\right)$. Therefore the elasticity of the NN curve is larger than one. The upward shift of the curve in response to a rise in τ satisfies

$$\hat{\phi}^{\tau} = \frac{1}{1-\alpha\left(1-\varepsilon\right)} \hat{\tau}.$$

Therefore, ϕ^{τ} rises proportionately less for $\varepsilon > 1$. As a result, the marginal cost ϕ^{τ} rises, holding constant the number of firms.

We show at the end of this section that the NN curve is steeper than the MM curve for general distribution functions (i.e., not necessarily Pareto), as long as the choice of $\bar{a}$ that maximizes profits satisfies the second-order condition. In this event the above comparative static results also hold.

Next, consider the incentives for new firms to enter. For $\varepsilon > 1$, equations (16), (17) and (18) imply

$$\hat{\phi}^{\tau} = \frac{\theta + 1 - \gamma^{\tau}}{\theta + 1 - \gamma^{\tau} - \gamma^{\tau}\alpha\left(\varepsilon - 1\right)} \hat{\tau} \tag{A.21}$$

and

$$\hat{\bar{a}}^{\tau} = \frac{\alpha\left(\varepsilon - 1\right)}{\theta + 1 - \gamma^{\tau} - \gamma^{\tau}\alpha\left(\varepsilon - 1\right)} \hat{\tau}, \tag{A.22}$$

where

$$\gamma^{\tau} = \frac{\left(1-\beta\right)\bar{a}^{\tau}}{\beta\bar{a} + \left(1-\beta\right)\bar{a}^{\tau}}.$$

Using (A.7) and (A.17), the objective function of a potential entrant is

$$\pi(\tau) = \max_{a} P(\tau)^{\sigma-\varepsilon} \frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}} [\tau w \mu_a(a)]^{\alpha(1-\sigma)} - \frac{f}{\beta G(a)} - f_o - f_e.$$

Therefore $\pi'(\tau) > 0$ if and only if $P(\tau)^{\sigma-\varepsilon} \tau^{\alpha(1-\sigma)}$ is rising in τ. However, using (A.21) and $\theta > \alpha(\sigma-1)$ we obtain

$$\begin{aligned}
\frac{(\sigma-\varepsilon)\hat{P}^{\tau} - \alpha(\sigma-1)\hat{\tau}}{\alpha\hat{\tau}} &= \frac{(\sigma-\varepsilon)\hat{\phi}^{\tau} - (\sigma-1)\hat{\tau}}{\hat{\tau}} \\
&= \frac{(\theta+1-\gamma^{\tau})(\sigma-\varepsilon)}{\theta+1-\gamma^{\tau}-\gamma^{\tau}\alpha(\varepsilon-1)} - (\sigma-1) \\
&< \frac{[\alpha(\sigma-1)+1-\gamma^{\tau}](\sigma-\varepsilon)}{\alpha(\sigma-1)+1-\gamma^{\tau}-\gamma^{\tau}\alpha(\varepsilon-1)} - (\sigma-1) \\
&= -\frac{(1-\gamma^{\tau})(\varepsilon-1)[\alpha(\sigma-1)+1]}{\alpha(\sigma-1)+1-\gamma^{\tau}-\gamma^{\tau}\alpha(\varepsilon-1)} < 0.
\end{aligned}$$

It follows that potential entrants face negative profits for all small tariff levels. Therefore, we have

Lemma A.3 *Suppose Assumptions 1-3 hold and $\sigma > \varepsilon > 1$. Then for small tariffs there is no entry of new final-good producers and prospective profits of potential entrants decline with the tariff rate.*

General Productivity Distribution and Cost Function

We now show that the NN curve is steeper than the MM curve for a general productivity distribution and cost function as long as the second-order condition for the choice of $\bar{a}$ is satisfied. We consider the case of a small tariff, so that the outside option is to search in country A. In this case

$$p^{\tau} = \frac{\sigma}{\sigma-1} c(\phi^{\tau}), \tag{A.23}$$

$$P^{\tau} = \frac{\sigma}{\sigma-1} c(\phi^{\tau}) n^{\frac{1}{1-\sigma}}, \tag{A.24}$$

$$x^{\tau} = (P^{\tau})^{\sigma-\varepsilon} \left[\frac{\sigma}{\sigma-1} c(\phi^{\tau})\right]^{-\sigma}, \tag{A.25}$$

$$m^{\tau} = (P^{\tau})^{\sigma-\varepsilon} \frac{(\sigma-1)^{\sigma}}{\sigma^{\sigma}} c(\phi^{\tau})^{-\sigma} c'(\phi^{\tau}). \tag{A.26}$$

These equations also apply to the case $\tau = 0$, i.e., the initial equilibrium. In the initial equilibrium $\phi = w\mu_a(\bar{a})$ and operating profits are (see (A.7))

$$\pi_o = (P)^{\sigma-\varepsilon} \frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}} c[w\mu_a(\bar{a})]^{1-\sigma} - \frac{1-\beta}{\beta} \frac{f}{G(\bar{a})} - f_o.$$

The choice of $\bar{a}$ maximizes operating profits minus search costs, $f/G(\bar{a})$, which yields the first-order condition

$$-\left(P^{\tau}\right)^{\sigma-\varepsilon}\frac{(\sigma-1)^{\sigma}}{\sigma^{\sigma}}c\left[w\mu_a\left(\bar{a}^{\tau}\right)\right]^{-\sigma}c'\left[w\mu_a\left(\bar{a}^{\tau}\right)\right]w\mu_a'\left(\bar{a}^{\tau}\right)+\frac{1}{\beta}\frac{fg\left(\bar{a}^{\tau}\right)}{G\left(\bar{a}^{\tau}\right)^2}=0.$$

Since

$$\mu_a\left(\bar{a}\right)=\frac{1}{G\left(\bar{a}\right)}\int_0^{\bar{a}}ag\left(a\right)da,$$

$$\mu_a'\left(\bar{a}\right)=\frac{g\left(\bar{a}\right)}{G\left(\bar{a}\right)}\left[\bar{a}^{\tau}-\mu_a\left(\bar{a}^{\tau}\right)\right],$$

this first-order condition can be expressed as

$$-\left(P\right)^{\sigma-\varepsilon}\frac{(\sigma-1)^{\sigma}}{\sigma^{\sigma}}c\left[w\mu_a\left(\bar{a}\right)\right]^{-\sigma}c'\left[w\mu_a\left(\bar{a}\right)\right]w\left[\bar{a}-\mu_a\left(\bar{a}\right)\right]+\frac{1}{\beta}\frac{f}{G\left(\bar{a}\right)}=0.$$

It follows that the second-order condition requires

$$\left\{G\left(\bar{a}\right)c\left[w\mu_a\left(\bar{a}\right)\right]^{-\sigma}c'\left[w\mu_a\left(\bar{a}\right)\right]\left[\bar{a}-\mu_a\left(\bar{a}\right)\right]\right\}'>0. \tag{A.27}$$

With a Pareto distribution and a Cob-Douglas (C-D) production function this holds if and only if

$$\left\{\left(\bar{a}\right)^{\theta}\left(\bar{a}\right)^{-\alpha\sigma}\left(\bar{a}\right)^{\alpha-1}\bar{a}\right\}'>0,$$

which is satisfied if and only if $\theta>\alpha\left(\sigma-1\right)$. With C-D and a general distribution function, the second-order condition requires

$$\left\{G\left(\bar{a}\right)\mu_a\left(\bar{a}\right)^{-\alpha(\sigma-1)-1}\left[\bar{a}-\mu_a\left(\bar{a}\right)\right]\right\}'>0.$$

Now consider the MM curve. It is represented by

$$\phi^{\tau}=\beta\frac{G\left(a_c\right)}{G\left(\bar{a}\right)}\tau w\mu_a\left(a_c\right)+\left[1-\beta\frac{G\left(a_c\right)}{G\left(\bar{a}\right)}\right]\tau w\mu_a\left(\bar{a}^{\tau}\right),$$

where

$$a_c=\min\left\{\bar{a}^{\tau},\bar{a}\right\}.$$

Therefore

$$\phi^{\tau}=\begin{cases}\tau w\mu_a\left(\bar{a}^{\tau}\right) & \text{for } \bar{a}^{\tau}\leq\bar{a}\\ \tau w\beta\mu_a\left(\bar{a}\right)+\tau w\left(1-\beta\right)\mu_a\left(\bar{a}^{\tau}\right) & \text{for } \bar{a}^{\tau}\geq\bar{a}\end{cases}. \tag{A.28}$$

It is an increasing curve with a break in the slope at $\bar{a}^{\tau}=\bar{a}$, where the right-hand side slope is flatter than the left-hand side slope. The left-hand side slope equals $\tau w\mu_a'\left(\bar{a}\right)$.

We next derive the NN curve, using the first-order condition (12) in the paper,

$$\tau w \left[\bar{a}^{\tau} - \mu_a\left(\bar{a}^{\tau}\right)\right] G\left(\bar{a}^{\tau}\right) = \frac{f}{\beta m^{\tau}}.$$

Using (A.24) and (A.26) above, this yields

$$\tau G\left(\bar{a}^{\tau}\right) c\left(\phi^{\tau}\right)^{-\varepsilon} c'\left(\phi^{\tau}\right)\left[\bar{a}^{\tau} - \mu_a\left(\bar{a}^{\tau}\right)\right] = \frac{f\sigma^{\varepsilon}}{w\beta n^{\frac{\sigma-\varepsilon}{1-\sigma}}\left(\sigma-1\right)^{\varepsilon}}. \tag{A.29}$$

With C-D and Pareto this is

$$\tau w \frac{\left(\bar{a}^{\tau}\right)^{\theta+1}}{\theta+1} = \frac{f}{\beta n^{\frac{\sigma-\varepsilon}{1-\sigma}} \frac{(\sigma-1)^{\varepsilon}}{\sigma^{\varepsilon}} \alpha\left(\phi^{\tau}\right)^{-\alpha(\varepsilon-1)-1}},$$

which is what we have in the paper.

The slope of the MM curve to the left of $\bar{a}^{\tau} = \bar{a}$, i.e., evaluated at $\tau = 1$, equals $w\mu_a'\left(\bar{a}\right)$ (see (A.28)). From (A.29), the slope of the NN curve evaluated at $\bar{a}^{\tau} = \bar{a}$, i.e., at $\tau = 1$, equals

$$s_{NN} = -\frac{\left\{G\left(\bar{a}\right)\left[\bar{a} - \mu_a\left(\bar{a}\right)\right]\right\}' c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right)}{\left[c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right)\right]' G\left(\bar{a}\right)\left[\bar{a} - \mu_a\left(\bar{a}\right)\right]} \tag{A.30}$$

However, the second-order condition (A.27) implies

$$\left\{G\left(\bar{a}\right)\left[\bar{a} - \mu_a\left(\bar{a}\right)\right]\right\}' c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right) + \left[c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right)\right]' G\left(\bar{a}\right)\left[\bar{a} - \mu_a\left(\bar{a}\right)\right] w\mu_a'\left(\bar{a}\right) > 0,$$

or, using (A.30),

$$\left\{G\left(\bar{a}\right)\left[\bar{a} - \mu_a\left(\bar{a}\right)\right]\right\}' c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right)\left[1 - \frac{w\mu_a'\left(\bar{a}\right)}{s_{MM}}\right] > 0.$$

Since $\left\{G\left(\bar{a}\right)\left[\bar{a} - \mu_a\left(\bar{a}\right)\right]\right\}' c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right) > 0$, this yields $w\mu_a'\left(\bar{a}\right) < s_{NN}$. That is, the NN curve is steeper than the MM curve at this point.

Next consider the upward shift in each one of the curves at $\bar{a}^{\tau} = \bar{a}$ in response to and increase in τ. The MM curve shifts proportionately to τ. The NN curve shifts less than proportionately if and only if the elasticity of $c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right)$, which is negative, is smaller than -1 ($c'' < 0$ due to concavity of the cost function). In the C-D case this elasticity is $-\alpha\left(\varepsilon - 1\right) - 1 < 1$ and an increase in τ leads to $\bar{a}^{\tau} > \bar{a}$, as argued in the paper. This is true more generally, for cost functions whose elasticity of $c\left(\phi\right)^{-\varepsilon} c'\left(\phi\right)$ is smaller than -1.

Section 3.2 Large Tariffs

In this section, the outside option for buyers is to search for new suppliers in country B. The outside option is the same when a buyer bargains with a supplier in country A as when it bargains with one in country B. Since there are no tariffs on inputs purchased in country B, the bargaining game with a supplier in country B yields

$$\rho_B(b,\tau) = \arg\max_q \left[qm(\tau) - w_B bm(\tau)\right]^{1-\beta} \left[w_B \mu_b\left[\bar{b}(\tau)\right] m(\tau) + \frac{f}{\beta G\left[\bar{b}(\tau)\right]} - qm(\tau)\right]^{\beta}.$$

The first-order condition for this problem is

$$\frac{1-\beta}{\rho_B(b,\tau) - w_B b} = \frac{\beta}{w_B \mu_b\left[\bar{b}(\tau)\right] + \frac{f}{\beta m(\tau) G\left[\bar{b}(\tau)\right]} - \rho_B(b,\tau)},$$

and therefore

$$\rho_B(b,\tau) = \beta w_B b + (1-\beta) w_B \mu_b\left[\bar{b}(\tau)\right] + (1-\beta)\frac{f}{\beta m(\tau) G\left[\bar{b}(\tau)\right]}. \tag{A.31}$$

Taking the conditional mean of both sides of this equation for $b \leq \bar{b}(\tau)$, yields

$$\mu_{\rho_B}\left[\bar{b}(\tau)\right] = w_B \mu_b\left[\bar{b}(\tau)\right] + \frac{1-\beta}{\beta}\frac{f}{m(\tau) G\left[\bar{b}(\tau)\right]}. \tag{A.32}$$

Now use the first-order condition for $\bar{b}(\tau)$ that minimizes costs,

$$w_B\left\{\bar{b}(\tau) - \mu_b\left[\bar{b}(\tau)\right]\right\} = \frac{f}{\beta m(\tau) G\left[\bar{b}(\tau)\right]}, \tag{A.33}$$

to obtain

$$\rho_B(b,\tau) = \beta w_B b + (1-\beta) w_B \bar{b}(\tau). \tag{A.34}$$

Note that this cost of inputs depends on the tariff only through $\bar{b}(\tau)$ and it is the same for the original producers and new entrants.

Bargaining with suppliers in country A yields

$$\rho_A(a,\tau) = \arg\max_q \left[qm(\tau) - w_A am(\tau)\right]^{1-\beta} \left[w_B \mu_b\left[\bar{b}(\tau)\right] m(\tau) + \frac{f}{\beta G\left[\bar{b}(\tau)\right]} - \tau qm(\tau)\right]^{\beta}.$$

The first-order condition for this problem is

$$\frac{1-\beta}{\rho_A(a,\tau) - w_A a} = \frac{\beta\tau}{w_B \mu_b\left[\bar{b}(\tau)\right] + \frac{f}{\beta m(\tau) G\left[\bar{b}(\tau)\right]} - \tau\rho_A(a,\tau)}$$

and therefore

$$\tau\rho_A(a,\tau) = \beta\tau w_A a + (1-\beta) w_B \mu_b\left[\bar{b}(\tau)\right] + (1-\beta)\frac{f}{\beta m(\tau) G\left[\bar{b}(\tau)\right]}. \tag{A.35}$$

Substituting (A.32) and (A.33) into this equation we obtain

$$\rho_A(a,\tau) = \beta w_A a + (1-\beta) w_B \frac{\bar{b}(\tau)}{\tau}. \tag{A.36}$$

This negotiated price depends on τ through the ratio $\bar{b}(\tau)/\tau$. In these circumstances, it is cheaper to source an input a from country A if

$$\tau\rho_A(a,\tau) \leq \mu_{\rho_B}\left[\bar{b}(\tau)\right] + \frac{f}{m(\tau) G\left[\bar{b}(\tau)\right]}.$$

Using (A.32) and (A.33), the right-hand side of this inequality equals $w_B\bar{b}(\tau)$. Therefore this inequality can be expressed as

$$\tau w_A a \leq w_B \bar{b}(\tau).$$

From this result we have

Lemma A.4 *For given $\bar{b}(\tau)$, the cost minimizing cutoff a_B is*

$$a_B = \min\left\{\frac{w_B\bar{b}(\tau)}{\tau w_A}, \bar{a}\right\}. \tag{A.37}$$

Now consider the perceived marginal cost of the composite intermediate good for one of the original producers. From (A.31), we see that the average marginal cost of sourcing from country B is $w_B\mu_b\left[\bar{b}(\tau)\right]$, while from (A.35) we see that the average marginal cost of sourcing from country A is $\beta\tau w_A\mu_a(a_B) + (1-\beta) w_B\mu_b\left[\bar{b}(\tau)\right]$. Since an incumbent firm sources a fraction $G(a_B)/G(\bar{a})$ of its inputs from country A and the remaining fraction $1 - G(a_B)/G(\bar{a})$ from country B, its marginal cost of the intermediate input is

$$\begin{aligned}\phi^\tau &= \frac{G(a_B)}{G(\bar{a})}\left[\beta\tau w_A\mu_a(a_B) + (1-\beta) w_B\mu_b\left(\bar{b}^\tau\right)\right] + \left[1 - \frac{G(a_B)}{G(\bar{a})}\right] w_B\mu_b\left(\bar{b}^\tau\right) \\ &= \beta\frac{G(a_B)}{G(\bar{a})}\tau w_A\mu_a(a_B) + \left[1 - \beta\frac{G(a_B)}{G(\bar{a})}\right] w_B\mu_b\left(\bar{b}^\tau\right),\end{aligned}$$

where we have replace the function $\bar{b}(\tau)$ with the value of $\bar{b}$ at the tariff level τ, $\bar{b}^\tau$. Using (A.37) and properties of the Pareto distribution yields the equation for the MM curve,

$$\phi^\tau = \begin{cases} \frac{\theta}{\theta+1} w_B\bar{b}^\tau & \text{for } \bar{b}^\tau < \tau w_A\bar{a}/w_B \\ \frac{\theta}{\theta+1}\left[\beta\tau w_A\bar{a} + (1-\beta) w_B\bar{b}^\tau\right] & \text{for } \bar{b}^\tau > \tau w_A\bar{a}/w_B \end{cases}. \tag{A.38}$$

New entrants (if any exist) search for suppliers only in country B. Equation (A.32) implies that an entrant's marginal cost is

$$\phi^\tau_{new} = w_B\mu_b\left(\bar{b}^\tau\right) = \frac{\theta}{\theta+1} w_B\bar{b}^\tau. \tag{A.39}$$

For the tariff level $\tau = w_B/w_A$, the equilibrium values are $\bar{b}^\tau = \bar{a}$ and $\phi_{new}^\tau = \phi^\tau = \tau\phi = \frac{\theta}{\theta+1} w_B \bar{a}$.

We next derive the equation for the NN curve. We have (A.33). As we explained in the previous section, when all the firms are identical, m^τ, the volume of imported intermediate goods, is given by (see (A.19))

$$\begin{aligned} m^\tau &= (p^\tau)^{-\varepsilon} (n^\tau)^{-\frac{\sigma-\varepsilon}{\sigma-1}} c'(\phi^\tau) \\ &= \left[\frac{\sigma}{\sigma-1} c(\phi^\tau)\right]^{-\varepsilon} (n^\tau)^{-\frac{\sigma-\varepsilon}{\sigma-1}} c'(\phi^\tau) \\ &= \alpha \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} (n^\tau)^{-\frac{\sigma-\varepsilon}{\sigma-1}} (\phi^\tau)^{\alpha(1-\varepsilon)-1}, \end{aligned} \tag{A.40}$$

where $n^\tau = n$ in the elastic case. Since higher tariffs do not raise profits when $\varepsilon > 1$, there is no entry of new firms. Substituting the expression for m^τ into (A.33) yields

$$\frac{(\theta+1) f}{w_B \beta \left(\bar{b}^\tau\right)^{\theta+1}} = n^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} \alpha (\phi^\tau)^{\alpha(1-\varepsilon)-1} \quad , \tag{A.41}$$

which is the NN curve. It follows that the elasticity of the NN curve in this case is $(\theta+1)/[1-\alpha(1-\varepsilon)]$, which is larger than one under Assumption 3 for all $\varepsilon < \sigma$. From (A.38), the slope of the MM curve is smaller than one and therefore NN is steeper at the intersection point of the two curves, as drawn in Figure 3.

Now consider the response of ϕ^τ and $\bar{b}^\tau$ to tariff changes. First suppose that τ is such that $\bar{b}^\tau < \tau w_A \bar{a}/w_B$. In this case, there is sourcing from both countries and (A.38) and (A.41) imply that neither ϕ^τ nor $\bar{b}^\tau$ change as long as tariffs remain in the region with $\bar{b}^\tau < \tau w_A \bar{a}/w_B$. In contrast, consider an increase in the tariff when $\bar{b}^\tau > \tau w_A \bar{a}/w_B$. Then (A.38) and (A.41) imply

$$\begin{aligned} \hat{\phi}^\tau &= \gamma_B \hat{\bar{b}}^\tau + (1-\gamma_B)\hat{\tau}, \\ (\theta+1)\hat{\bar{b}}^\tau &= [1+\alpha(\varepsilon-1)]\hat{\phi}^\tau, \end{aligned}$$

where

$$\gamma_B = \frac{(1-\beta) w_B \bar{b}^\tau}{\beta \tau w_A \bar{a} + (1-\beta) w_B \bar{b}^\tau}.$$

Therefore,

$$\hat{\phi}^\tau = \frac{(\theta+1)(1-\gamma_B)}{\theta+1-\gamma_B-\gamma_B\alpha(\varepsilon-1)}\hat{\tau}, \tag{A.42}$$

$$\hat{\bar{b}}^\tau = \frac{[1-\alpha(1-\varepsilon)](1-\gamma_B)}{\theta+1-\gamma_B-\gamma_B\alpha(\varepsilon-1)}\hat{\tau}. \tag{A.43}$$

The numerators and the denominators of both equations are positive, implying that higher tariffs raise the cutoff and the marginal costs of intermediate inputs. Moreover, note from (A.43) that

$$\hat{\bar{b}}^\tau - \hat{\tau} = -\frac{(1-\gamma_B)[\theta-\alpha(\varepsilon-1)]}{\theta+1-\gamma_B-\gamma_B\alpha(\varepsilon-1)}\hat{\tau}.$$

The denominator on the right-hand side of this equation is positive. The numerator is negative under Assumption 3, because $\sigma > \varepsilon$. We conclude that the ratio $\bar{b}^\tau/\tau$ is declining with the tariff level.

As shown in the text, for $\tau \in (w_B/w_A, \tau_c)$ we have $\bar{b}^\tau > \tau w_A \bar{a}/w_B$, where τ_c is the tariff level at which $\tau_c w_A \bar{a} = w_B \bar{b}(\tau_c)$. For tariffs in this range, a higher tariff raises both ϕ^τ and $\bar{b}^\tau$ according to (A.42) and (A.43). In contrast, ϕ^τ and $\bar{b}^\tau$ are invariant to the tariff rate for all $\tau > \tau_c$. In this range, $a_B = w_B \bar{b}(\tau_c)/\tau w_A$ and $\bar{b}^\tau = \bar{b}(\tau_c)$, so we can express the weighted average of the foreign cost of the inputs using (A.34) and (A.36) as

$$\begin{aligned}\rho^\tau &= \frac{G(a_B)}{G(\bar{a})}\left[\beta w_A \mu_a(a_B) + (1-\beta) w_B \frac{\bar{b}^\tau}{\tau}\right] + \left[1 - \frac{G(a_B)}{G(\bar{a})}\right]\left[\beta w_B \mu_b\left(\bar{b}^\tau\right) + (1-\beta) w_B \bar{b}^\tau\right] \\ &= \left(\frac{\tau_c}{\tau}\right)^\theta \frac{\theta+1-\beta}{\theta+1}\frac{w_B \bar{b}^\tau}{\tau} + \left[\left\{1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right\}\right]\frac{\theta+1-\beta}{\theta+1} w_B \bar{b}^\tau.\end{aligned}$$

The second line reveals the offsetting effects on the terms of trade: ρ^τ declines as a result of the decline in prices paid to suppliers in country A, but it rises with reallocation of supply from country A to country B, because net-of-tariff costs are higher in country B. The combined impact can be seen by rewriting the equation for ρ^τ as

$$\rho^\tau = \left\{1 - \frac{\tau-1}{\tau}\left(\frac{\tau_c}{\tau}\right)^\theta\right\}\frac{\theta+1-\beta}{\theta+1} w_B \bar{b}^\tau. \tag{A.44}$$

From this, we obtain

Lemma A.5 *Suppose $\varepsilon > 1$. Then for $\tau > \tau_c$, higher tariffs generate better terms of trade if and only if*

$$\tau < \frac{\theta+1}{\theta}.$$

Finally, we derive an equation for τ_c. From (A.5) we have

$$\frac{1}{\theta+1} w_A \bar{a} = \frac{f}{\beta m \bar{a}^\theta},$$

where m is the volume of intermediates in the free-trade equilibrium, before any tariff is imposed. From (A.33) we have

$$\frac{1}{\theta+1} w_B \bar{b}(\tau_c) = \frac{f}{\beta m(\tau_c)\,\bar{b}(\tau_c)^\theta}$$

when the tariff is τ_c. Therefore,

$$\frac{w_B \bar{b}(\tau_c)^{\theta+1}}{w_A \bar{a}^{\theta+1}} = \frac{m}{m(\tau_c)}.$$

However, from (A.40),

$$m = \alpha\left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} n^{-\frac{\sigma-\varepsilon}{\sigma-1}}\left(\frac{\theta}{\theta+1} w_A \bar{a}\right)^{\alpha(1-\varepsilon)-1},$$

$$m(\tau_c) = \alpha \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} n^{-\frac{\sigma-\varepsilon}{\sigma-1}} \phi(\tau_c)^{\alpha(1-\varepsilon)-1}.$$

However, (A.38) implies that,

$$\phi(\tau_c) = \frac{\theta}{\theta+1} w_B \bar{b}(\tau_c) = \frac{\theta}{\theta+1} \tau_c w_A \bar{a}$$

and therefore,

$$\frac{w_B \bar{b}(\tau_c)^{\theta+1}}{w_A \bar{a}^{\theta+1}} = \left(\frac{w_A}{w_B}\right)^{\theta} (\tau_c)^{\theta+1} = \frac{m}{m(\tau_c)} = \frac{1}{(\tau_c)^{\alpha(1-\varepsilon)-1}}.$$

It follows that,

$$\tau_c = \left(\frac{w_B}{w_A}\right)^{\frac{\theta}{\theta-\alpha(\varepsilon-1)}}. \tag{A.45}$$

Since $\tau_c w_A \bar{a} = w_B \bar{b}(\tau_c)$, this implies

$$\bar{b}(\tau_c) = \left(\frac{w_B}{w_A}\right)^{\frac{\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} \bar{a}. \tag{A.46}$$

We now consider tariffs that are large enough to induce exit. We denote by τ_{ex} the tariff rate at which the operating profits net of new search costs equal zero. To avoid taxonomy, we assume that $\tau_{ex} > \tau_c$; that profits drop to zero at a tariff rate that is high enough to induce surviving firms to switch suppliers from country A to country B.

For tariffs above τ_c the suppliers in country A that are replaced with suppliers from country B are all those with inverse productivity $a \in (a_B, \bar{a}]$, where

$$a_B = \frac{w_B \bar{b}^{\tau}}{\tau w_A} < \bar{a} \quad \text{for } \tau > \tau_c. \tag{A.47}$$

For these tariffs, the perceive marginal cost ϕ^{τ} and search cutoff $\bar{b}^{\tau}$ satisfy

$$\phi^{\tau} = \frac{\theta}{\theta+1} w_B \bar{b}^{\tau} \tag{A.48}$$

and

$$\frac{(\theta+1) f}{w_B \beta \left(\bar{b}^{\tau}\right)^{\theta+1}} = (n^{\tau})^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} \alpha (\phi^{\tau})^{\alpha(1-\varepsilon)-1}, \tag{A.49}$$

respectively. It follows, as we have already noted, that perceived marginal cost and the search cutoff are independent of the tariff rate for $\tau \in [\tau_c, \tau_{ex}]$ and that $n^{\tau} = n$ for all tariffs in this range.

We can write operating profits net of new search costs for the representative firm as a function of the number of active firms, n^{τ}, as follows:

$$\pi_{ex}^{\tau} = (P^{\tau})^{\sigma-\varepsilon} \frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}} (\phi^{\tau})^{\alpha(1-\sigma)} - \frac{(1-\beta) f}{\beta \left(\bar{b}^{\tau}\right)^{\theta}} - \left[1 - \left(\frac{w_B \bar{b}^{\tau}}{\tau w_A \bar{a}}\right)^{\theta}\right] \frac{f}{\left(\bar{b}^{\tau}\right)^{\theta}} - f_o. \tag{A.50}$$

The first term on the right-hand side represents revenue minus labor costs minus the variable costs of intermediate input. The second term represents payments to suppliers of intermediate inputs that do not depend on m^τ; these are the fixed payments that result from bargaining in the shadow of an outside option to search for a new supplier in country B. These fixed payments apply to all inputs, regardless of their source, because the outside option always involves search in country B when the tariff rate is large. The third term represents the new search costs incurred as a result of actual searches in country B to replace original suppliers in country A. These costs apply to the fraction of inputs with $a \in (a_B, \bar{a}]$ that are replaced after the tariff is introduced. Using (A.47), this fractions is $1 - \left(w_B \bar{b}^\tau / \tau w_A \bar{a}\right)^\theta$.

Note that

$$P^\tau = \frac{\sigma}{\sigma - 1} \left(\phi^\tau\right)^\alpha \left(n^\tau\right)^{-\frac{1}{\sigma-1}}. \tag{A.51}$$

It is apparent from (A.50) and (A.51) that, as long as the number of firms remains unchanged, and therefore ϕ^τ and $\bar{b}^\tau$ also do not change, operating profits net of new search costs decline with the tariff. Although revenues net of input costs are independent of the tariff rate, higher tariffs generate greater trade diversion to country B and thus greater expense on new searches. The critical tariff rate τ_{ex} that is large enough to induce exit is determined implicitly by

$$\pi_{ex}^\tau = \left(P_c^\tau\right)^{\sigma-\varepsilon} \frac{(\sigma-1)^{\sigma-1}}{\sigma^\sigma} \left(\phi_c^\tau\right)^{\alpha(1-\sigma)} - \frac{(1-\beta) f}{\beta \left(\bar{b}_c^\tau\right)^\theta} - \left[1 - \left(\frac{w_B \bar{b}_c^\tau}{\tau_{ex} w_A \bar{a}}\right)^\theta\right] \frac{f}{\left(\bar{b}_c^\tau\right)^\theta} - f_o = 0, \tag{A.52}$$

where ϕ_c^τ and $\bar{b}_c^\tau$ are the solution to (A.48) and (A.49) for $n^\tau = n$ and

$$P_c^\tau = \frac{\sigma}{\sigma-1} \left(\phi_c^\tau\right)^\alpha n^{-\frac{1}{\sigma-1}}.$$

Now consider the relationship between ϕ^τ and $\bar{b}^\tau$ and the tariff rate for $\tau \geq \tau_{ex}$. Substituting (A.51) into (A.50) yields the zero-profit condition,

$$\left(n^\tau\right)^{-\frac{\sigma-\varepsilon}{\sigma-1}} \frac{(\sigma-1)^{\varepsilon-1}}{\sigma^\varepsilon} \left(\phi^\tau\right)^{\alpha(1-\varepsilon)} - \frac{(1-\beta) f}{\beta \left(\bar{b}^\tau\right)^\theta} - \left[1 - \left(\frac{w_B \bar{b}^\tau}{\tau w_A \bar{a}}\right)^\theta\right] \frac{f}{\left(\bar{b}^\tau\right)^\theta} = f_o.$$

Next use (A.48) to rewrite (A.49) as

$$\frac{\theta f}{\beta \left(\bar{b}^\tau\right)^\theta} = \left(n^\tau\right)^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} \alpha \left(\phi^\tau\right)^{\alpha(1-\varepsilon)}. \tag{A.53}$$

These two equations imply

$$\frac{\theta}{\alpha(\sigma-1)} \frac{f}{\beta \left(\bar{b}^\tau\right)^\theta} - \frac{(1-\beta) f}{\beta \left(\bar{b}^\tau\right)^\theta} - \left[1 - \left(\frac{w_B \bar{b}^\tau}{\tau w_A \bar{a}}\right)^\theta\right] \frac{f}{\left(\bar{b}^\tau\right)^\theta} = f_o,$$

or

$$\frac{1}{\beta\left(\bar{b}^{\tau}\right)^{\theta}}\left[\frac{\theta}{\alpha\left(\sigma-1\right)}-1\right]+\left(\frac{w_B}{\tau w_A\bar{a}}\right)^{\theta}=\frac{f_o}{f}. \tag{A.54}$$

Assumption 3 ensures that the term in the square bracket is positive, implying that higher tariffs induce more selective search; i.e., lower values of $\bar{b}^{\tau}$. Moreover,

$$\widehat{\bar{b}^{\tau}}=-\xi^{\tau}\hat{\tau},\quad \xi^{\tau}=\frac{\beta\alpha\left(\sigma-1\right)}{\theta-\alpha\left(\sigma-1\right)}\left(\frac{w_B\bar{b}^{\tau}}{\tau w_A\bar{a}}\right)^{\theta}>0. \tag{A.55}$$

From (A.48), we see that ϕ^{τ} is proportional to $\bar{b}^{\tau}$ and therefore

$$\hat{\phi}^{\tau}=\widehat{\bar{b}^{\tau}}=-\xi^{\tau}\hat{\tau}.$$

Then (A.49) implies

$$\frac{\sigma-\varepsilon}{\sigma-1}\hat{n}^{\tau}=-\left[\theta-\alpha\left(\varepsilon-1\right)\right]\xi^{\tau}\hat{\tau}. \tag{A.56}$$

So the number of firms also declines. We therefore have

Proposition A.1 *Suppose Assumptions 1-3 hold and that $\tau\geq\tau_{ex}$. Then, the larger is the tariff, the smaller is ϕ^{τ}, $\bar{b}^{\tau}$, and n^{τ}.*

This proposition implies that, in the elastic case, the perceived marginal cost is a non-monotonic function of the size of the tariff. For tariffs in the range $\tau\in(1,\tau_c)$ perceived marginal cost rises with the tariff rate, in the range $\tau\in(\tau_c,\tau_{ex})$ it is independent of that rate, and in the range $\tau\geq\tau_{ex}$ it declines with τ. Since $\bar{b}^{\tau}$ follows the same non-monotonic pattern as ϕ^{τ}, and m^{τ} is decreasing in $\bar{b}^{\tau}$ from the equation that describes the optimal choice of $\bar{b}^{\tau}$ for a given m^{τ}, it follows that m^{τ} is also non-monotonic; it declines initially, remains constant for a range of tariffs, and then rises with τ when $\tau\geq\tau_{ex}$.

Next use (A.51) and (A.53) to obtain

$$\left(P^{\tau}\right)^{\sigma-\varepsilon}=\frac{\theta f}{\alpha\beta\left(\bar{b}^{\tau}\right)^{\theta}}\left(\frac{\sigma}{\sigma-1}\right)^{\sigma}\left(\phi^{\tau}\right)^{\alpha(\sigma-1)}.$$

Substituting (A.49) into this equation yields

$$\left(P^{\tau}\right)^{\sigma-\varepsilon}=\frac{\theta f}{\alpha\beta\left(\bar{b}^{\tau}\right)^{\theta-\alpha(\sigma-1)}}\left(\frac{\sigma}{\sigma-1}\right)^{\sigma}\left(\frac{\theta}{\theta+1}w_B\right)^{\alpha(\sigma-1)}. \tag{A.57}$$

Since $\bar{b}^{\tau}$ declines with the tariff, this implies that the price index is rising with the tariff in the range of large tariffs that induce exit. Moreover, (A.55) implies

$$\hat{P}^{\tau}=\frac{\theta-\alpha\left(\sigma-1\right)}{\sigma-\varepsilon}\xi^{\tau}\hat{\tau}.$$

Evidently, the price index rises with the tariff when $\tau\geq\tau_{ex}$ despite the decline in perceived marginal costs, because the variety reducing effect of exit dominates the effect on the price index of falling prices for brands that survive.

We can compute the size of the critical tariff, τ_{ex}., using (A.54) with $\bar{b}^{\tau} = \bar{b}_c^{\tau}$. Substituting (A.45) and (A.46) into (A.54), we find that τ_{ex} satisfies

$$\frac{\theta - \alpha(\sigma-1)}{\beta\alpha(\sigma-1)} + \left(\frac{\tau_c}{\tau_{ex}}\right)^{\theta} = \frac{f_o}{f}\bar{a}^{\theta}\left(\frac{w_B}{w_A}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}.$$

Now use the solution for $\bar{a}^{\theta}$ in (A.10) to obtain

$$\left(\frac{\tau_c}{\tau_{ex}}\right)^{\theta} = \frac{\theta - \alpha(\sigma-1)}{\beta\alpha(\sigma-1)}\left[\frac{f_o}{f_o+f_e}\left(\frac{w_B}{w_A}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} - 1\right]. \tag{A.58}$$

Clearly, this implies that, for $\tau_{ex} > \tau_c$, we need the term in the square brackets to be positive and the right-hand side to be smaller than one. These two conditions can be satisfied if and only if

$$\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} < \frac{f_o}{f_o+f_e} < \frac{\theta-(1-\beta)\alpha(\sigma-1)}{\theta-\alpha(\sigma-1)}\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}. \tag{A.59}$$

For every pair of wage rates w_A and w_B such that $w_B > w_A$ there exist fixed operating costs f_o and fixed entry costs f_e that satisfy these inequalities.

Section 4 Welfare Effects of Unanticipated Tariffs

Section 4.1 Increase in a Small Tariff

Consider the welfare effects of small tariffs. We showed in the main text that, apart from a constant, welfare can be expressed as

$$V(\tau) = U(X^{\tau}) - n^{\tau}\rho^{\tau}m^{\tau} - n^{\tau}\ell^{\tau} - n^{\tau}f\left[\frac{1}{G(a_c)} - \frac{1}{G(\bar{a})}\right].$$

In the elastic case, i.e., $\varepsilon > 1$, $a_c = \bar{a}$ and there are no additional search costs. Moreover, there is no entry, so that $n^{\tau} = n$. Therefore

$$V(\tau) = U(X^{\tau}) - n\rho^{\tau}m^{\tau} - n\ell^{\tau}$$

and

$$\frac{dV}{d\tau} = P^{\tau}\frac{dX^{\tau}}{d\tau} - n\frac{d\ell^{\tau}}{d\tau} - n\rho^{\tau}\frac{dm^{\tau}}{d\tau} - nm^{\tau}\frac{d\rho^{\tau}}{d\tau}.$$

The CES aggregator implies that

$$X^{\tau} = n^{\frac{\sigma}{\sigma-1}}z(\ell^{\tau}, m^{\tau})$$

and therefore

$$
\begin{aligned}
P^{\tau}\frac{dX^{\tau}}{d\tau} &= n^{\frac{\sigma}{\sigma-1}}P^{\tau}\left(z_{\ell}\frac{d\ell^{\tau}}{d\tau}+z_{m}\frac{dm^{\tau}}{d\tau}\right) \\
&= n^{\frac{\sigma}{\sigma-1}}\frac{\sigma}{\sigma-1}\frac{P^{\tau}}{p^{\tau}}\left(\frac{d\ell^{\tau}}{d\tau}+\phi^{\tau}\frac{dm^{\tau}}{d\tau}\right) \\
&= n\frac{\sigma}{\sigma-1}\left(\frac{d\ell^{\tau}}{d\tau}+\phi^{\tau}\frac{dm^{\tau}}{d\tau}\right).
\end{aligned}
$$

The second line is obtained from the first by noting that the marginal revenue generated by an increase in an input equals the input's marginal cost, which is one for labor and ϕ^{τ} for intermediate inputs. The third line is obtained from $P = pn^{-\frac{1}{\sigma-1}}$. Using this result, we obtain

$$
\frac{dV}{d\tau} = n\frac{1}{\sigma-1}\frac{d\ell^{\tau}}{d\tau}+n\left(\frac{\sigma}{\sigma-1}\phi^{\tau}-\rho^{\tau}\right)\frac{dm^{\tau}}{d\tau}-nm^{\tau}\frac{d\rho^{\tau}}{d\tau}, \tag{A.60}
$$

which is equation (28) in the main text.

Next, the assumption of a Cobb-Douglas technology implies

$$
\ell^{\tau} = \frac{1-\alpha}{\alpha}\phi^{\tau}m^{\tau}
$$

and therefore

$$
\frac{1}{\sigma-1}\frac{d\ell^{\tau}}{d\tau} = \frac{1}{\sigma-1}\frac{1-\alpha}{\alpha}\frac{d\left(\phi^{\tau}m^{\tau}\right)}{d\tau}.
$$

However, spending on intermediate inputs is a fraction α of spending on all inputs,

$$
n\phi^{\tau}m^{\tau} = \alpha\frac{\sigma-1}{\sigma}P^{\tau}X^{\tau}, \tag{A.61}
$$

and therefore

$$
\begin{aligned}
n\frac{1}{\sigma-1}\frac{d\ell^{\tau}}{d\tau} &= n\frac{1}{\sigma-1}\frac{1-\alpha}{\alpha}\frac{d\left(\phi^{\tau}m^{\tau}\right)}{d\tau} = \frac{1-\alpha}{\sigma}\frac{d\left(P^{\tau}X^{\tau}\right)}{d\tau} \\
&= -\frac{1-\alpha}{\tau\sigma}\left(\varepsilon-1\right)\alpha\left(\frac{d\phi^{\tau}}{d\tau}\frac{\tau}{\phi^{\tau}}\right)P^{\tau}X^{\tau}.
\end{aligned} \tag{A.62}
$$

Using $P^{\tau} = \left(\phi^{\tau}\right)^{\alpha}n^{-\frac{1}{\sigma-1}}\sigma/\left(\sigma-1\right)$, the last equality is obtained from

$$
\frac{d\left(P^{\tau}X^{\tau}\right)}{d\tau} = \frac{d\left(P^{\tau}\right)^{1-\varepsilon}}{d\tau} = -\left(\varepsilon-1\right)\alpha\left(\frac{d\phi^{\tau}}{d\tau}\frac{\tau}{\phi^{\tau}}\right)\frac{1}{\tau}P^{\tau}X^{\tau}.
$$

Therefore, using (A.21),

$$
n\frac{1}{\sigma-1}\frac{d\ell^{\tau}}{d\tau} = -\frac{1-\alpha}{\tau\sigma}\left(\varepsilon-1\right)\alpha\frac{\theta+1-\gamma^{\tau}}{\theta+1-\gamma^{\tau}-\gamma^{\tau}\alpha\left(\varepsilon-1\right)}P^{\tau}X^{\tau}.
$$

This gives us the first term in (A.60). Since $\varepsilon > 1$, the tariff reduces employment and this has a negative (partial) effect on welfare.

To obtain the second term in (A.60), we again use (A.61) and (A.21), which gives

$$\begin{aligned} n\phi^\tau \frac{dm^\tau}{d\tau} &= \frac{\sigma-1}{\sigma}\alpha\frac{d\left(P^\tau X^\tau\right)}{d\tau} - nm^\tau\frac{d\phi^\tau}{d\tau} \\ &= -\frac{1-\alpha}{\tau\sigma}\left(\varepsilon-1\right)\alpha\frac{\theta+1-\gamma^\tau}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)}P^\tau X^\tau - \frac{1}{\tau}nm^\tau\phi^\tau\frac{\theta+1-\gamma^\tau}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)} \\ &= -\frac{1}{\tau}\frac{\sigma-1}{\sigma}\alpha\left[\left(\varepsilon-1\right)\alpha+1\right]\frac{\theta+1-\gamma^\tau}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)}P^\tau X^\tau. \end{aligned}$$

Now, (14) and (17) imply

$$\phi^\tau = \tau w\frac{\theta}{\theta+1}\left[\beta\bar{a}+\left(1-\beta\right)\bar{a}^\tau\right] \tag{A.63}$$

and

$$\rho^\tau = \beta w\frac{\theta}{\theta+1}\bar{a}+\left(1-\beta\right)w\bar{a}^\tau. \tag{A.64}$$

Therefore,

$$\begin{aligned} n\left(\frac{\sigma}{\sigma-1}\phi^\tau-\rho^\tau\right)\frac{dm^\tau}{d\tau} &= \left(\rho^\tau-\frac{\sigma}{\sigma-1}\phi^\tau\right)\frac{1}{\tau\phi^\tau}\frac{\sigma-1}{\sigma}\alpha\left[\left(\varepsilon-1\right)\alpha+1\right]\frac{\theta+1-\gamma^\tau}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)}P^\tau X^\tau \\ &= \left(\frac{\theta+\gamma^\tau}{\theta}-\frac{\sigma}{\sigma-1}\tau\right)\frac{1}{\tau^2}\frac{\sigma-1}{\sigma}\alpha\left[\left(\varepsilon-1\right)\alpha+1\right]\frac{\theta+1-\gamma^\tau}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)}P^\tau X^\tau. \end{aligned}$$

While the tariff reduces demand for the composite intermediate good, the welfare effect is ambiguous for the reasons discussed in the main text. This component of the welfare effect is positive if and only if

$$\frac{\theta+\gamma^\tau}{\theta} > \frac{\sigma}{\sigma-1}\tau.$$

This is the second term in (A.60).

To obtain the third term in the welfare formula, we use (A.64) and (A.22) to obtain

$$\begin{aligned} nm^\tau\frac{d\rho^\tau}{d\tau} &= wnm^\tau\left(1-\beta\right)\frac{d\bar{a}^\tau}{d\tau} \\ &= \frac{1}{\tau}nm^\tau\left(1-\beta\right)\frac{\alpha\left(\varepsilon-1\right)w\bar{a}^\tau}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)}. \end{aligned}$$

Next, (A.61) and (A.63) imply

$$nm^\tau = \frac{1}{\tau w\frac{\theta}{\theta+1}\left[\beta\bar{a}+\left(1-\beta\right)\bar{a}^\tau\right]}\frac{\sigma-1}{\sigma}\alpha P^\tau X^\tau.$$

Therefore,

$$nm^\tau\frac{d\rho^\tau}{d\tau} = \frac{1}{\tau^2}\frac{\theta+1}{\theta}\gamma^\tau\frac{\sigma-1}{\sigma}\alpha\frac{\alpha\left(\varepsilon-1\right)}{\theta+1-\gamma^\tau-\gamma^\tau\alpha\left(\varepsilon-1\right)}P^\tau X^\tau.$$

So, in this case, $d\rho^\tau/d\tau > 0$; i.e., the terms of trade deteriorate.

Combining the three terms in the expression for the change in welfare, we have

$$\begin{aligned}
&\frac{\theta+1-\gamma^{\tau}-\gamma^{\tau}\alpha\left(\varepsilon-1\right)}{\theta+1-\gamma^{\tau}}\frac{\sigma\tau^{2}}{\alpha P^{\tau}X^{\tau}}\frac{dV}{d\tau}= \\
&-\tau\left(1-\alpha\right)\left(\varepsilon-1\right) \\
&+\left(\frac{\theta+\gamma^{\tau}}{\theta}-\frac{\sigma}{\sigma-1}\tau\right)\left(\sigma-1\right)\left[\left(\varepsilon-1\right)\alpha+1\right] \\
&-\frac{\theta+1}{\theta}\left(\sigma-1\right)\frac{\alpha\left(\varepsilon-1\right)\gamma^{\tau}}{\theta+1-\gamma^{\tau}}.
\end{aligned} \tag{A.65}$$

A marginal tariff raises welfare if and only if the right-hand side of this equation is positive. Since at free trade $\gamma\left(1\right)=1-\beta$, it follows that, starting with free trade, a very small tariff reduces welfare if and only if

$$\frac{\theta\varepsilon\left(\theta+\beta\right)}{\theta+\beta-\left(\varepsilon-1\right)\alpha\left(1-\beta\right)}>\left(\sigma-1\right)\left(1-\beta\right).$$

Next, note that, holding γ^{τ} constant, the right-hand side of (A.65) is declining in τ. Hence, any positive tariff must reduce welfare if

$$\frac{\theta\varepsilon\left(\theta+1-\gamma^{\tau}\right)}{\theta+1-\gamma^{\tau}-\left(\varepsilon-1\right)\alpha\gamma^{\tau}}>\left(\sigma-1\right)\gamma^{\tau}\quad\text{for all }\tau\geq1.$$

Section 4.2 Increase in a Large Tariff

We now examine the welfare effects of tariffs for $\tau>w_B/w_A$. First, consider tariffs in the range $\tau\in\left(w_B/w_A,\tau_c\right)$. In this range, there are no new searches by any of the incumbent producers and country A continues to supply all intermediate inputs. As a result, tariffs are imposed on all imports, generating a revenue of $\left(\tau-1\right)\rho^{\tau}m^{\tau}$. Tariff revenue plus variable profits plus consumer surplus sum to

$$\begin{aligned}
V\left(\tau\right)&=T\left(\tau\right)+\Pi\left(\tau\right)+\Gamma\left(\tau\right) \\
&=\left(\tau-1\right)\rho^{\tau}m^{\tau}+\left[P^{\tau}X^{\tau}-\tau\rho^{\tau}nm^{\tau}-n\ell^{\tau}\right]+\left[U\left(X^{\tau}\right)-P^{\tau}X^{\tau}\right] \\
&=U\left(X^{\tau}\right)-\rho^{\tau}nm^{\tau}-n\ell^{\tau}.
\end{aligned}$$

Differentiating this equation gives

$$\begin{aligned}
\frac{1}{n}\frac{dV}{d\tau}&=\frac{1}{n}P^{\tau}\frac{dX^{\tau}}{d\tau}-\frac{d\ell^{\tau}}{d\tau}-\rho^{\tau}\frac{dm^{\tau}}{d\tau}-m^{\tau}\frac{d\rho^{\tau}}{d\tau} \\
&=\left(\frac{\sigma}{\sigma-1}-1\right)\frac{d\ell^{\tau}}{d\tau}+\left(\frac{\sigma}{\sigma-1}\phi^{\tau}-\rho^{\tau}\right)\frac{dm^{\tau}}{d\tau}-m^{\tau}\frac{d\rho^{\tau}}{d\tau}.
\end{aligned}$$

We have shown that, in this range, $\bar{b}^{\tau}$ is larger for larger tariffs whereas $\bar{b}^{\tau}/\tau$ is smaller for larger tariffs. The optimal choice of $\bar{b}^{\tau}$ for a given m^{τ}, equation (A.33), therefore implies that m^{τ} declines with the tariff, while (A.36) implies that ρ^{τ} declines. For these reasons, the change in the sourcing of intermediate inputs raises welfare if and only if

$$\frac{\sigma}{\sigma-1}\frac{\phi^{\tau}}{\rho^{\tau}}=\tau\frac{\sigma}{\sigma-1}\frac{\frac{\theta}{\theta+1}\left[\beta\tau w_{A}\bar{a}+(1-\beta)\,w_{B}\bar{b}^{\tau}\right]}{\frac{\theta}{\theta+1}\beta\tau w_{A}\bar{a}+(1-\beta)\,w_{B}\bar{b}^{\tau}}=\frac{\sigma}{\sigma-1}\frac{\theta\tau}{\theta+\gamma_{B}}<1.$$

Meanwhile, better terms of trade always contribute to higher welfare. Finally, since

$$n\ell^{\tau}=(1-\alpha)\,\frac{\sigma-1}{\sigma}P^{\tau}X^{\tau}$$

and ϕ^{τ} rises with the tariff level, it follows that $P^{\tau}X^{\tau}$ declines with the size of the tariff in the elastic case. As a result, ℓ^{τ} declines, which reduces welfare, all else the same. Clearly, in this case, a marginal increase in the tariff rate may increase or reduce welfare.

We next consider $\tau>\tau_{c}$. In this range, $d\ell^{\tau}/d\tau=dm^{\tau}/d\tau=dX^{\tau}/d\tau=dP^{\tau}/d\tau=0$, because neither ϕ^{τ} nor $\bar{b}^{\tau}$ vary with the size of the tariff. As a result,

$$\frac{dV}{d\tau}=-nm^{\tau}\frac{d\rho^{\tau}}{d\tau}-\frac{d\Sigma}{d\tau},$$

where $\Sigma\left(\tau\right)$ is the cost of the new searches that take place by incumbent producers. Using (A.33) and $a_{B}=\frac{w_{B}\bar{b}(\tau_{c})}{\tau w_{A}}$, the cost of new searches amounts to

$$\begin{aligned}\Sigma&=n\left[1-\frac{G\left(a_{B}\right)}{G\left(\bar{a}\right)}\right]\frac{f}{G\left[\bar{b}\left(\tau_{c}\right)\right]}\\&=nm^{t}\left[1-\left(\frac{\tau_{c}}{\tau}\right)^{\theta}\right]\frac{\beta}{\theta+1}w_{B}\bar{b}\left(\tau_{c}\right).\end{aligned}$$

Therefore, the variation in the search cost that results from a slightly higher tariff is

$$\frac{d\Sigma}{d\tau}=nm^{\tau}\frac{\theta}{\tau^{\theta+1}}\left(\tau_{c}\right)^{\theta}\frac{\beta}{\theta+1}w_{B}\bar{b}\left(\tau_{c}\right).$$

The terms of trade now are a weighted average of the cost of sourcing from country A and the cost of sourcing from country B,

$$\rho^{\tau}=\frac{G\left(a_{B}\right)}{G\left(\bar{a}\right)}\left[\beta w_{A}\mu_{a}\left(a_{B}\right)+(1-\beta)\,w_{B}\frac{\bar{b}^{\tau}}{\tau}\right]+\left[1-\frac{G\left(a_{B}\right)}{G\left(\bar{a}\right)}\right]w_{B}\left[\beta\mu_{b}\left(\bar{b}^{\tau}\right)+(1-\beta)\,\bar{b}^{\tau}\right].$$

The first term on the right-hand side represents the fraction of goods sourced from country A, $G\left(a_{B}\right)/G\left(\bar{a}\right)$, times the average cost of goods sourced from that country, while the second term represents the fraction of goods sourced from country B times the average cost of those inputs.

Using $a_B = \frac{w_B \bar{b}(\tau_c)}{\tau w_A}$ and properties of the Pareto distribution, this equation becomes

$$\begin{aligned}
\rho^\tau &= \left(\frac{\tau_c}{\tau}\right)^\theta \frac{\theta+1-\beta}{\theta+1} \frac{w_B \bar{b}(\tau_c)}{\tau} + \left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right] \frac{\theta+1-\beta}{\theta+1} w_B \bar{b}(\tau_c) \\
&= \frac{\theta+1-\beta}{\theta+1} w_B \bar{b}(\tau_c) \left[1 - \frac{\tau-1}{\tau^{\theta+1}} (\tau_c)^\theta\right],
\end{aligned}$$

$$\frac{d\rho^\tau}{d\tau} = \frac{\theta(\tau-1)-1}{\tau^{\theta+2}} (\tau_c)^\theta \frac{\theta+1-\beta}{\theta+1} w_B \bar{b}(\tau_c)$$

Since the right-hand side of the last equation is negative if and only if

$$\tau < \frac{\theta+1}{\theta},$$

it follows that the terms of trade improve if $\tau < (\theta+1)/\theta$ and deteriorate if $\tau > (\theta+1)/\theta$. Combining terms, we now have

$$\begin{aligned}
\frac{1}{nm^\tau} \frac{dV}{d\tau} &= -\frac{d\rho^\tau}{d\tau} - \frac{1}{n^\tau m^\tau} \frac{d\Sigma}{d\tau} \\
&= w_B \bar{b}(\tau_c) \frac{\theta+1-\beta-\theta\tau}{\tau^{\theta+2}} (\tau_c)^\theta.
\end{aligned}$$

Therefore, welfare rises with the tariff for $\tau > \tau_c$ if and only if

$$\tau < \frac{\theta+1-\beta}{\theta}.$$

When the label B denotes the home country, the social cost of inputs is

$$\rho^\tau = \frac{G(a_B)}{G(\bar{a})} \left[\beta w_A \mu_a(a_B) + (1-\beta) \frac{\bar{b}^\tau}{\tau}\right] + \left[1 - \frac{G(a_B)}{G(\bar{a})}\right] w_B \mu_b\left(\bar{b}^\tau\right),$$

where the second term now represents the cost of producing inputs at home. Using properties of the Pareto distribution and $a_B = \frac{w_B \bar{b}(\tau_c)}{\tau w_A}$, we have

$$\rho^\tau = \left(\frac{\tau_c}{\tau}\right)^\theta \frac{\theta+1-\beta}{\theta+1} \frac{w_B \bar{b}(\tau_c)}{\tau} + \left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right] \frac{\theta}{\theta+1} w_B \bar{b}(\tau_c),$$

$$\begin{aligned}
\frac{d\rho^\tau}{d\tau} &= -\frac{\theta+1}{\tau^{\theta+2}} (\tau_c)^\theta \frac{\theta+1-\beta}{\theta+1} w_B \bar{b}(\tau_c) + \frac{\theta}{\tau^{\theta+1}} (\tau_c)^\theta \frac{\theta}{\theta+1} w_B \bar{b}(\tau_c) \\
&= \frac{1}{(\theta+1)\tau^{\theta+2}} (\tau_c)^\theta \left[\tau\theta^2 - (\theta+1)(\theta+1-\beta)\right] w_B \bar{b}(\tau_c).
\end{aligned}$$

In this case, the resource cost of inputs declines with the tariff if and only if

$$\tau < \frac{(\theta+1)(\theta+1-\beta)}{\theta^2}.$$

The effect of a higher tariff on social welfare can now be expressed as

$$
\begin{aligned}
\frac{1}{n^{\tau}m^{\tau}}\frac{dV}{d\tau} &= -\frac{d\rho^{\tau}}{d\tau}-\frac{1}{n^{\tau}m^{\tau}}\frac{d\Sigma}{d\tau} \\
&= -\frac{1}{(\theta+1)\,\tau^{\theta+2}}\left(\tau_c\right)^{\theta}\left[\tau\theta^2-(\theta+1)(\theta+1-\beta)\right]w_B\bar{b}\left(\tau_c\right) \\
&- \frac{\theta}{\tau^{\theta+1}}\left(\tau_c\right)^{\theta}\frac{\beta}{\theta+1}w_B\bar{b}\left(\tau_c\right) \\
&= w_B\bar{b}\left(\tau_c\right)\frac{-\tau\theta^2+(\theta+1)(\theta+1-\beta)-\beta\theta\tau}{(\theta+1)\,\tau^{\theta+2}}\left(\tau_c\right)^{\theta}.
\end{aligned}
$$

Therefore, welfare rises with the tariff if and only if

$$
\tau<\frac{(\theta+1)(\theta+1-\beta)}{\theta(\theta+\beta)}.
$$

Finally, we turn to the welfare effects of tariffs that induce exit. Recall that the welfare components that might vary with the tariff are income from operating profits net of new search costs, tariff revenue, and consumer surplus. However, for $\tau\geq\tau_{ex}$ operating profits net of new search costs are zero, and we are left with tariff revenue and consumer surplus as the welfare components of interest, namely

$$
V_{ex}(\tau)=T(\tau)+\Gamma(\tau).
$$

Tariffs are collected on imports from country A only and are equal to

$$
T(\tau)=\frac{G(a_B)}{G(\bar{a})}(\tau-1)\left[\beta w_A\mu_a(a_B)+(1-\beta)\frac{w_B\bar{b}^{\tau}}{\tau}\right]m^{\tau}.
$$

Here, term in the square brackets represents the average ex-factory price paid for inputs from country A, while $G(a_B)/G(\bar{a})$ represents the fraction of inputs imported from A. Using (A.47), the revenue can be expressed as

$$
T(\tau)=\frac{\theta+1-\beta}{\theta+1}\left(\frac{1}{w_A\bar{a}}\right)^{\theta}\left(\frac{w_B\bar{b}^{\tau}}{\tau}\right)^{\theta+1}(\tau-1)\,m^{\tau}.
$$

In addition, the cost minimizing choice of $\bar{b}^{\tau}$ for a given m^{τ} implies

$$
w_B\left(\bar{b}^{\tau}\right)^{\theta+1}=\frac{f(\theta+1)}{\beta m^{\tau}}
$$

and therefore

$$
T(\tau)=(\theta+1-\beta)\left(\frac{w_B}{w_A\bar{a}}\right)^{\theta}\frac{f}{\beta}\frac{\tau-1}{\tau^{\theta+1}}.
$$

Again using (13), this can be written as

$$
T(\tau)=\frac{(\theta+1-\beta)\,\alpha(\sigma-1)}{\theta-\alpha(\sigma-1)}\left(\frac{w_B}{w_A}\right)^{\theta}(f_o+f_e)\frac{\tau-1}{\tau^{\theta+1}}.
$$

It follows that tariff revenue declines with τ for $\tau > \tau_{ex}$ if and only if $\tau > (\theta+1)/\theta$. Since the price index unambiguously rises with the size of the tariff, consumer surplus is inversely related to the tariff rate. Therefore, for $\tau > (\theta+1)/\theta$, higher tariffs in the range where exit occurs must result in lower welfare.

Section 5 Application to the Trump Tariffs

In this section we first show that our measure of welfare change relative to initial spending on differentiated products does not depend on search costs f nor on f_o or f_e. To this end we note that in all equilibria

$$p = \frac{\sigma}{\sigma-1}c = \frac{\sigma}{\sigma-1}\phi^{\alpha},$$

$$X = P^{-\varepsilon},$$

and therefore

$$x = X\left(\frac{p}{P}\right)^{-\sigma} = P^{\sigma-\varepsilon}\left(\frac{\sigma}{\sigma-1}\phi^{\alpha}\right)^{-\sigma}. \tag{A.66}$$

In the initial equilibrium, (A.9)-(A.11) provide a solution to $\bar{a}$, P and n. To emphasize the dependence on f, f_o and f_e, we express these equations as

$$\bar{a} = B_a\left(\frac{f}{f_o+f_e}\right)^{1/\theta}, \tag{A.67}$$

$$P = B_P\left(f_o+f_e\right)^{\frac{1}{\sigma-\varepsilon}}\bar{a}^{\frac{\alpha(\sigma-1)}{\sigma-\varepsilon}}, \tag{A.68}$$

$$n^{\frac{1}{\sigma-1}} = B_n\left(f_o+f_e\right)^{-\frac{1}{\sigma-\varepsilon}}\bar{a}^{-\frac{\alpha(\varepsilon-1)}{\sigma-\varepsilon}}, \tag{A.69}$$

where B_j, $j = a, P, n$ include neither f nor f_o or f_e. We also have from (A.16) and (A.17)

$$\phi = \frac{\theta}{\theta+1}w\bar{a}, \tag{A.70}$$

$$\rho = \left[\beta\frac{\theta}{\theta+1} + (1-\beta)\right]w\bar{a}. \tag{A.71}$$

Equation (A.68) implies

$$pxn = PX = P^{1-\varepsilon} = B_P^{1-\varepsilon}\left(f_o+f_e\right)^{\frac{1-\varepsilon}{\sigma-\varepsilon}}\bar{a}^{\frac{\alpha(\sigma-1)(1-\varepsilon)}{\sigma-\varepsilon}}. \tag{A.72}$$

Together with (A.69), it implies,

$$px = B_P^{1-\varepsilon}B_n^{1-\sigma}\left(f_o+f_e\right). \tag{A.73}$$

That is, px is proportional to (f_o+f_e) and independent of the search cost f. This implies that ℓ

is also proportional to $(f_o + f_e)$ and independent of the search cost f, i.e.,

$$\ell = B_\ell \left(f_o + f_e\right),$$

where B_ℓ is independent of f, f_o or f_e

Next, (A.8), (A.68) and (A.70) yield

$$\begin{aligned} m &= \alpha P^{\sigma-\varepsilon} \left(\frac{\sigma-1}{\sigma}\right)^{\sigma} \phi^{\alpha(1-\sigma)-1} \\ &= B_m \left(f_o + f_e\right) \bar{a}^{-1}, \end{aligned}$$

where B_m is independent of f, f_o or f_e. Therefore, using (A.71),

$$\rho m = B_{\rho m} \left(f_o + f_e\right),$$

where $B_{\rho m}$ is independent of f, f_o or f_e.

Welfare is

$$V = U\left(X\right) - \rho m n - n\ell.$$

Therefore, using $X = P^{-\varepsilon}$,

$$\begin{aligned} V + \frac{\varepsilon}{\varepsilon-1} &= \frac{\varepsilon}{\varepsilon-1} X^{\frac{\varepsilon-1}{\varepsilon}} - \rho m n - n\ell \\ &= \frac{\varepsilon}{\varepsilon-1} P^{1-\varepsilon} - \rho m n - n\ell \\ &= \frac{\varepsilon}{\varepsilon-1} p x n - \rho m n - n\ell. \end{aligned} \tag{A.74}$$

It follows that

$$\frac{V + \frac{\varepsilon}{\varepsilon-1}}{pxn} = \frac{\varepsilon}{\varepsilon-1} - \frac{B_{\rho m} + B_\ell}{B_P^{1-\varepsilon} B_n^{1-\sigma}},$$

which is independent of f, f_o or f_e.

We now focus on the large tariff case $\tau > \tau_c > w_B/w_A$, which is relevant for the calibration. In this case (A.46) and (A.48) imply

$$\bar{b}^\tau = \bar{b}_c := B_b^\tau \bar{a}, \tag{A.75}$$

$$\phi^\tau = \phi_c := B_\phi^\tau \bar{a}, \tag{A.76}$$

where B_b^τ and B_ϕ^τ are independent of f, f_o or f_e. In other words, ϕ^τ and $\bar{b}^\tau$ are proportional to $\bar{a}$ for all $\tau \geq \tau_c$.

Consider the range $\tau \geq \tau_c$. In this range (A.40), (A.44) and (A.49) imply

$$m^\tau = \alpha \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} n^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\phi^\tau\right)^{\alpha(1-\varepsilon)-1} = \frac{(\theta+1) f}{w_B \beta \left(\bar{b}^\tau\right)^{\theta+1}}. \tag{A.77}$$

$$\rho^{\tau} m^{\tau} = \alpha \left[1 - \frac{\tau - 1}{\tau} \left(\frac{\tau_c}{\tau}\right)^{\theta}\right] \frac{\theta + 1 - \beta}{\theta + 1} \frac{(\theta + 1) f}{\beta \left(\bar{b}^{\tau}\right)^{\theta}}.$$

Using (A.67) and (A.75) then implies

$$\rho^{\tau} m^{\tau} = \left[1 - \frac{\tau - 1}{\tau} \left(\frac{\tau_c}{\tau}\right)^{\theta}\right] B_{\rho m}^{\tau} \left(f_o + f_e\right), \quad \text{for } \tau \geq \tau_c, \tag{A.78}$$

where $B_{\rho m}^{\tau}$ does not depend on f, f_o or f_e.

First, consider a tariff $\tau = \tau_c$. In this case, there are no new searches by any of the incumbent producers and country A continues to supply all intermediate inputs. As a result, tariffs are imposed on all imports, generating a revenue of $(\tau - 1)\, \rho^{\tau} m^{\tau}$. Tariff revenue plus variable profits plus consumer surplus sum to

$$\begin{aligned} V^{\tau_c} &= T^{\tau_c} + \Pi^{\tau_c} + \Gamma^{\tau_c} \\ &= (\tau - 1)\, \rho^{\tau_c} m^{\tau_c} + \left[P^{\tau_c} X^{\tau_c} - \tau \rho^{\tau_c} n m^{\tau_c} - n \ell^{\tau_c}\right] + \left[U\left(X^{\tau_c}\right) - P^{\tau_c} X^{\tau_c}\right] \\ &= U\left(X^{\tau_c}\right) - n \rho^{\tau_c} m^{\tau_c} - n \ell^{\tau_c}. \end{aligned}$$

In this case (A.78) implies

$$\rho^{\tau_c} m^{\tau_c} = \frac{1}{\tau_c} B_{\rho m}^{\tau} \left(f_o + f_e\right).$$

Labor employment is

$$n \ell^{\tau_c} = (1 - \alpha) \frac{\sigma - 1}{\sigma} P^{\tau} X^{\tau} = (1 - \alpha) \frac{\sigma - 1}{\sigma} \left(P^{\tau_c}\right)^{1 - \varepsilon}. \tag{A.79}$$

In addition,

$$U\left(X^{\tau_c}\right) + \frac{\varepsilon}{\varepsilon - 1} = \frac{\varepsilon}{\varepsilon - 1} \left(X^{\tau_c}\right)^{\frac{\varepsilon - 1}{\varepsilon}} = \frac{\varepsilon}{\varepsilon - 1} \left(P^{\tau_c}\right)^{1 - \varepsilon}.$$

Also,

$$\left(P^{\tau_c}\right)^{1 - \varepsilon} = p^{\tau_c} x^{\tau_c} n = \left(P^{\tau_c}\right)^{\sigma - \varepsilon} \left(\frac{\sigma}{\sigma - 1} \phi_c^{\alpha}\right)^{1 - \sigma} n$$

and

$$P^{\tau_c} = \frac{\sigma}{\sigma - 1} \phi_c^{\alpha} n^{\frac{1}{1 - \sigma}}.$$

Therefore, (A.69) and (A.76) yield,

$$\left(P^{\tau_c}\right)^{1 - \varepsilon} = C_P^{\tau_c} \left(f_o + f_e\right) n, \tag{A.80}$$

where $C_P^{\tau_c}$ does not vary with f, f_o or f_e. Together with (A.79), the last equation implies that ℓ^{τ_c} is proportional to $(f_o + f_e)$.

Using (A.74) and (A.80), we now have

$$V^{\tau_c} + \frac{\varepsilon}{\varepsilon - 1} = \frac{\varepsilon}{\varepsilon - 1} \left(f_o + f_e\right) C_P^{\tau_c} n - \rho^{\tau_c} m^{\tau_c} n - n \ell^{\tau_c}.$$

It follows that

$$\frac{V^{\tau_c} + \frac{\varepsilon}{\varepsilon - 1}}{pxn} = \frac{\frac{\varepsilon}{\varepsilon - 1} C_P^{\tau_c} (f_o + f_e) - \rho^{\tau_c} m^{\tau_c} - \ell^{\tau_c}}{px}.$$

Here both the numerator and the denominator of the right-hand side are proportional to $(f_o + f_e)$, and therefore the right-hand side does not depend on f, f_o or f_e.

For $\tau \geq \tau_c$ we have $P = P^{\tau_c}$, $X = X^{\tau_c}$ and $\ell = \ell^{\tau_c}$. There are now search costs, equal to (see Section 4.2 above)

$$\Sigma^\tau = nm^\tau \left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right] \frac{\beta}{\theta + 1} w_B \bar{b} (\tau_c).$$

Using (A.67), (A.75) and (A.77) this yields

$$\Sigma^\tau = n \left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right] B_\Sigma^\tau (f_o + f_e),$$

where B_Σ^τ is independent of f, f_o and f_e. We can express the utility at $\tau \geq \tau_c$ as

$$V^\tau + \frac{\varepsilon}{\varepsilon - 1} = V^{\tau_c} + \frac{\varepsilon}{\varepsilon - 1} - (\rho^\tau m^\tau - \rho^{\tau_c} m^{\tau_c}) n - n \left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right] B_\Sigma^\tau (f_o + f_e).$$

Now use (A.78) to obtain

$$V^\tau + \frac{\varepsilon}{\varepsilon - 1} = V^{\tau_c} + \frac{\varepsilon}{\varepsilon - 1} - n \left[\frac{\tau_c - 1}{\tau_c} - \frac{\tau - 1}{\tau} \left(\frac{\tau_c}{\tau}\right)^\theta\right] B_{\rho m}^\tau (f_o + f_e) - n \left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right] B_\Sigma^\tau (f_o + f_e).$$

It follows that

$$\frac{V^\tau + \frac{\varepsilon}{\varepsilon - 1}}{pxn} = \frac{V^{\tau_c} + \frac{\varepsilon}{\varepsilon - 1}}{pxn} - \frac{\frac{\tau_c - 1}{\tau_c} - \frac{\tau - 1}{\tau} \left(\frac{\tau_c}{\tau}\right)^\theta}{px} B_{\rho m}^\tau (f_o + f_e) - \frac{1 - \left(\frac{\tau_c}{\tau}\right)^\theta}{px} B_\Sigma^\tau (f_o + f_e),$$

which is independent of f, f_o and f_e. Finally, this implies that

$$\frac{V^\tau - V}{pxn}$$

is independent of f, f_o and f_e.

Section 5.1: Calibration Equations

In the remaining part of this appendix we describe the equations that are pertinent for the calibration. Condition $\tau > \tau_c$ requires (see (A.45))

$$\tau > \tau_c = \left(\frac{w_B}{w_A}\right)^{\frac{\theta}{\theta - \alpha(\varepsilon - 1)}},$$

while condition $\tau_c < \tau < \tau_{ex}$ requires (see (A.59))

$$\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} < \frac{f_o}{f_o+f_e} < \frac{\theta-(1-\beta)\,\alpha\,(\sigma-1)}{\theta-\alpha\,(\sigma-1)}\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}},$$

where (see (A.58))

$$\tau_{ex} = \tau_c\left[\frac{\beta\alpha\,(\sigma-1)}{\theta-\alpha\,(\sigma-1)}\right]^{\frac{1}{\theta}}\left[\frac{f_o}{f_o+f_e}\left(\frac{w_B}{w_A}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}-1\right]^{-\frac{1}{\theta}}.$$

Free Trade Equilibrium

We solve for equilibrium sequentially, starting with the reservation productivity (see (A.10)):

$$\overline{a} = \left[\frac{f}{f_o+f_e}\frac{\theta-\alpha\,(\sigma-1)}{\beta\alpha\,(\sigma-1)}\right]^{\frac{1}{\theta}}.$$

Expected differentiated variety marginal cost is:

$$\phi = w_A\mu_a\left(\overline{a}\right) = w_A\frac{\theta}{\theta+1}\overline{a},$$

$$c\left(\phi\right) = \phi^{\alpha}.$$

Free entry requires

$$\pi_o = f_e + \frac{f}{G\left(\overline{a}\right)} = f_e + \frac{f}{\overline{a}^{\theta}},$$

where operating profits, π_o, are (see (A.7))

$$\pi_o = \frac{(\sigma-1)^{\sigma-1}}{\sigma^{\sigma}}P^{\sigma-\varepsilon}c\left(\phi\right)^{(1-\sigma)} - \frac{(1-\beta)\,f}{\beta\overline{a}^{\theta}} - f_o,$$

yielding the price index

$$P = \left\{\frac{1}{c\left(\phi\right)^{(1-\sigma)}}\frac{\sigma^{\sigma}}{(\sigma-1)^{\sigma-1}}\left[\pi_o + \frac{(1-\beta)\,f}{\beta\overline{a}^{\theta}} + f_o\right]\right\}^{\frac{1}{\sigma-\varepsilon}}.$$

Differentiated sector variety prices are

$$p = \frac{\sigma}{\sigma-1}\phi^{\alpha},$$

and the price index

$$P = n^{-\frac{1}{\sigma-1}}p$$

yields

$$n = \left(\frac{p}{P}\right)^{\sigma-1}.$$

From the optimal stopping rule (A.3) we have:

$$m = \frac{f(\theta+1)}{\beta w_A \overline{a}^{\theta+1}}.$$

Employment is (due to the Cobb-Douglas production function):

$$\ell = \frac{1-\alpha}{\alpha} m\phi.$$

Differentiated sector consumption index is:

$$X = P^{-\varepsilon}.$$

Quantity demanded of individual differentiated sector variety is:

$$x = X\left(\frac{p}{P}\right)^{-\sigma}.$$

Average price of differentiated sector imported intermediate inputs is:

$$\rho = \mu_\rho(\overline{a}) = w_A\overline{a}\left[\beta\frac{\theta}{\theta+1} + (1-\beta)\right],$$

where

$$\rho(a) = \beta w_A a + (1-\beta) w_A \overline{a}.$$

Aggregate value of differentiated sector imports is:

$$M = nm\rho.$$

Expected fixed costs are:

$$f_o + f_e + \frac{f}{\overline{a}^\theta}.$$

Expected variable costs are:

$$\rho m + \ell.$$

Free entry imposes:

$$\pi_o - f_e - \frac{f}{\overline{a}^\theta} = 0.$$

Share of profits in differentiated sector expenditure is:

$$\frac{n\pi_o}{P^{1-\varepsilon}}.$$

Share of imported input costs in differentiated sector expenditure is:

$$\frac{M}{P^{1-\varepsilon}}.$$

Welfare is (see (A.74)):

$$V = \frac{\varepsilon}{\varepsilon - 1}\left(X^{\frac{\varepsilon-1}{\varepsilon}} - 1\right) - n\rho m - n\ell.$$

Post-Tariff Equilibrium

We have the following system of simultaneous equations for $\overline{b}^{\tau}$ and ϕ^{τ} given n (see (A.38) and (A.41)):

$$\phi^{\tau} = \frac{\theta}{\theta+1} w_B \overline{b}^{\tau},$$

$$\frac{(\theta+1) f}{w_B \beta \left(\overline{b}^{\tau}\right)^{\theta+1}} = (n)^{-\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{-\varepsilon} \alpha \left(\phi^{\tau}\right)^{\alpha(1-\varepsilon)-1},$$

where we have used $n^{\tau} = n$. Substituting the first equation into the second equation, we obtain the following closed-form solution for $\overline{b}^{\tau}$:

$$\overline{b}^{\tau} = \left[\frac{(\theta+1) f}{\alpha\beta} (n)^{\frac{\sigma-\varepsilon}{\sigma-1}} \left(\frac{\sigma}{\sigma-1}\right)^{\varepsilon} \left(\frac{\theta}{\theta+1}\right)^{-\alpha(1-\varepsilon)+1} (w_B)^{-\alpha(1-\varepsilon)}\right]^{\frac{1}{\theta+\alpha(1-\varepsilon)}}.$$

Substituting this solution for $\overline{b}^{\tau}$ into the first of the two equations above, we recover ϕ^{τ}:

$$\phi^{\tau} = \frac{\theta}{\theta+1} w_B \overline{b}^{\tau}.$$

We can now solve for the rest of the post-tariff equilibrium sequentially. We start with a_B:

$$a_B = \frac{w_B \overline{b}^{\tau}}{\tau w_A}.$$

Average price of differentiated sector imported intermediate inputs is:

$$\rho^{\tau} = \left(\frac{a_B}{\overline{a}}\right)^{\theta} \left[\beta w_A \frac{\theta}{\theta+1} a_B + (1-\beta) w_B \frac{\overline{b}^{\tau}}{\tau}\right] + \left[1 - \left(\frac{a_B}{\overline{a}}\right)^{\theta}\right] w_B \left[\beta \frac{\theta}{\theta+1} \overline{b}^{\tau} + (1-\beta) \overline{b}^{\tau}\right].$$

Average price of differentiated sector imported intermediate inputs conditional on sourcing from Country A is:

$$\rho_A^{\tau} = \beta w_A \frac{\theta}{\theta+1} a_B + (1-\beta) w_B \frac{\overline{b}^{\tau}}{\tau}.$$

Average price of differentiated sector imported intermediate inputs conditional on sourcing from Country B is:

$$\rho_B^{\tau} = \beta w_B \frac{\theta}{\theta+1} \overline{b}^{\tau} + (1-\beta) w_B \overline{b}^{\tau}.$$

Differentiated sector variety prices are:

$$p^{\tau} = \frac{\sigma}{\sigma-1} \left(\phi^{\tau}\right)^{\alpha}.$$

Differentiated sector price index is:

$$P^{\tau} = n^{-\frac{1}{\sigma-1}} p^{\tau}.$$

Differentiated sector consumption index is:

$$X^{\tau} = (P^{\tau})^{-\varepsilon}$$

Quantity demanded of individual differentiated sector variety is:

$$x^{\tau} = X^{\tau} \left(\frac{p^{\tau}}{P^{\tau}} \right)^{-\sigma}.$$

Imports (from optimal stopping rule) of intermediate inputs per product are:

$$m^{\tau} = \frac{f}{\beta \left(\overline{b}^{\tau}\right)^{\theta} w_B} \frac{1}{\left[\overline{b}^{\tau} - \frac{\theta}{\theta+1}\overline{b}^{\tau}\right]} = \frac{(\theta+1) f}{\beta \left(\overline{b}^{\tau}\right)^{\theta+1} w_B}.$$

Employment (from Cobb-Douglas production function) is:

$$\ell^{\tau} = \frac{1-\alpha}{\alpha} \phi^{\tau} m^{\tau}, \qquad n\phi^{\tau} m^{\tau} = \alpha \frac{\sigma-1}{\sigma} P^{\tau} X^{\tau},$$

$$\Rightarrow \qquad \ell^{\tau} = (1-\alpha) \frac{\sigma-1}{\sigma} \frac{P^{\tau} X^{\tau}}{n}.$$

Aggregate value of imports of intermediate inputs from Country A is:

$$M^{A} = nm^{\tau} \left(\frac{a_B}{\overline{a}} \right)^{\theta} \rho_A^{\tau}.$$

Aggregate value of imports of intermediate input from Country B is:

$$M^{B} = nm^{\tau} \left[1 - \left(\frac{a_B}{\overline{a}} \right)^{\theta} \right] \rho_B^{\tau}.$$

Welfare is:

$$\begin{aligned} V^{\tau} &= \frac{\varepsilon}{\varepsilon-1} \left[(X^{\tau})^{\frac{\varepsilon-1}{\varepsilon}} - 1 \right] - n\rho^{\tau} m^{\tau} - n\ell^{\tau} - n \left[1 - \frac{G(a_B)}{G(\overline{a})} \right] \frac{f}{G\left(\overline{b}^{\tau}\right)} \\ &= \frac{\varepsilon}{\varepsilon-1} \left[(X^{\tau})^{\frac{\varepsilon-1}{\varepsilon}} - 1 \right] - n\rho^{\tau} m^{\tau} - n\ell^{\tau} - n \left[1 - \left(\frac{a_B}{\overline{a}} \right)^{\theta} \right] \frac{f}{\left(\overline{b}^{\tau}\right)^{\theta}}. \end{aligned}$$

Appendix B: Calibration Appendix

When Tariffs Disturb Global Supply Chains

by

Gene M. Grossman, Elhanan Helpman and Stephen J. Redding

Table of Contents

B.1 Introduction

In this Calibration Appendix, we provide further details on the calibration of the model's parameters using the estimated price and quantity response to the Trump administration's tariffs. All sections of this Calibration Appendix contain additional information for Section 5 of the paper.

In Subsection B.2, we provide some descriptive evidence on the Trump tariffs. In Subsection B.3, we provide further evidence of a relocation of import sourcing away from China and towards Other Asian countries in response to these tariffs.

In Subsection B.4, we replicate the event-study estimates of the price and quantity response to the Trump tariffs in Amiti et al. (2020). We use these event-study estimates to generate predicted changes in U.S.-China import values and Chinese export prices, which we use in our calibration of the model's parameters.

In Subsection B.5, we discuss in further detail the calibration of the model's parameters using these estimated price and quantity responses to the Trump tariffs and other empirical moments for the United States. In Subsection B.6, we provide further details on the terms of trade and welfare predictions of our calibrated model.

In Subsection B.7, we show the wedge between the perceived marginal cost of inputs and expected input prices as a function of the size of the tariff for our calibrated parameter values.

In Subsections B.8-B.10, we report a number of robustness tests on our baseline calibration of the model. We begin in Subsection B.8 by examining the robustness of our quantitative conclusions to the assumption of alternative parameter values.

In Subsection B.9, we report a robustness test, in which we exclude consumer goods from our calibration, and demonstrate a similar pattern of results. In Subsection B.10, we report a counterfactual in which the country where new searches occur is the home country (reshoring), such that the profits of new suppliers are included in home welfare.

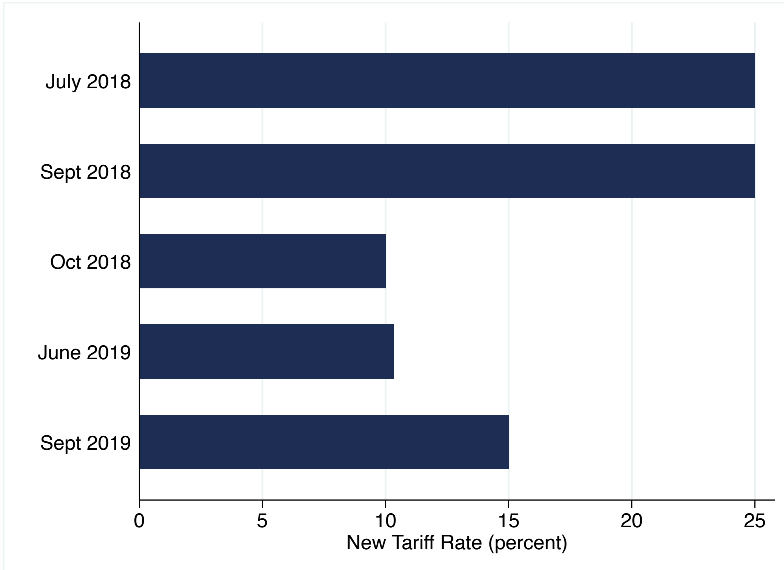
In Subsection B.11, we provide further information on the data sources used for the calibration of the model parameters in Subsection B.5 of this Calibration Appendix.

B.2 Trump administration tariffs

From February 2018 to the end of our sample period in October 2019, the Trump administration imposed eight waves of new U.S. tariffs. Starting in July 2018, the last five of these tariff waves targeted U.S. imports from China. In Figure B.1 below, we show the unweighted average of new U.S. tariffs on China for these last five waves. In July and September 2018, average tariffs of 25 percent were imposed on \$34 billion and \$16 billion of U.S. imports, respectively. In October 2018 and June 2019, average tariffs of around 10 percent were applied to \$200 and \$200 billion of U.S. imports, respectively. In September 2019, average tariffs of 15 percent were introduced on \$112 billion of U.S. imports.

While countries have traditionally targeted final consumption goods with tariffs, the Trump administration's tariffs on China were distinctive in that they initially were concentrated on inter-

Figure B.1: Average Tariff Rate by Wave of Tariffs on China



Note: Unweighted average of the additional U.S. tariffs imposed on imports from China by tariff wave; total U.S. import values affected by each wave of tariffs on China were: \$34 billion (July 2018); \$16 billion (September 2018); \$200 billion (October 2018); \$200 billion (June 2019); \$112 billion (September 2019); import values correspond to headline values when each tariff wave was imposed.

mediate goods. In Figure B.2, we show the share of import value on which additional U.S. tariffs on China were imposed by category of good and tariff wave. Early tariff waves were concentrated on intermediate and capital goods. Later tariff waves expanded to include consumer goods, as the administration began to "run out" of intermediate and capital goods to target.

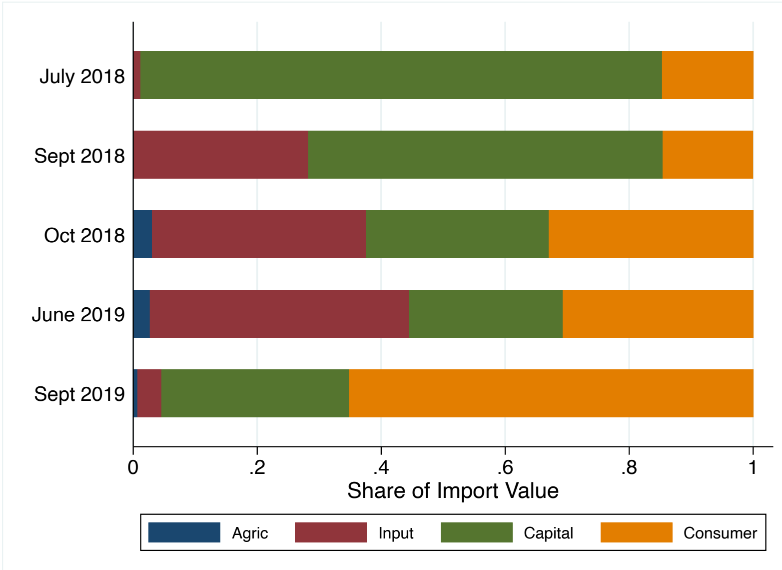
In our baseline specification in the paper, we calibrate our model for all goods, recognizing that supply chains can extend to consumer goods. In Section B.9 of this calibration appendix, we report a robustness test, in which we exclude consumer goods from the calibration, and demonstrate a similar pattern of results.

B.3 Relocation of Import Sourcing

In the introduction in the paper, we provide evidence that the Trump tariffs on China lead to a relocation of import sourcing away from China and towards other Asian countries. In this subsection of the calibration appendix, we provide further evidence in support of this relocation of import sourcing.

In Figure B.3, we show the shares of China and other Asian countries in the total value of U.S. imports. We define other Asian countries as Bangladesh, Cambodia, Hong Kong, India, Indonesia, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam, as identified by Kearney (2020), in addition to China, as "traditional offshoring trade partners." After the first wave of tariffs on China in July 2018, we find a sharp decline in China's share of U.S. imports of around 3 percent (left scale), and a corresponding rise in Other Asia's share of U.S.

Figure B.2: Share of Import Value on Which Additional Tariffs were Imposed by Category of Good and Tariff Wave



Note: Share of import value on which additional tariffs were imposed by product end-use according to the U.S. Census Bureau classification.

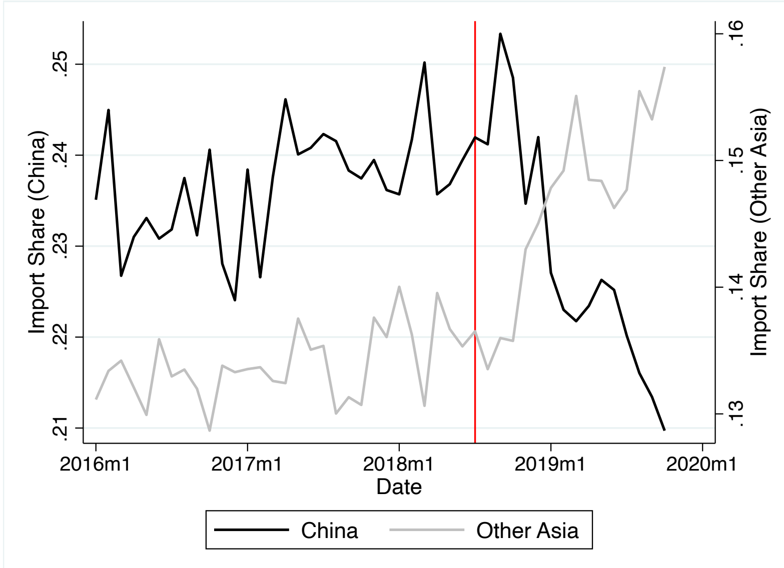
imports of a similar magnitude (right scale). This similarity between the decline for China and the rise for Other Asia's import share provides a first piece of evidence of a relocation of import sourcing from China to Other Asia.

In Figure B.4, we provide additional evidence of this relocation using the extensive margin of the number of products by import source. The black solid line shows the number of products that were (i) sourced from China in the twelve months preceding the first Trump tariff wave on China in July 2018, (ii) not sourced from other Asian countries during this preceding twelve-month period, (iii) sourced from other Asian countries following the first Trump tariff wave on China in July 2018. In the immediate aftermath of this first wave of tariffs on China (announced June 15, 2018 and enacted July 6, 2018), we observe a substantial number of products for which there is a relocation of import sourcing from China to other Asian countries.

In Table 1 in the paper, we provide regression evidence that an increase in U.S. tariffs on China relative to U.S. tariffs on Other Asian countries reduces U.S. imports from China and increases U.S. imports from these Other Asian countries. We now provide further evidence that these empirical findings are not driven by differences in pre-trends between U.S. imports from these two groups of countries.

In our baseline specification in the paper, we estimate the following regression of the log value of U.S. imports for either China or Other Asia ($\ln m_{ji}$ for $j = CH$ or $j = OA$) on the log of one plus the U.S. *ad valorem* tariff on China minus the log of one plus the U.S. *ad valorem* tariff on

Figure B.3: Share of China and Other Asia in U.S. Imports



Note: Black solid line shows share of U.S. imports from China; gray solid line shows share of U.S. imports from other Asian countries; we define other Asian countries as Bangladesh, Cambodia, Hong Kong, India, Indonesia, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, and Vietnam following Kearney (2020); red vertical line shows the date of the first Trump tariff wave on China; both series seasonally adjusted by removing month fixed effects.

Other Asia ($\ln\left((1+\tau_{CHit})/(1+\tau_{OAit})\right)$):

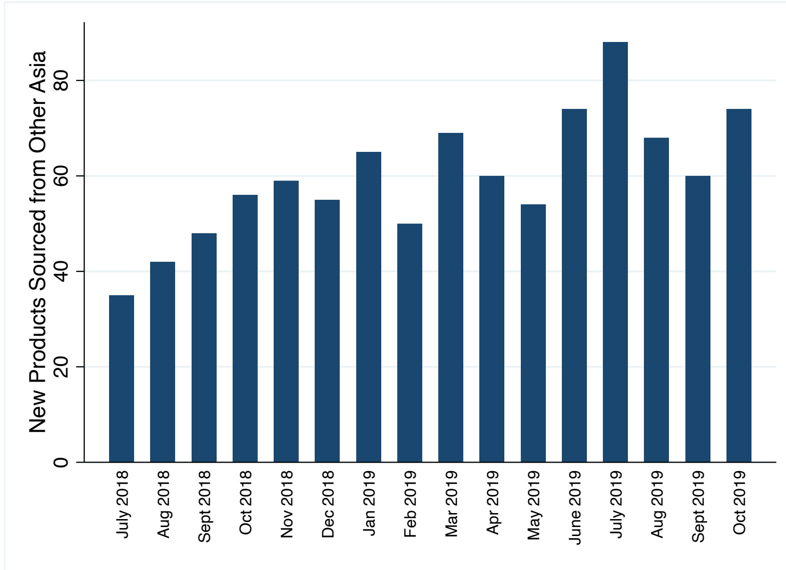
$$\ln m_{jit} = \beta \ln \left(\frac{1+\tau_{CHit}}{1+\tau_{OAit}} \right) + \eta_i + d_t + u_{jit}, \tag{B.1}$$

where j denotes exporter (either China or Other Asia); i indicates 10-digit Harmonized Tariff Schedule (HTS) products; t indexes date (month $\times$ year); τ_{jit} is the *ad valorem* import tariff; β is the key coefficient of interest on log relative tariffs; η_i are fixed effects for 10-digit HTS products; d_t are date fixed effects; u_{jit} is a stochastic error; and we cluster standard errors by Harmonized System (HS) 8-digit product to control for serial correlation over time and because some tariffs were imposed at this level.

We estimate this regression (B.1) for China and Other Asia separately using observations across products and over time.[33] The inclusion of the product and date fixed effects implies that this specification has a "difference-in-differences" interpretation, where the first difference is over time, and the second difference is across products experiencing different levels of tariff increases. The inclusion of the date fixed effects controls for different time trends in imports across all products for China and Other Asia (e.g., imports across all products could be growing faster or slower for Other Asia compared to China even before the imposition of the Trump tariffs). The key identifying assumption is parallel trends within a given exporter for products experiencing high versus low changes in relative tariffs.

[33] In contrast, our event-study specifications in Subsection B.4 of this Calibration Appendix use observations across exporting countries, products and time.

Figure B.4: Products Previously Sourced from China and Now Sourced from Other Asia



Note: Vertical bars show number of products that were (i) sourced from China during the 12 months before the first wave of tariffs on China in July 2018, (ii) not sourced from other Asian countries during this preceding 12-month period; (iii) sourced from other Asian countries after the first wave of tariffs on China in July 2018; red vertical line shows the date of the first Trump tariff wave on China; other Asian countries are defined as in Figure B.3.

A potential concern is that there could be differences in pre-trends within a given exporter for products experiencing different levels of tariff increases. As first step to addressing this concern, we augment the regression specification in equation (B.1) with linear time trends for each 2-digit HS sector, which allows 2-digit sectors to have different linear pre-trends. In this augmented specification, the estimated coefficient on log relative tariffs (β) is identified from deviations from these linear time trends. As shown in Table B.1, we find the same pattern of results as in our baseline specification in Table 1 in the paper. We find that imports from China were significantly lower for goods that experienced large tariff hikes, while imports from Other Asia were correspondingly higher. We find this pattern whether we consider all goods (Columns (1) and (2)) or exclude consumer goods (Columns (3) and (4)).

As a further check for differences in pre-trends, we estimate a placebo specification, using 12-month periods before and after each Trump tariff wave. We begin by computing the log change in relative U.S. tariffs, measured as the log of one plus the U.S. *ad valorem* tariff on China minus the log of one plus the U.S. *ad valorem* tariff on Other Asia. We refer to pairs of countries and 10-digit Harmonized Tariff Schedule (HTS) products on which new tariffs were imposed by the Trump administration as treated country-products. We assign each of these treated country-products to the first tariff wave in which it was treated. For each of these treated country-product pairs, we compute the log change in relative tariffs between the last month before that tariff wave and the twelfth month thereafter. For untreated country-products, we use the same twelve-month period for differencing as for the first tariff wave. We next compute the log difference in U.S. imports from China and Other Asia for these twelve-month periods before and after each tariff wave.

Table B.1: U.S. Imports from China and Other Asian Countries

	(1)	(2)	(3)	(4)
	Log U.S. Imports from China	Log U.S. Imports from Other Asia	Log U.S. Imports from China	Log U.S. Imports from Other Asia
	All Goods	All Goods	Excluding Consumer Goods	Excluding Consumer Goods
Log Relative Tariffs	-1.929***	0.299***	-1.697***	0.249**
	(0.084)	(0.086)	(0.111)	(0.104)
Product Fixed Effects	Yes	Yes	Yes	Yes
Month Fixed Effects	Yes	Yes	Yes	Yes
Date × HS2 Linear Time Trends	Yes	Yes	Yes	Yes
R-squared	0.88	0.86	0.87	0.86
Observations	315,316	315,316	193,871	193,871

Note: Observations are at the source-HTS10-date level from January 2016 to October 2019, where source is either China or Other Asia, and date is month × year; Columns (1) and (2) include all goods; Columns (3) and (4) exclude consumption goods; regressions include only products with positive imports from both sources; log Relative Tariffs is the log difference between one plus the *ad valorem* tariff rate on imports from China and one plus the weighted-average *ad valorem* tariff rate on imports from Other Asia; Other Asia is defined as in Figure B.3 above; the weighted-average tariffs use the annual import values in 2017 as weights. Standard errors are clustered at the HS8 level; *, ** and *** indicate significance at the 10, 5 and 10 percent, respectively.

Finally, we estimate separate long-difference regressions of these log changes in U.S. imports *before* and *after* each tariff wave ($\Delta_{12} \log m_{jit}$) on the log change in tariffs *after* each tariff wave ($\Delta_{12}^{Post} \ln \left(\frac{1+\tau_{CHit}}{1+\tau_{OAit}}\right)$):

$$\Delta_{12} \log m_{jit} = \beta \Delta_{12}^{Post} \ln \left(\frac{1+\tau_{CHit}}{1+\tau_{OAit}} \right) + u_{jit}, \tag{B.2}$$

where j denotes exporter (either China or Other Asia); i indicates 10-digit Harmonized Tariff Schedule (HTS) products; t indexes a twelve-month period; u_{jit} is a stochastic error; and we again cluster standard errors by HS 8-digit product, because some tariffs were imposed at this level.

We estimate this regression (B.2) separately over the twelve-month periods *before* and *after* each Trump Tariff wave, such that observations correspond to a cross-section of ten-digit Harmonized System (HS) products. In Columns (1) and (2) of Table B.2, we report the results for the twelve-month period *after* each Trump tariff wave. Consistent with the results in Table B.1 above, we find statistically significant reductions in imports from China and statistically significant increases in imports from Other Asia after the Trump tariffs. In contrast, in Columns (3) and (4), we report the results using import growth for the twelve-month period *before* each Trump tariff wave and log changes in tariffs for the twelve-month period *after* each Trump tariff wave. We find a quite different relationship between *past* import growth and *future* tariff changes. In Column (3), we find a positive (rather than negative) and statistically significant relationship between past import growth from China and future tariff changes. In Column (4), we find a positive but statistically insignificant relationship between past import growth from Other Asia and future tariff changes. This pattern of results provides evidence that our findings in Columns (1) and (2) of Table B.2, and in Table B.1 above, are not capturing differences in pre-trends.

Table B.2: Long Differences of U.S. Imports from China and Other Asian Countries

	(1)	(2)	(3)	(4)
	Δ log U.S. Imports from China	Δ log U.S. Imports from China	Δ log U.S. Imports from Other Asia	Δ log U.S. Imports from Other Asia
	All Goods	All Goods	All Goods	All Goods
Δ log Trump Tariff	-2.129***	0.548**	0.739***	0.198
	(0.2151)	(0.2388)	(0.1862)	(0.2305)
Time Period	12 Months Post Trump Tariff	12 Months Post Trump Tariff	12 Months Pre Trump Tariff	12 Months Pre Trump Tariff
Observations	5,625	5,625	5,625	5,625
R-squared	0.019	0.001	0.003	0.000

Note: Observations are a cross-section of HTS10 products sourced from either China (Columns (1) and (3)) or Other Asia (Columns (2) and (4)); Δ log Relative Tariff Post is the log change in U.S. relative tariffs on China and Other Asia for the twelve-month period *after* each Trump tariff wave ($\Delta_{12}^{Post} \ln\left(\frac{1+\tau_{CHit}}{1+\tau_{OAit}}\right)$); in Columns (1) and (2), the log changes in U.S. imports ($\Delta_{12} \log m_{jit}$) are for the twelve-month period *after* each Trump tariff wave; in Columns (3) and (4), the log changes in U.S. imports ($\Delta_{12} \log m_{jit}$) are for the twelve-month periods *before* each Trump Tariff wave; Columns (1) and (3) report results for U.S. imports from China; Columns (2) and (4) report results for U.S. imports from Other Asia; Other Asia is defined as in Figure B.3 above; standard errors are clustered at the HTS8 level. *, ** and *** indicate significance at the 10, 5 and 10 percent, respectively.

Taken together, the empirical findings of this subsection provide evidence of a relocation of import sourcing from China to other Asian countries following the Trump administration's tariffs on China. Such a relocation of import sourcing occurs in the model for parameter values for which $\tau > \tau_c$. We show in Subsection B.5 below that this parameter inequality is indeed satisfied for our calibrated parameter values.

B.4 Price and Quantity Responses to the Trump Tariffs

We follow Amiti et al. (2019, 2020) and Fajgelbaum et al. (2019) in estimating the price and quantity response to the Trump tariffs using event-study specifications. In particular, we replicate the event-study estimates in Amiti et al. (2020), since the sample period includes the two later waves of U.S. tariffs on China in June and September 2019.[34] We use these event-study estimates to generate predicted changes in U.S.-China import values and Chinese export prices, which we use below in our calibration of the model's parameters.

We consider the following event-study regression specification for exporting country j, product i and month t:

$$\ln x_{jit} = \eta_{ji} + \sum_{s=-T}^{T} \beta_s \left(1_{jis} \times \ln \left(\frac{1+\tau_{jis}}{1+\tau_{ji0}} \right) \right) + \mu_{jt} + \delta_{it} + u_{jit}, \tag{B.3}$$

[34] In contrast, the sample periods in Amiti et al. (2019) and Fajgelbaum et al. (2020) end in December 2018 and April 2019, respectively.

where x_{jit} is either U.S. import prices (unit values) inclusive of the tariff or U.S. import values. The excluded category is the last untreated month (i.e., $\beta_0 = 0$). We measure the log change in tariffs between month s and the last untreated month ($\ln\left[(1+\tau_{jis})\,/\,(1+\tau_{ji0})\right]$).). Products correspond to Harmonized Tariff Schedule (HTS) 10-digit categories. We include country-product fixed effects (η_{ji}) to control for the level of import prices or values in the last untreated month and capture differences in quality or comparative advantage across countries and products. The country-time fixed effects (μ_{jt}) capture time-varying factors that affect import prices or values (e.g., exchange rates). The product-time fixed effects (δ_{it}) allow for time-varying forces that affect import prices or values for a product across all countries (e.g., common technological change).

We begin by replicating the event-study estimates in Figures 2 and 3 of Amiti et al. (2020). In Columns (1) and (3) of Table B.3, we report the estimated coefficients for U.S. import prices (inclusive of the tariffs). In line with a range of other empirical studies, we find no evidence of pre-trends, and high rates of pass-through for the Trump tariffs. In the twelve months leading up to a tariff wave, we find coefficients that are close to zero and, if anything, negative. In contrast, in the months immediately after a tariff wave, we find large, positive and statistically significant coefficients that are close to one. After 12 months, we find an elasticity of U.S. import prices with respect to the tariff of 0.96, which implies a corresponding elasticity of Chinese export prices of $0.96 - 1 = -0.04$.

Table B.3: Estimated Event-Study Coefficients

	(1)	(2)		(3)	(4)
Treatment Time	**Import Prices (inclusive of tariff)**	**Import Values**	**Treatment Time**	**Import Prices (inclusive of tariff)**	**Import Values**
s=-12	-0.0724**	-0.3073***	s=1	0.8363***	-0.9549***
s=-11	-0.1457***	-0.2573**	s=2	0.8421***	-1.3556***
s=-10	-0.1269***	-0.2028*	s=3	0.8228***	-1.1244***
s=-9	-0.0737*	-0.1144	s=4	0.8903***	-1.7185***
s=-8	-0.0889**	-0.4006***	s=5	0.8300***	-1.8107***
s=-7	-0.0616	0.0207	s=6	0.9304***	-1.9154***
s=-6	-0.0791**	0.1873*	s=7	0.9325***	-1.5717***
s=-5	-0.0647*	0.2493**	s=8	0.9529***	-1.8898***
s=-4	-0.0307	-0.0816	s=9	0.9438***	-1.6936***
s=-3	-0.0075	0.1556*	s=10	0.8592***	-1.9701***
s=-2	-0.0452	0.1139	s=11	0.8836***	-2.1519***
s=-1	0.0131	0.0535	s=12	0.9559***	-2.2151***

Note: Replication of the event-study estimates in Figures 1 and 2 of Amiti et al. (2020); estimated coefficients (β_s) on the interactions between treatment years (s) and tariff changes; negative values of s correspond to months before a tariff wave; positive values of s correspond to months after a tariff wave; *** significant at the 1 percent level; ** significant at the 5 percent level; * significant at the 10 percent level.

In Columns (2) and (4), we report the estimated coefficients for U.S. import values. In line with other evidence, we again find little evidence of pre-trends, and substantial changes in U.S. import sourcing in response to the Trump tariffs. In the twelve months leading up to a tariff wave, we find coefficients that are typically small in magnitude and often statistically insignificant. In contrast, in the months immediately after a tariff wave, we find large, negative and statistically significant coefficients. After 12 months, we find an elasticity of U.S.-China import values with respect to the tariffs of -2.22.[35]

Table B.4: Predicted Percentage Changes in Chinese Export Prices and U.S.-China Import Values in Response to the Trump Tariffs

	(1)	(2)		(3)	(4)
Year and Month	**Chinese Export Prices**	**U.S.-China Import Values**	**Year and Month**	**Chinese Export Prices**	**U.S.-China Import Values**
2018m2	-0.00	-0.05	2019m1	-0.84	-13.65
2018m3	-0.01	-0.08	2019m2	-0.98	-14.94
2018m4	-0.12	-0.68	2019m3	-0.51	-14.89
2018m5	-0.11	-0.90	2019m4	-0.65	-14.21
2018m6	-0.12	-0.77	2019m5	-0.51	-15.89
2018m7	-0.37	-3.16	2019m6	-1.55	-21.49
2018m8	-0.39	-4.06	2019m7	-1.87	-25.37
2018m9	-0.46	-4.24	2019m8	-1.81	-24.70
2018m10	-1.10	-9.86	2019m9	-1.77	-32.77
2018m11	-1.19	-12.00	2019m10	-2.14	-35.09
2018m12	-1.07	-11.44			

Note: Predicted percentage changes in Chinese export prices and U.S.-China import values over time; we use the estimated event-study coefficients from Table B.3, subtracting one from the coefficients for import prices (inclusive of the tariff) to obtain the implied change in export prices (exclusive of the tariff); we multiply these estimated coefficients by the change in U.S.-China import tariffs, and aggregate across 10-digit Harmonized Tariff Schedule (HTS) products.

Using these event-study estimates, we compute the implied changes in Chinese export prices and U.S.-China import values by multiplying the estimated elasticities by the change in tariffs for each product ($\log\left[(1+\tau_{ijs})\,/\,(1+\tau_{ij0})\right]$) and aggregating across products. In Columns (1) and (3) of Table B.4, we report the predicted decline in the price received by Chinese exporters. By October 2019, we find a small reduction in Chinese export prices of 2.14 percent. In Columns (2) and (4), we report the corresponding predicted decline in the value U.S.-China imports. By October 2019, we find a substantial reduction in U.S.-China imports of 35.09 percent.[36]

We use these two empirical moments for the percentage decline in Chinese export prices and U.S.-China imports of 2.14 and 35.09 percent, respectively, in our calibration of the model's parameters in the next subsection.

B.5 Parameter Calibration

We discipline the quantitative predictions of our model for the terms of trade and welfare by calibrating its parameters such that it matches the above empirical estimates of the price and

[35] These estimated elasticities for import values are comparable to the estimated elasticities of -1.424 in Amiti et al. (2019) and -2.53 in Fajgelbaum et al. (2020).

[36] In comparison, the observed share of China in U.S. imports declined from 21.6 percent in 2017 to 17.0 percent by the end of 2022, which reflects not only the change in U.S.-China tariffs, but the combined impact of all other shocks in the data.

quantity response to the Trump administration's tariffs.

We interpret Country A in the model as corresponding to China in the data. Motivated by our empirical findings of a relocation of U.S. imports towards other Asian countries, we use Other Asia as the destination for new searches in our baseline specification (Country B). In Section B.10 of this Calibration Appendix, we report a counterfactual, in which we instead evaluate the welfare effects of the Trump tariffs under the counterfactual assumption that all relocated parts of supply chains return to the United States.

We assume a Pareto distribution of supplier productivity ($G(a) = a^{\theta}$), as commonly assumed in the theoretical and empirical literature on heterogeneous firms following Melitz (2003). In this specification, the key parameter determining the return to supplier search is the Pareto shape parameter (θ). A larger value for θ corresponds to less dispersion in supplier productivity ($1/a$), and hence less dispersion in supplier costs (a).

In the remainder of this section, we discuss the calibration of each of the model's parameters in turn: the tariff (τ); the demand elasticities (σ and ε); the share of intermediate inputs in firm costs (α); the Nash bargaining parameter (β); the fixed operating, entry and search costs (f_o, f_e, f); wage costs in Countries A and B (w_A, w_B); and the dispersion of supplier productivity (θ). In Table B.5, we list these parameters, their calibrated values, and the source for each calibrated value, as discussed further in the remainder of this subsection. In Subsection B.11 below, we provide further details of the data sources used for the calibration of the model's parameters.

B.5.1 Tariff

In our baseline specification, we set the tariff equal to the import-weighted average of the tariffs imposed on China by the Trump administration on China across all goods, using 2017 import shares as weights, which yields $\tau = 1.14$. Given our other calibrated model parameters, we show below that $\tau > \tau_c$, such that firms search for new suppliers in Country B, consistent with the relocation of import sourcing in the data.

B.5.2 Demand Parameters (σ, ϵ)

We now turn to the demand parameters. We calibrate the elasticity of substitution across varieties within the differentiated sector (σ) and the elasticity of demand for the differentiated sector (ε) based on the estimated elasticities within and across sectors using the Trump administration tariffs in Fajgelbaum et al. (2020). Therefore, we set $\sigma = 2.53$ equal to the estimated elasticity across 10-digit Harmonized Tariff Schedule (HTS) products within 4-digit North American Industry Classification Systems (NAICS) codes. This calibrated value is close to the median estimate of 3.1 at the same level of product aggregation in Broda and Weinstein (2006). We set $\varepsilon = 1.19$ equal to the estimated elasticity across 4-digit NAICS industries. This calibrated value is close to the estimate of 1.36 at the same level of sector aggregation in Redding and Weinstein (2021). Therefore, these empirical estimates provide support for our assumptions of elastic demand across sectors ($\varepsilon > 1$), and a higher elasticity across varieties within sectors than across sectors ($\sigma > \varepsilon$).

Table B.5: Calibration of Model Parameters

Parameter	Notation	Calibrated Value	Source
Sector elasticity	ε	1.19	Fajgelbaum et al. (2020)
Variety elasticity	σ	2.53	Fajgelbaum et al. (2020)
Intermediate costs	α	0.45	Input cost share U.S. manufacturing
Bargaining weight	β	0.80	Profit share U.S. manufacturing
Home wage		1	Numeraire
Labor supply	L	19.48	U.S. Gross Domestic Product (GDP) in 2017
Fixed operating cost	f_o	0.0025	Share of Manufacturing in GDP
Fixed search cost	f	f_o / 100	Institute of Management (2018)
Fixed entry cost	f_e	Such that $\tau_c < \tau < \tau_{ex}$	Relocation of import sourcing in response to the Trump tariffs
Country A wage	w_A	0.20	Relative China-U.S. GDP per capita (purchasing power parity)
Relative Country B wage	w_B / w_A	1.12	Estimated declines of U.S.-China imports
and productivity dispersion	θ	9.26	(34.23%) and of Chinese export prices (2.14%)

Note: The first column lists each parameter; the second column contains the corresponding notation; the third column gives its calibrated value; the fourth column summarizes the source for this calibrated value.

B.5.3 Variable Cost and Bargaining Parameters (α, β)

We next turn to the variable cost and bargaining parameters. We calibrate the share of intermediate inputs in firm costs (α) using the aggregate share of intermediate inputs in firm costs in U.S. data, which yields $\alpha = 0.45$. We calibrate the Nash bargaining parameter (β) such that the share of profits in differentiated sector expenditure matches the observed profit share in U.S. data of around 5 percent, which yields $\beta = 0.8$.

B.5.4 Fixed Costs (f_o, f, f_e)

We now determine the various fixed costs. We calibrate the level of the fixed operating cost (f_o) such that the share of the differentiated sector in gross domestic product (GDP) is equal to the share of manufacturing in U.S. GDP immediately prior to the Trump administration's tariffs (11 percent). We calibrate the fixed search cost relative to the fixed operating cost (f/f_o) using data on the share of procurement in firm costs. From the evidence reported in Institute of Supply Management (2018), procurement accounts for around 1 percent of firm costs. Based on these empirical findings, we calibrate the fixed search as 1 percent of the fixed operating cost ($f/f_o = 0.01$). We calibrate the fixed entry cost relative to the fixed operating cost (f_e/f_o) such that the tariff ($\tau = 1.14$) induces a relocation of import sourcing but does not induce exit ($\tau_c < \tau < \tau_{ex}$), which requires the following parameter inequalities to be satisfied:

$$\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} < \frac{1}{1+f_e/f_o} < \frac{\theta-(1-\beta)\,\alpha\,(\sigma-1)}{\theta-\alpha\,(\sigma-1)}\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}.$$

Note that $0 < \frac{w_A}{w_B} < 1$ and $0 < \frac{1}{1+f_e/f_o} < 1$ for all finite and positive values of (f_e, f_o). Therefore, given f_o, we can always find a value of f_e such that the above inequalities are satisfied. In particular, we choose the fixed entry cost (f_e) such that $\frac{1}{1+f_e/f_o} < 1$ lies mid-way between the above lower bound of $\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} < 1$ and its upper bound of one.

B.5.5 Wages (w, w_A)

We next turn to wages. We choose the home wage as the numeraire ($w = 1$). We calibrate the wage in China (w_A) such its income per capita equals one fifth of that in home ($w_A/w = 0.2$), which is line with relative gross domestic product (GDP) per capita in purchasing power parity (PPP) terms in China and the United States in 2017.

B.5.6 Dispersion of Supplier Productivity (θ) and Relative Cost Disadvantage of Country B (w_B/w_A)

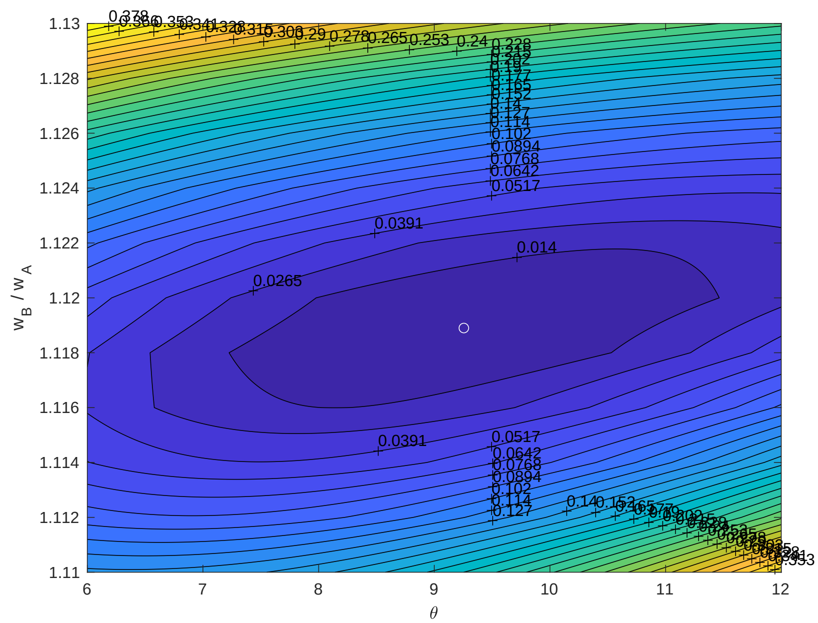
Under our assumption of a Pareto distribution of supplier productivity, the remaining two parameters of the Pareto shape parameter (θ) and the relative cost disadvantage of Country B (w_B/w_A) play a key role in determining the terms of trade and welfare impact of the tariff in the model. In contrast, the welfare impact of the tariff is invariant to the fixed search cost (f) for a Pareto productivity distribution. The reason is that although this fixed search cost determines the level of average supplier productivity before the tariff ($\overline{a}$) and after the tariff ($\overline{b}^{\tau}$), it leaves relative supplier productivity between these two equilibria ($\overline{b}^{\tau}/\overline{a}$) unchanged, and hence does not influence the welfare impact of the tariff.

We choose the Pareto shape parameter (θ) and the relative cost disadvantage of Country B (w_B/w_A) to match the predicted declines in U.S.-China import values and Chinese export prices (35.09 and 2.14 percent, respectively) from Subsection B.4 above. Other things equal, a larger value of θ implies less dispersion in supplier productivity, which makes it easier to find new suppliers in Country B, and hence implies a larger drop in import values and exporter prices from Country A. Similarly, a smaller value of $w_B/w_A > 1$ implies a higher return to searching for new suppliers in Country B, and hence a larger drop in import values and exporter prices from Country A, other things equal.

In Figure B.5, we display the objective function of the sum of squared deviations between the model's predictions for the declines in U.S.-China import values and Chinese export prices and the empirical values of these moments. We show contours of this objective function across a two-dimensional grid of parameter values for the Pareto shape parameter $\theta \in [6, 12]$ and the relative cost disadvantage of Country B $w_B/w_A \in [1.11, 1.13]$. We find that this objective function is well behaved in the parameter space with a unique global minimum. Our model exactly matches the two empirical moments of a 35.09 percent decline in U.S.-China import values and a 2.14 percent percent decline in Chinese export prices for the parameter values of $\theta = 9.26$ and $w_B/w_A = 1.12$.

Our calibrated Pareto shape parameter of $\theta = 9.26$ is somewhat high relative to the range of values from 2-12 typically considered in the empirical trade literature. In our model, this parameter governs productivity dispersion across intermediate input suppliers, where these intermediate inputs account for only 45 percent of production costs. For our calibrated parameter values of $\theta = 9.26$

Figure B.5: Sum of Squared Deviations Between the Model's Predictions for the Declines in U.S.-China Import Values and Chinese Export Prices and the Empirical Moments



Note: Contour plot of the objective function of the sum of squared deviations between the model's predictions for the declines in U.S.-China import values and Chinese export prices and the two empirical moments (declines of 35.09 and 2.14 percent, respectively) across a two-dimensional parameter grid for $\theta \in [6, 12]$ and $w_B/w_A \in [1.11, 1.13]$; darker blue corresponds to lower values; lighter yellow corresponds to higher values; the white hollow circle shows our calibrated parameter values ($\theta = 9.26$ and $w_B/w_A = 1.12$) for which the model's predictions exactly match the two empirical moments.

and $w_B/w_A = 1.12$, our model exactly matches the percentage declines in U.S.-China import values and Chinese export prices with respect to the U.S. tariff in the data, and hence exactly matches the reduced-form elasticities of U.S.-China imports and Chinese export prices with respect to this tariff.

Our calibrated relative cost disadvantage of Country B of $w_B/w_A = 1.12$ is larger than observed differences in income per capita in purchasing power parity terms between Other Asian countries and China. However, w_B/w_A in the model corresponds to the relative wage per efficiency unit of labor in Country B, which can differ from relative observed wages. By construction, relative production costs in Other Asia must have been higher than in China before the tariff, otherwise these imports would not have been sourced from China. More broadly, if labor is less productive in Other Asian countries than in China, relative production costs in Other Asia will be larger than relative observed wages.

B.5.7 Model Solution

For given parameter values (ε, σ, α, β, w, L, f_o, f, f_e, w_A, w_B/w_A, θ, τ), we solve for the pre-tariff and post-tariff equilibria using the system of equations in Section 5.1 of the Analytical Appendix A. To calibrate (w_B/w_A, θ), we vary these two parameters holding all other parameters (ε, σ, α, β, w, L, f_o, f, f_e, w_A, τ) constant, until the model's predictions for the log changes in U.S.-China imports and Chinese export prices (where recall that China corresponds to Country A) equal the predicted declines from our event-study estimates in the previous subsection.

B.6 Terms of Trade and Welfare Effects

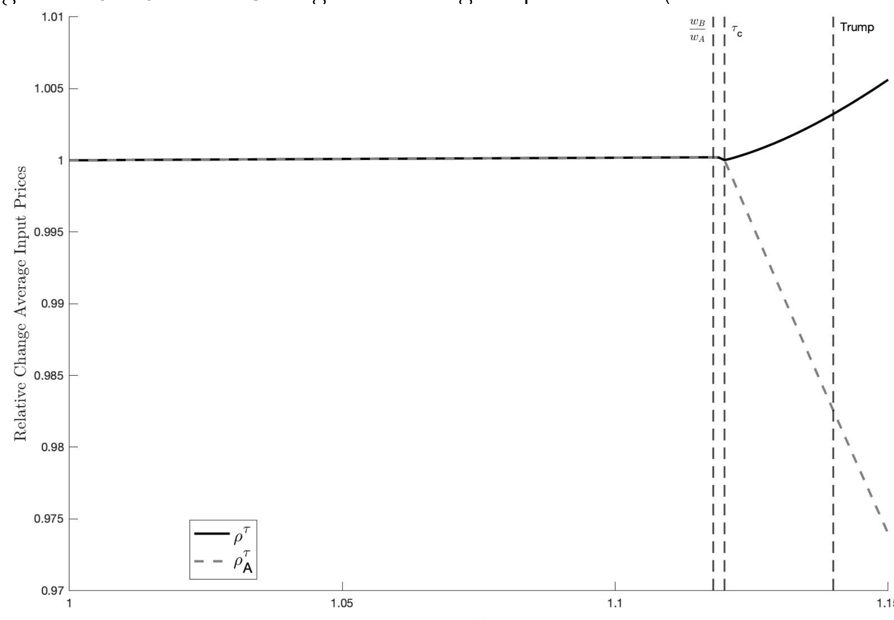
In this subsection, we provide further details on the predicted terms of trade and welfare effects of tariffs in our calibrated model.

B.6.1 Terms of Trade

In Figure B.6, we show changes in the terms of trade as a function of the level of the tariff. The solid black line depicts the relative change in home's average input price (ρ^τ/ρ), which corresponds to an inverse measure of its overall terms of trade. The gray dashed line indicates the relative change in home's average input price from Country A (ρ^τ_A/ρ), which is inversely related to its terms of trade with that nation.

For small tariffs in the range $\tau \in (1, w_B/w_A)$, the solid blue line is upward-sloping, as larger tariffs progressively strengthen the bargaining position of the suppliers, which implies that renegotiation under the shadow of the tariff increases the average input price. However, for our calibrated parameter values that give most bargaining power to the buyer, we find that this effect is small in magnitude, such that $\rho^\tau/\rho = 1.0002$ for $\tau = w_B/w_A = 1.12$. Throughout this range of tariffs, all imports are sourced from Country A, such that the gray dashed line for home's average input price from Country A coincides with the black solid line for its overall average input price.

Figure B.6: Relative Change in Average Input Prices (Inverse Terms of Trade)



Note: Black solid line shows the relative change in overall average input prices under the tariff (ρ^τ/ρ); gray dashed line shows the relative change in average input prices from Country A (ρ^τ_A/ρ); vertical black dashed lines show w_B/w_A, τ_c and our calibrated Trump tariff of $\tau = 1.14$.

Next comes a range of larger tariffs with $\tau \in (w_B/w_A, \tau_c)$ wherein an increase in the tariff strengthens the bargaining power of the *buyers* without inducing any relocation away from Country A. Here, the solid black line is downward-sloping (improving terms of trade), until at $\tau_c = 1.12$, the average input price returns to its free trade level ($\rho^\tau/\rho = 1$). As all imports continue to be sourced from Country A throughout this range of tariffs, the gray dashed and black solid lines again coincide with one another.

For still larger tariffs with $\tau > \tau_c$, there are two offsetting effects of further tariff hikes. On the one hand, higher tariffs continue to strengthen the buyers' bargaining positions vis-à-vis their suppliers in Country A. This strengthening bargaining position leads to a further improvement in the terms of trade with Country A, as shown by the downward-sloping gray dashed line. On the other hand, increases in the tariff rate beyond τ_c cause parts of the supply chain to relocate from a relatively low-cost to a relatively high-cost country. When this relatively high-cost country is a foreign nation, as in our baseline specification here, this amounts to Vinerian trade diversion, and it contributes towards an overall deterioration in the terms of trade.

In Lemma A.5 of this Online Appendix, we show that this Vinerian trade diversion effect dominates if and only if $\tau > (\theta+1)/\theta$. For our calibrated parameter values, we have $(\theta+1)/\theta = 1.1$, and $\tau_c = 1.12$. Therefore, throughout the entire range of tariffs $\tau > \tau_c$, further increases in tariffs raise average input prices and lead to a deterioration in the terms of trade, as shown by the upward-sloping solid black line. Across this range of tariffs $\tau > \tau_c$, we find that our novel mechanism for terms of trade effects through bargaining in the shadow of the tariff (downward-sloping gray dashed line) is quantitatively sizable relative to Vinerian trade diversion (the difference between the upward-sloping solid black line and the downward-sloping gray dashed line).

For our calibrated parameter values that match the price and quantity response to the Trump tariffs ($\tau = 1.14$), we find a small improvement in home's terms of trade with Country A ($\rho_A^{\tau=1.14}/\rho = 0.98$), and a small deterioration in its overall terms of trade ($\rho^{\tau=1.14}/\rho = 1.0042$).

B.6.2 Welfare Decomposition

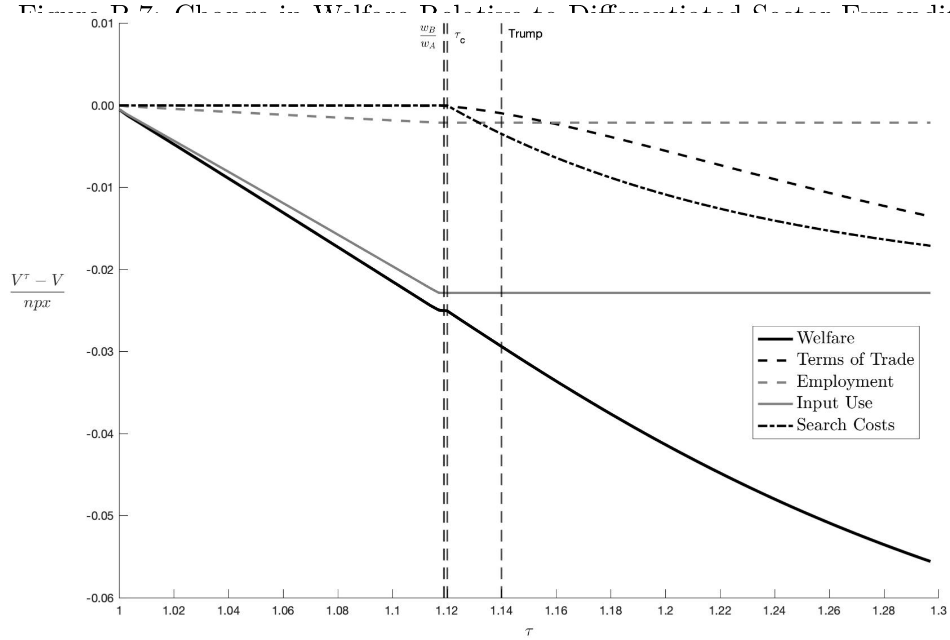
In Figure B.7, the solid black line shows the percentage change in home welfare relative to differentiated sector expenditure ($(V^\tau - V)/npx$) for alternative values of the tariff.[37] We also decompose this welfare impact into the contributions of the terms of trade (black dashed line), differentiated sector employment (gray dashed line), differentiated sector inputs (gray solid line), and additional search costs in Country B (black dashed-dotted line). To implement these decompositions, we use the expressions for the derivatives of welfare for the intervals $\tau \in (1, \tau_c)$ and $\tau \in (\tau_c, \tau_{ex})$ in equations (28) and (31). We implement these expressions as numerical derivatives, by considering a grid of small increments (0.001) in tariffs, and cumulating the resulting changes in each component of welfare from $\tau = 1$ to $\tau = 1.3$. Given our use of these small tariff increments, we find that the

[37] We normalize the change in home welfare by differentiated sector expenditure to ensure that these welfare changes are invariant to the choice of units to measure home income, given the presence of an additive constant in our quasi-linear utility function (equation (1)).

cumulative sum of these small changes in welfare is close to our closed-form solution for the overall change in welfare ($(V^{\tau} - V)/npx$). Again we denote w_B/w_A, τ_c and the Trump tariff of $\tau = 1.14$ by the dashed black vertical lines.

In Proposition 3 in Section 4.1 in the paper, we provide a necessary and sufficient condition for welfare to be decreasing in the tariff at $\tau = 1$, a condition that is satisfied for our calibrated parameter values. For values of $\tau < w_B/w_A$, an increase in the tariff leads to a deterioration in the terms of trade as suppliers in Country A are able to negotiate a higher price, which contributes negatively to welfare (the black dashed line falls below zero). However, given the relatively small cost disadvantage of Country B and relatively high bargaining power of the final goods firm for our calibrated parameter values, this effect is small in magnitude and not discernible visibly. We find that the welfare loss from the reduction in input use (black dashed-dotted line) is substantially larger than the welfare loss from the reallocation of employment away from the differentiated sector (gray dashed line), which highlights that our welfare results are not driven by reallocation away from the differentiated sector. As the tariff rises to $\tau_c = 1.12$, we find a reduction in welfare of 2.5 percent of pre-tariff spending on differentiated products.

Figure B.7: Change in Welfare Relative to Differentiated Sector Expenditure



Note: Changes in welfare and its components are scaled by differentiated sector expenditure (npx) to ensure that they are invariant to the choice of units in which to measure home income; black solid line shows the overall change in welfare ($\left(V^{\tau} - V\right)/npx$); black dashed line shows the change in the terms of trade ($\left(\rho^{\tau} - \rho\right)/npx$); gray dashed line shows the change in employment ($\left(l^{\tau} - l\right)/npx$); gray solid line shows the change in input use ($\left(m^{\tau} - m\right)/npx$); black dashed-dotted line shows the additional fixed costs for new searches in Country B (Σ/npx); vertical black dashed lines show w_B/w_A, τ_c and our calibrated Trump tariff of $\tau = 1.14$.

Further increases in the tariff beyond τ_c reduce welfare if equation (32) is violated, which again is the case for our calibrated parameter values. For all $\tau \in (\tau_c, \tau_{ex})$, both employment and input use in the differentiated sector are invariant with respect to the tariff, such that both of these welfare components are flat (gray dashed and gray solid line). In contrast, as the tariff rises above τ_c, the additional search costs incurred in Country B reduce home welfare (black dashed-dotted line). Furthermore, we find that these additional search costs are quantitatively substantial relative to the impact of tariff on welfare through both employment and input use. For our calibrated parameters, we find that increases in the tariff beyond τ_c also lead to a deterioration in the terms of trade (the black dashed line falls further below one), as Vinerian trade diversion (the replacement of a lower cost source of supply in Country A with a higher cost source of supply in Country B) dominates the improvement in the terms of trade with Country A (through renegotiation in the shadow of the tariff).

Taking these results as a whole, we find welfare losses from the tariff that increase with the size of the tariff. For the Trump tariff ($\tau = 1.14$), this welfare loss is around 3 percent of pre-tariff spending on differentiated products, which is of a comparable magnitude to existing empirical findings for the Trump tariffs. Amiti et al. (2019) and Fajgelbaum et al. (2020) estimate welfare losses from the Trump tariffs of \$8.2 billion and \$7.2 billion, respectively, which equals around 0.04 percent of GDP. These estimated welfare losses are small relative to GDP, in part because of much of GDP consists of services that were not directly affected by the Trump tariffs. But they are comparable to the estimated welfare gains from the North American Free Trade Agreement (NAFTA) in the quantitative trade model of Caliendo and Parro (2015).

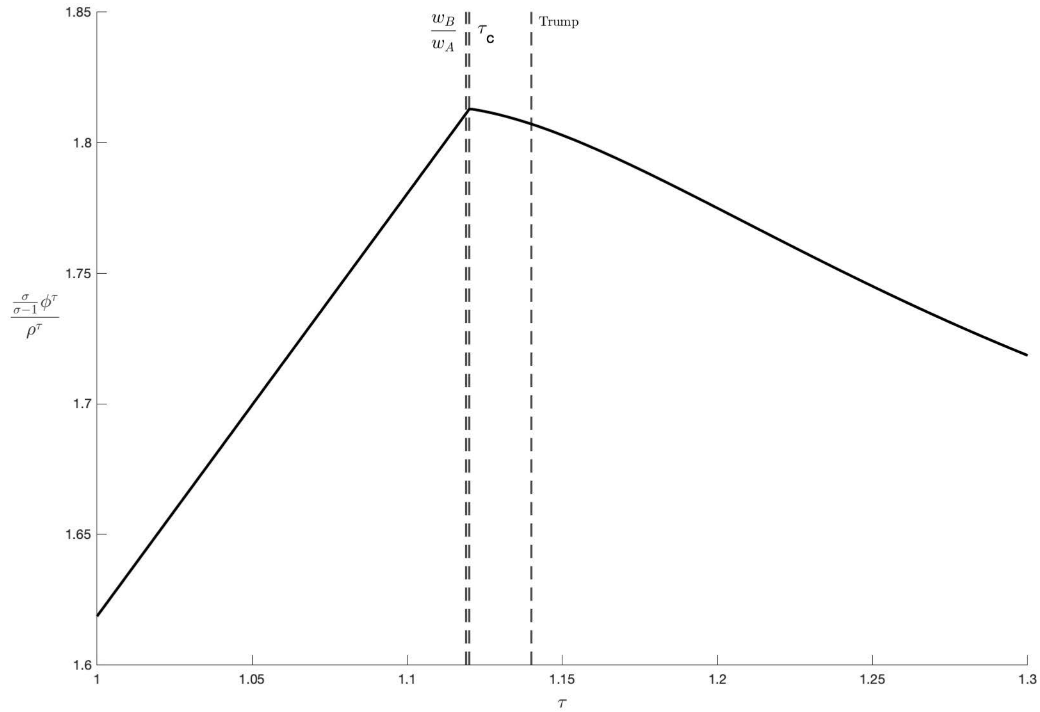
In comparison, our welfare loss of 3.03 percent of differentiated sector expenditure corresponds to 0.30 percent of GDP, where we calibrate the share of the differentiated sector in GDP to match the share of the US manufacturing sector in GDP (approximately 10 percent). Therefore, our calibrated model predicts a somewhat larger welfare loss than the above empirical studies. Nevertheless, it remains less than 0.5 percent of GDP, and is of a comparable magnitude to predictions of standard quantitative trade models.

B.7 Input Wedge

In our welfare decomposition in equation (28) in the paper and the previous subsection, the impact of changes in input use ($dm^\tau/d\tau$) on welfare depends on the wedge between the perceived marginal cost of inputs ($\frac{\sigma}{\sigma-1}\phi^\tau$) and expected input prices (ρ^τ).

In Figure B.8, the solid black line shows the value of this input distortion wedge ($\frac{\sigma}{\sigma-1}\phi^\tau/\rho^\tau$) for our calibrated parameter values and alternative values of the tariff ranging from $\tau \in [1, 1.3]$. Although, in principle, this wedge can be either less than or greater than one, we find that it is greater than one across the entire range of values of the tariff for our calibrated parameter values. For all values of the tariff for which supply chains remain concentrated in Country A ($\tau < \tau_c$), this wedge is monotonically increasing in the tariff. As we increase the tariff to $\tau = \tau_c$, this wedge rises to over 1.8. For larger tariffs for which supply chains begin to relocate to Country B ($\tau_c < \tau < \tau_{ex}$), this wedge is monotonically decreasing in the tariff.

Figure B.8: Input Wedge for Alternative Values of the Tariff



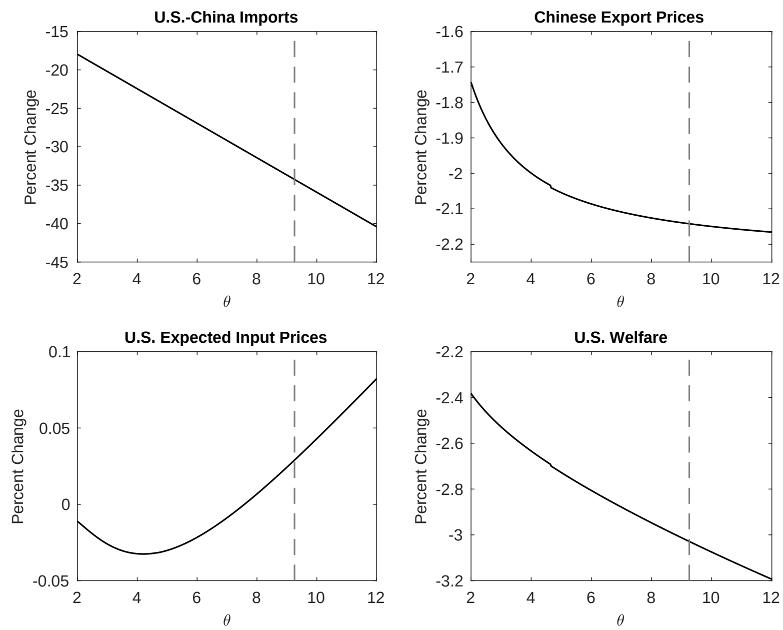
Note: Ratio of the perceived marginal cost of inputs ($\frac{\sigma}{\sigma-1}\phi^{\tau}$) to expected input prices (ρ^{τ}) for our calibrated parameter values and alternative values of the tariff ranging from $\tau \in [1, 1.3]$; vertical black dashed lines show w_B/w_A, τ_c and our calibrated Trump tariff of $\tau = 1.14$.

B.8 Robustness to Alternative Parameter Values

In our baseline specification in Subsection B.5 above, we calibrate the dispersion of supplier productivity (θ) and the relative cost disadvantage of Country B (w_B/w_A) to match event-study estimates of the predicted decline in U.S.-China import values (35.09 percent) and Chinese export prices (2.14 percent). In this subsection, we examine the impact of alternative values for the model's parameters on the predicted changes in U.S.-China import values, Chinese export prices, the terms of trade, and U.S. welfare.

In Figure B.9, we vary the dispersion of supplier productivity (θ), holding constant the relative cost disadvantage of Country B (w_B/w_A) and the other model parameters at their baseline values in Table B.5 above. A larger value of θ implies less dispersion in supplier productivity, which means that it easier to find new suppliers in Country B (Other Asia), and hence in turn implies a larger drop in U.S.-China import values and Chinese export prices. As we vary θ from $4 - 12$, we find that the decline in U.S.-China imports (m_A^{τ}/m) rises from around $20 - 40$ percent (top-left panel), while the decline in Chinese export prices (ρ_A^{τ}/ρ) increases from around $1.8 - 2.1$ percent (top-right panel). These changes in the value of θ affect both the strength of buyer-seller bargaining and also Vinerian trade diversion in the model. As a result, the change in expected input prices ($(\rho^{\tau} - \rho)/npx$) ranges from a small decrease (terms of trade improvement) for low values of θ to a small increase (terms of trade deterioration) for high values of θ (bottom-left panel).

Figure B.9: Model Predictions for Alternative Values of θ

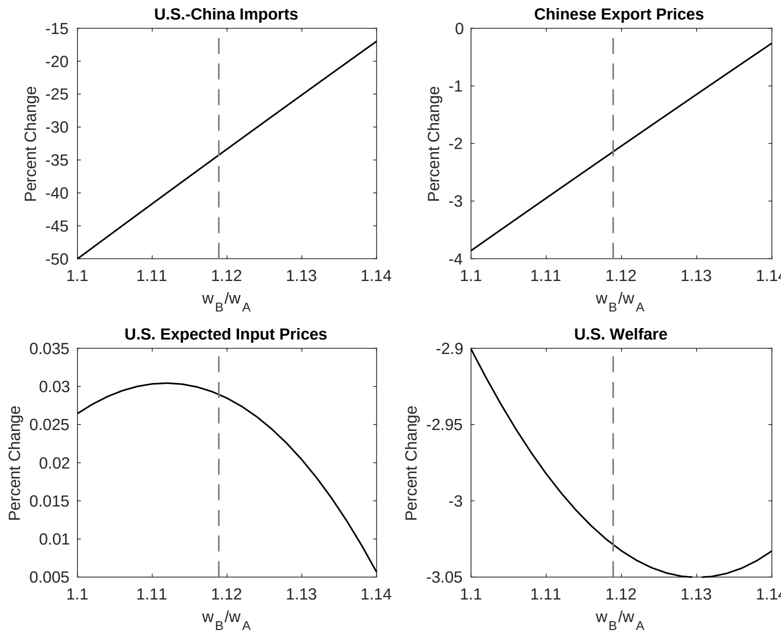


Note: Model predictions for alternative values of the Pareto shape parameter determining the dispersion of supplier productivity (θ) and the baseline value of all other parameters from Table B.5 above; top-left panel shows the log change in U.S.-China import values ($\log(m_A^\tau/m)$) in percent; top-right panel shows the log change in Chinese export prices ($\log(\rho_A^\tau/\rho)$) in percent; bottom left panel shows the change in the overall terms of trade as a percentage of differentiated sector expenditure ($(\rho^\tau - \rho)/npx$); bottom right panel shows the change in welfare as a percentage of differentiated sector expenditure ($(V^\tau - V)/npx$); gray dashed line vertical line shows the baseline parameter value of $\theta = 9.26$.

Nevertheless, we find a similar welfare reduction ($(V^\tau - V)/npx$) from around $2.4 - 3.2$ percent of differentiated sector expenditure ($0.24 - 0.32$ percent of GDP) across this entire range of values for θ (bottom-right panel). Therefore, the model is able to accommodate both larger and smaller declines in U.S.-China import values and Chinese export prices than those estimated in the data. Nevertheless, the model's welfare predictions are robust across the entire range of values for the Pareto shape parameter typically considered in the empirical trade literature.

In Figure B.10, we vary the relative cost disadvantage of Country B (w_B/w_A), holding constant the dispersion of supplier productivity (θ) and the other model parameters at their baseline values in Table B.5 above. A smaller value of $w_B/w_A > 1$ implies a higher return to searching for new suppliers in Country B (Other Asia), and hence a larger drop in import values and exporter prices from Country A (China), other things equal. As we vary w_B/w_A from $1.10 - 1.14$, we find that the decline in U.S.-China imports falls in absolute magnitude from around -50 to -15 percent (top-left panel), while the decline in Chinese export prices falls in absolute magnitude from around -4 percent to just below zero (top-right panel). As we change the value of w_B/w_A, we again affect the strength of both buyer-seller bargaining and also Vinerian trade diversion in the model. Nevertheless, we find a small increase in expected input prices (deterioration in the terms of trade) in the bottom-left panel, and a similar welfare reduction of around 3 percent of differentiated sector expenditure (or 0.3 percent of GDP) in the bottom-right panel, across this entire range of values

Figure B.10: Model Predictions for Alternative Values of w_B/w_A



Note: Model predictions for alternative values of the cost disadvantage of Other Asia (w_B/w_A) and the baseline value of all other parameters from Table B.5; top-left panel shows the log change in U.S.-China import values ($\log(m_A^\tau/m)$) in percent; top-right panel shows the log change in Chinese export prices ($\log(\rho_A^\tau/\rho)$) in percent; bottom left panel shows the change in the overall terms of trade as a percentage of differentiated sector expenditure ($(\rho^\tau - \rho)/npx$); bottom right panel shows the change in welfare as a percentage of differentiated sector expenditure ($(V^\tau - V)/npx$); gray dashed line vertical line shows the baseline parameter value of $w_B/w_A = 1.1189$.

for w_B/w_A. Therefore, we once more find that the model is able to accommodate both larger and smaller declines in U.S.-China import values and Chinese export prices than estimated in the data. However, the model's welfare predictions are again robust across these alternative values for the relative cost disadvantage of Country B.

B.9 Robustness to Excluding Consumer Goods

In our baseline specification in the paper, we calibrate our model for all goods, recognizing that supply chains can extend to consumer goods. In this section of the Calibration Appendix, we report a robustness test, in which we recalibrate the model excluding consumption goods.

We begin by re-estimating the price and quantity response to the Trump tariffs using the event-study specification in equation (B.3), dropping consumer goods as defined by the U.S. Census Bureau from the estimation sample. As reported in Amiti et al. (2020), estimated rates of pass-through of the Trump tariffs into U.S. import prices are smaller for intermediate inputs than for consumer goods, implying larger declines in Chinese export prices for intermediate inputs. Nevertheless, even after excluding consumer goods, we continue to find high rates of pass-through into U.S. import prices. After 12 months, we estimate an elasticity of U.S. import prices to the tariff of 0.82, which implies an elasticity of Chinese export prices of $1 - 0.82 = -0.18$ (compared to -0.04 in our baseline specification). We also continue to find large quantity responses. After 12 months, we find an elasticity U.S.-China import values to the tariff of -1.51 (compared to -2.22 in our baseline specification).

We again use these estimates to compute the implied changes in Chinese export prices and U.S.-China import values by multiplying the estimated elasticities by the change in tariffs for each product ($\log\left[(1+\tau_{ijs})\,/\,(1+\tau_{ij0})\right]$) and aggregating across products. By October 2019, we find a small reduction in Chinese export prices of 4.26 percent, and a substantial decline in U.S.-China imports of 31.85 percent.

Following an analogous approach as for our baseline specification, we set the tariff equal to the import-weighted average of the tariffs imposed by the Trump administration, excluding consumer goods. We calibrate the Pareto shape parameter for the dispersion of supplier productivity (θ) and the relative cost disadvantage of Country B (w_B/w_A) to match the estimated reductions in Chinese export prices and U.S.-China imports above for this specification excluding consumer goods.

In Panel A of Table B.6, we summarize the differences in the targeted moments for our baseline specification and this robustness test excluding consumer goods. In Panel B, we report the resulting differences in the calibrated parameter values. To match the larger estimated fall in Chinese export prices excluding consumer goods (4.26 percent compared to our baseline 2.14 percent), the model requires a lower value for the Pareto shape parameter for supplier productivity ($\theta = 3.95$ compared to our baseline $\theta = 9.26$). To simultaneously match the larger fall in Chinese export prices and smaller fall in U.S.-China import values, we also require a marginally smaller cost disadvantage in Country B (w_B/w_A), which equals 1.10 compared to 1.12 in our baseline specification. All other model parameters are held constant at the values in our baseline specification in Table B.5 above.

In Panel C of Table B.6, we compare the terms of trade and welfare predictions of our calibrated model excluding consumer goods to those of our baseline specification. The overall terms of trade (ρ^τ) is a weighted average of the terms of trade with Countries A (ρ_A^τ) and B (ρ_B^τ), weighted by the probability of sourcing from each country. The model without consumer goods is calibrated to a larger fall in the terms of trade with Country A (ρ_A^τ). As a result, we find a small improvement in the overall terms of trade in this specification ($(\rho^\tau - \rho)/\rho = -1.91$ percent), compared to a small deterioration in the overall terms of trade in our baseline specification ($(\rho^\tau - \rho)/\rho = 0.42$ percent). Nevertheless, since the terms of trade is only one channel through which the tariff affects welfare, we find a similar overall welfare loss from the tariff ($(V^\tau - V)/npx$) as in our baseline specification (-2.44 percent compared to -3.03 percent).

B.10 Onshoring Robustness

In our baseline calibration, we evaluate the welfare effects of the tariff under the assumption that the country for new searches (Country B) is Other Asian countries, based on our empirical findings above of a relocation of import sourcing from China to Other Asian countries. Under this assumption, the profits of new suppliers do not count towards home welfare, because they are accrued in

Table B.6: Robustness to the Exclusion of Consumption Goods

	(1)	(2)	(3)	(4)
A. Targeted Moments	**Data All Goods**	**Model All Goods**	**Data Excl. Cons. Goods**	**Model Excl. Cons. Goods**
Log Growth U.S.-China Imports	-34.23%	-34.23%	-31.85%	-31.85%
Log Growth Chinese Export Prices	-2.14%	-2.14%	-4.26%	-4.26%
B. Model Parameters		**Model All Goods**		**Model Excl. Cons. Goods**
Productivity Dispersion (θ)		9.2554		3.9541
Cost Disadvantage (w_B/w_A)		1.1189		1.1017
C. Model Predictions		**Model All Goods**		**Model Excl. Cons. Goods**
Expected Input Prices ($(\rho_\tau$-$\rho)/\rho$)		0.42%		-1.91%
Change in Welfare ($(V_\tau$-$V)/npx$)		-3.03%		-2.44%

Note: Columns (1)-(2) report results for all goods from our baseline specification in Table B.5 above; Columns (3)-(4) report results excluding consumption goods; the Pareto shape parameter controlling the dispersion of supplier productivity (θ) and the cost disadvantage of Country B (w_B/w_A) in Panel B are calibrated such that the model exactly matches the log change in U.S.-China import values and the log change in Chinese export prices excluding consumer goods, as reported in Panel A; all other parameters held constant at their values in our baseline specification in Table B.5 above; Panel C reports model predictions.

Other Asian countries.

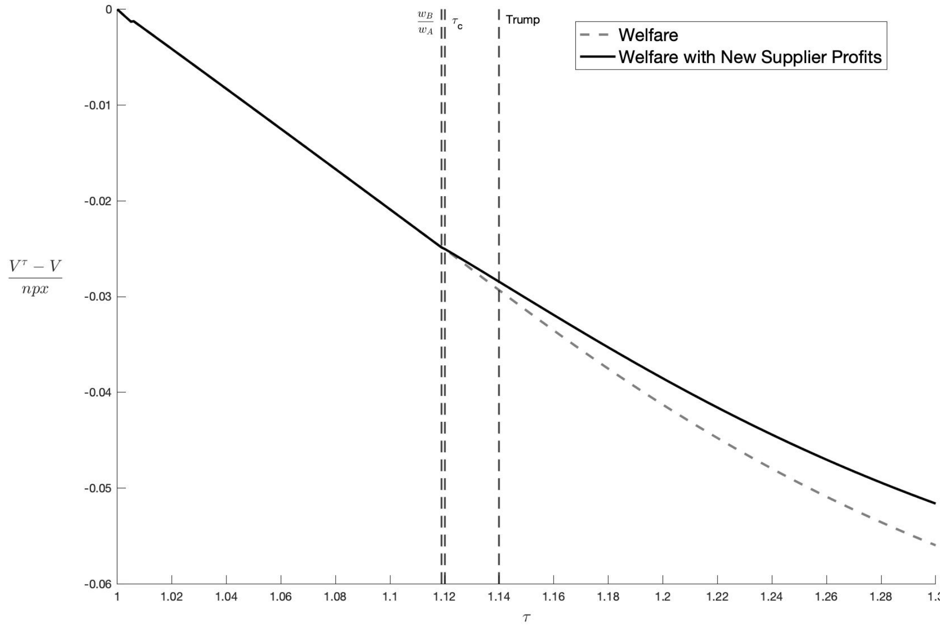
In this subsection, we undertake a counterfactual, in which the country for new searches is the home country (onshoring), but we hold all other parameters including marginal costs constant at the same values as in our baseline specification. In this counterfactual, the only difference from our baseline specification is that the profits of these new suppliers are included in home welfare, because they are accrued domestically.

In Figure B.11, we show the change in welfare relative to differentiated sector expenditure $((V^\tau - V)/npx)$ for alternative values of τ ranging from 1 to 1.3. The black solid line shows the change in welfare in our baseline specification, in which new searches occur offshore, and the profits of these new suppliers are not included in home welfare. The gray dashed line shows the change in welfare in this robustness test, in which new searches occur onshore, and the profits of these new suppliers are included in home welfare. While the inclusion of the profits of new suppliers reduces the welfare costs of the tariff, we find that this effect is relatively modest for our calibrated parameter values that match the price and quantity response to the Trump tariffs. In both specifications, we find welfare losses that increase with the size of the tariff.

B.11 Data Sources

In this subsection, we discuss the data sources used for our calibration of the model in Subsection B.5 of this Calibration Appendix above.

U.S. Import Values and Import Prices: We use the data on U.S. import values and prices from Amiti et al. (2020) for the event-study estimates of the price and value response to the Trump administration's tariffs in Subsection B.4 above. Data on U.S. import values and quantities at the ıoring



Note: Black solid line shows the welfare loss from the tariff as a percentage of differentiated sector expenditure $((V^\tau - V)/npx)$ for our baseline specification, in which searches for new suppliers occur offshore, and new supplier profits are not included in home welfare; gray dashed line shows this welfare loss for our robustness test in which searches for new suppliers occur onshore, and new supplier profits are included in home welfare. Black dashed lines show w_B/w_A, τ_c and our calibrated value of the Trump tariffs of $\tau = 1.14$.

10-digit level of the Harmonized Tariff Schedule (HTS10) are from the U.S. Census Bureau and U.S. Trade Representative (USTR). The import values are divided by the import quantities to obtain unit values (foreign export prices) for each source country and 10-digit product. These unit values are multiplied by duty rates from the U.S. International Trade Commission (USITC) to obtain U.S. import prices inclusive of tariffs. We also use these data to compute the import-weighted average of the new tariffs imposed on China by the Trump administration (2017 import value weights) in our calibration of the model; to compute the average tariffs by wave in Figure B.1 and the import share by category of good and tariff wave in Figure B.2 in Subsection B.2 above; to construct the import shares of China and Other Asia in Figure 1 in the paper and Figure B.3 in Subsection B.3 above; to measure the relocation of import sourcing from China to Other Asia in Figure B.4 in Subsection B.3 above; and in the difference-in-differences regressions in Table 1 in the paper and Tables B.1 and B.2 in Subsection B.3 above.

US GDP: We assume a home wage of $w = 1$ and calibrate home population (L) using data on U.S. gross domestic product (GDP) in 2017 in current price dollars ($19.477337) from the World Bank: `https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=US`.

Relative GDP in China and United States: We assume a relative wage in China and the United States of $w_A = 0.2$ based on data on relative GDP per capita in 2017 in China and the United States in purchasing power parity (PPP) terms from the Penn World Tables.

Input Cost Share: We assume an intermediate cost share of $\alpha = 0.45$ based on data on intermediate inputs as a share of gross output from Federal Reserve Economic Data (FRED): `https://fred.stlouisfed.org/graph/?g=jAuF`.

Profit Share: We assume a bargaining parameter of $\beta = 0.8$ to match a share of profits in gross domestic income of around 5 percent based on Federal Reserve Economic Data (FRED): `https://fred.stlouisfed.org/series/W273RE1A156NBEA`.

Manufacturing GDP Share: We choose a value for the fixed operating cost in the differentiated sector of $f_o = 0.0025$ to match a share of manufacturing value added in GDP of 11 percent based on Federal Reserve Economic Data (FRED): `https://fred.stlouisfed.org/series/VAPGDPMA`.

Procurement Costs: We choose a value for the fixed search cost relative to the fixed operating cost (f/f_o) to match a share of procurement in firm costs of around 1 percent based on the estimates in Institute of Management (2018).

References

Amiti, Mary, Stephen J. Redding and David Weinstein (2019) "The Impact of the 2018 Trade War on U.S. Prices and Welfare," *Journal of Economic Perspectives*, 33(4), 187-210.

Amiti, Mary, Stephen J. Redding and David E. Weinstein (2020) "Who's Paying for the U.S. Tariffs? A Longer Term Perspective," *American Economic Review*, Papers and Proceedings, 110, 541-546.

Broda, Christian and David E. Weinstein (2006) "Globalization and the Gains from Variety," *Quarterly Journal of Economics*, 121, 541-86.

Fajgelbaum, Pablo D., Pinelopi K. Goldberg, Patrick J. Kennedy and Amit K. Khandelwal (2020) "The Return to Protectionism," *Quarterly Journal of Economics*, 135(1), 1-55.

Fajgelbaum, Pablo D., Pinelopi K. Goldberg, Patrick J. Kennedy, Amit K. Khandelwal and Daria Taglioni (2021) "The US-China Trade War and Global Reallocations," UCLA, mimeograph.

Institute of Supply Management (2018) "The Monthly Metric: Cost of Procurement as a Percentage of Spend," *Inside Supply Management Magazine*, May. `https://www.ismworld.org/supply-management-news-and-reports/news-publications/inside-supply-management-magazine/blog/2018-05/the-monthly-metric-cost-of-procurement-as-a-percentage-of-spend/`

Kearney, 2020. *Trade War Spurs Sharp Reversal in 2019 Reshoring Index, Foreshadowing COVID-19 Test of Supply Chain Resilience*, Washington DC: Kearney.

Melitz, Marc J. (2003) "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71, 1695-1725.

Redding, Stephen J. and David E. Weinstein (2021) "Accounting for Trade Patterns," *NBER Working Paper*, 24051.