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When Tariffs Disrupt Global Supply Chains†

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We study unanticipated tariffs in a setting with firm-to-firm supply relationships. Firms conduct costly searches and negotiate with potential suppliers that pass a reservation level of match productivity. Global supply chains form in anticipation of free trade. Then, 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 match initial import shares and the estimated responses to the US tariffs imposed on China, we find an overall welfare loss of 0.12 percent of GDP, with substantial contributions from changes in input sourcing and search costs. (*JEL* D72, F13, F14, L14, O19, P33)

Global supply chains feature prominently in the landscape of modern trade. The 2020 World Development Report (World Bank 2020) highlights the distinctive features of such supply chains. They derive from technological advances that make feasible the *fragmentation* of production processes. They impose nontrivial *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 imparts "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 (which 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

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[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, Koren, and Szeidl (2015); Antràs, Fort, and Tintelnot (2017); Bernard and Moxnes (2018), and many others.

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 percent 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, 2021) 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 US imports from China rose to 17.1 percent 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 US 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 US 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 auto parts.[4] Therefore, although in principle firms could adopt a "wait and see" strategy to ascertain how permanent the changes in trade policy might prove to be, there is substantial evidence that a reorganization of many supply chains has already occurred.

This relocation of US 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 US imports.[5] After the first wave of tariffs on China in July 2018 (marked by the dashed vertical line), we see a sharp decline in China's share of US imports of around 3 percent (left scale) and a corresponding rise in Other Asia's share of US imports of a strikingly similar magnitude (right scale).

We also find evidence of supply chain reorganization at the micro level. In Table 1, we use monthly US 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, Redding, and Weinstein (2019, 2020)

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

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

[5] The 13 low-cost countries include Bangladesh, Cambodia, Hong Kong, India, Indonesia, Malaysia, Pakistan, the 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 online Appendix B for more detail on the data sources that underlie Figure 1.

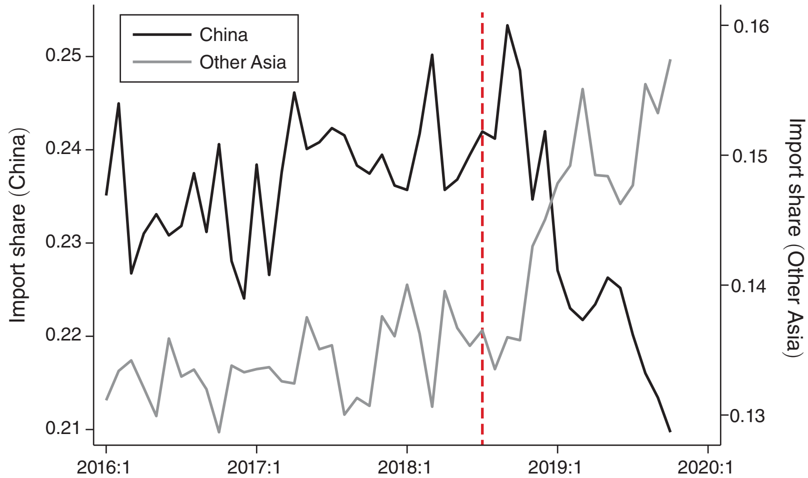

Figure 1. Share of China and Other Asia in US Imports

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

Table 1—US Imports from China and Other Asia

	log US imports from China (1)	log US imports from Other Asia (2)	log US imports from China (3)	log US imports from Other Asia (4)
	All goods	All goods	Excluding consumer goods	Excluding consumer goods
log relative tariffs	−1.713	0.339	−1.538	0.259
	(0.093)	(0.088)	(0.122)	(0.110)
Product fixed effects	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes
R^2	0.87	0.86	0.87	0.86
Observations	297,980	297,980	183,236	183,236

Notes: 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.

in their investigations of the price and volume effects of the Trump tariffs.[6] We

[6]See also Figure B.4 in online Appendix B. There, we provide evidence that relocation of US imports from China to Other Asia took place on the product extensive margin. To draw that figure, we began with the set of

regress the log of 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]

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 (World Bank 2020). 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 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 to 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.

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.

[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. Online Appendix B uses a long-differences methodology to show that the evidence of a sourcing response to the policy shock does not reflect trends that predated the tariffs.

In Section II, 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 III examines the implications of the unanticipated tariffs modeled in Section II 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 IV, we apply our model to evaluate the welfare effects of the tariffs imposed on China by the Trump administration during 2018 and 2019 (henceforth, the "Trump tariffs"). We interpret the differentiated sector as manufacturing and the outside sector as nonmanufacturing. We calibrate the model to match the initial share of imports from China in US manufacturing value added, the initial share of manufacturing value added in US GDP, and the event-study estimates of the price and quantity responses to the Trump tariffs from Amiti, Redding, and Weinstein (2020). The weighted average of the new tariffs imposed on China is 14 percent. By October 2019, we find a 34 percent decline in US-China import values and a 2 percent decline in Chinese export prices. The corresponding estimated elasticities of US imports and foreign export prices with respect to the Trump tariffs are -2.15 and -0.04, respectively, close to those estimated in Fajgelbaum et al. (2020).

We find that the Trump tariffs on China led to a small improvement in the US terms of trade vis-à-vis China, which acts to raise welfare. But this terms of trade improvement is more than offset by Vinerian trade diversion from the relocation of production to a higher-cost exporter and additional search costs. As a result, we find a reduction in overall welfare from these tariffs of around 1.04 percent of differentiated sector expenditure or 0.12 percent of GDP. We show that these results are robust to a range of parameter values for the productivity dispersion parameter, the cost disadvantage of the next lowest-cost exporter, and the buyer-supplier bargaining parameter. Simulating a counterfactual in which all supply relationships are reshored to the United States, we continue to find welfare losses from the Trump tariffs on China.

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, Bown, and Johnson (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 multicountry 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 holdup 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 holdup 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 noncooperative policy setting in the two countries. Efficiency can be achieved by an input subsidy that resolves the holdup problem together with free trade in the final good. But the governments have unilateral incentives to invoke suboptimal 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, Turner, and Bickwit (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 holdup problem. Interestingly, a preferential trade agreement might generate welfare gains in their setting even in the absence of any trade creation.

I. 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, 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 II, we introduce tariff shocks and study how they impact the original supply chain relationships.

A. *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

[8] In an online 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.

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

where $\Omega(X,Y)$ 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 $U(\cdot)$ has a constant elasticity ε greater than one, so that[9]

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

The consumption index takes the familiar form

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

where $x(\omega)$ 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

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

where $p(\omega)$ 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 $U'(X) = P$ or $X = \mathcal{X}(P) = P^{-\varepsilon}$. Each individual demands variety ω as a function of its price and the aggregate price index according to

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

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., $\sigma > \varepsilon$.

B. *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.

[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 (2013). 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.

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 $z(\ell, m)$. 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.

C. *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 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

[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.

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—which 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.

D. *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

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

[13] For a discussion of the game-theoretic foundations of Nash-in-Nash bargaining, see Collard-Wexler, Gowrisankaran, and Lee (2019). Neither the Stole and Zwiebel (1996) protocol nor Brügemann, Gautier, and Menzio'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.

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,

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

The Nash bargaining solution implies

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

and that

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

where $\mu_a(\bar{a})$ 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 $\mu_\rho(\bar{a})$ per unit for its composite intermediate good plus the fixed cost of search, $f/G(\bar{a})$. Thus, the total cost of m units of the intermediate good runs to $\left\{w\mu_a(\bar{a}) + \left[(1-\beta)/\beta\right]\left[f/(mG(\bar{a}))\right]\right\}m + f/G(\bar{a}) = w\mu_a(\bar{a})m + f/\beta G(\bar{a})$.[15] Note that each firm perceives a constant marginal cost of $\phi = w\mu_a(\bar{a})$ for each unit of the composite intermediate good.

[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.

[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 $w\mu_a(\bar{a}) + (1/\beta)\left\{f/\left[mG(\bar{a})\right]\right\} < 1$.

E. *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 $\ell + w\mu_a(\bar{a})m + f/\beta G(\bar{a})$, subject to $z(\ell, m) \geq x$. 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 $f/\beta G(\bar{a})$ and a constant marginal cost of $c(1, w\mu_a(\bar{a}))$, where $c(\cdot)$ is the unit cost function dual to $z(\cdot)$. We shall henceforth suppress the first argument in $c(\cdot)$—which is the constant, unitary home wage—and write the unit cost more compactly as $c(\phi)$, where $\phi = w\mu_a(\bar{a})$ is the perceived marginal cost of a unit of m. Shephard's Lemma then gives us the factor demands, so that $m = xc'$ and $\ell = x(c - w\mu_a c')$.

Turning to the optimal search strategy, the total (flow) cost of m units of the composite intermediate comprises the aggregate payment to suppliers, $m\mu_\rho(\bar{a}) = mw\mu_a(\bar{a}) + (1-\beta)f/[\beta G(\bar{a})]$, and the debt service on the up-front cost of search, $f/G(\bar{a})$. The trade-off 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., $\bar{a} = \arg\min_a \{mw\mu_a(a) + f/\beta G(a)\}$. Then, if an interior solution exists, the first-order condition implies

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

Noting that $\mu_a'(\bar{a}) = g(\bar{a})[\bar{a} - \mu_a(\bar{a})]/G(\bar{a})$, and substituting (5) into (4), we can write the negotiated price of an input with inverse productivity a as

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

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

F. *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.

G. *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 $(\bar{a})$, 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 Online 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.

H. *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 IV to calibrate the model to the observed US experience with the Trump tariffs. While we make these parametric assumptions to derive closed-form solutions and quantify our model, our mechanism of buyer-supplier bargaining under the shadow of the tariff naturally applies more generally.

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 heterogeneous 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 $\mu_a(\bar{a}) = [\theta/(\theta+1)]\bar{a}$ 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 online 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 invoke 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 online 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.

II. 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]

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 of 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 US 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.

A. *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

[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 online Appendix A for details.

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.

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 free on board (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 $a \le \bar{a}(\tau)$. 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

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

Note that the left-hand side of (13) is increasing in $\bar{a}(\tau)$; the derivative is $G\left[\bar{a}(t)\right] > 0$. 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 (2012) and Ornelas and Turner (2012).

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 reengage 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 inputs, 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 $a_c = \min\left\{\bar{a}(\tau), \bar{a}\right\}$.

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 $\beta\tau w\mu_a(a_c) + (1-\beta)\tau w\mu_a\left[\bar{a}(\tau)\right]$, according to (11). For the remaining inputs (if any), they perceive an average marginal cost of $\tau w\mu_a\left[\bar{a}(\tau)\right]$. The weighted average gives the marginal cost of *m* that firms use in making their decisions about

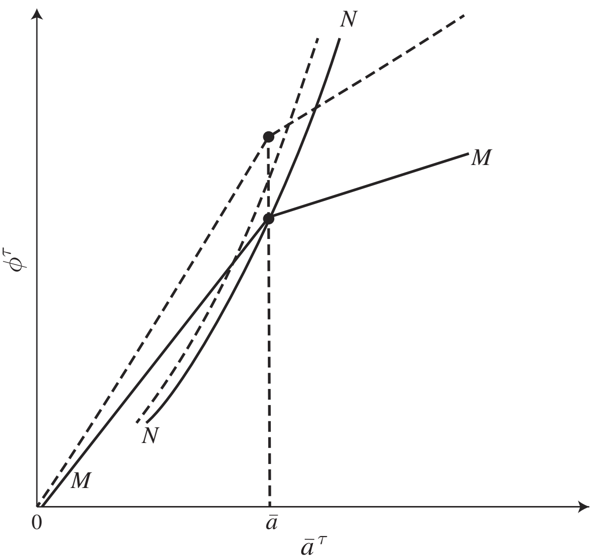

FIGURE 2. SMALL-TARIFF EQUILIBRIUM

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]

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

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 $\bar{a}$.

[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 online 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.

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 $p^{\tau} = [\sigma/(\sigma-1)](\phi^{\tau})^{\alpha}$, and hypothesizing that there is no induced entry of 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 become 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 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.

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

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

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

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. Letting a caret over a variable denote a proportional change, 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 $\gamma^{\tau} = (1-\beta)\bar{a}^{\tau}/\left[\beta\bar{a} + (1-\beta)\bar{a}^{\tau}\right]$ 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.*

B. *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.

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 inverse of 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 online 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 $\rho_B(\bar{b}^{\tau},\tau) \ = \ w_B\bar{b}^{\tau}$. However, even before 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 $a_B \ = \ \min\{w_B\bar{b}^{\tau}/\tau w_A, \bar{a}\}$ and that producers retain suppliers with $a \ \leq \ (w_B/\tau w_A)\bar{b}^{\tau}$, while replacing those (if any) with $a \ > \ (w_B/\tau w_A)\bar{b}^{\tau}$.

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

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

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

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

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

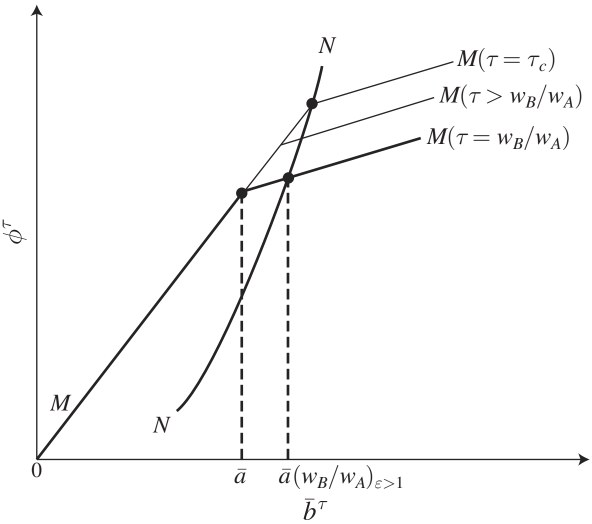

Figure 3. Large-Tariff Equilibrium with Elastic Demand

of $\beta\tau w\,\mu_a(a_B) + (1-\beta)w_B\,\mu_b(\bar{b}^\tau)$. 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 $w_B\,\mu_b(\bar{b}^\tau)$. After collecting terms, the weighted average becomes

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

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

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

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

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,

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

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 $\tau \geq \tau_c$, $a_B = (w_B/\tau w_A)\bar{b}(\tau_c) = \tau_c \bar{a}/\tau$, and so $\phi^{\tau} = [\theta/(\theta+1)]\tau_c w_A \bar{a}$. 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 $a \leq (\tau_c/\tau)\bar{a}$, while replacing those with $\bar{a} \geq a > (\tau_c/\tau)\bar{a}$. The number of active firms is $n^{\tau} = n(1)$ for all $\tau > w_B/w_A$.*

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 online Appendix A we show that $\bar{b}^{\tau}$ rises less than in proportion to τ, so $\bar{b}^{\tau}/\tau$ declines with

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

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

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

where $a_B = (w_B/\tau w_A)\bar{b}(\tau_c)$ in these circumstances. In online 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 is 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 $\tau \in (w_B/w_A, \tau_c)$. 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).

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

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

III. 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.

A. *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 $\zeta^\tau \equiv [\sigma/(\sigma - 1)]\phi^\tau - \rho^\tau$. Three factors determine its sign and magnitude. First, $\sigma/(\sigma - 1) > 1$ contributes to a positive sign, suggesting underutilization 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 $\tau(1 - \beta)[\sigma/(\sigma - 1)][\theta/(\theta + 1)]d\bar{a}^\tau$, 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 *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 arm's-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

[24] See, for example, Helpman and Krugman (1989) or Campolmi, Fadinger, and Forlati (2021). Under our assumptions of CES preferences and monopolistic competition within the differentiated sector, markups are constant. With departures from either of these assumptions, international trade also can affect welfare through endogenous changes in markups, as in Arkolakis et al. (2019) and Edmond, Midrigan, and Xu (2015).

[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.

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 online 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*

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

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 $\theta/(\sigma-1) > (1-\beta)$, which is equivalent to $[\sigma/(\sigma-1)]\phi(1) > \rho(1)$; i.e., the middle term in (28) is negative when evaluated at $\tau = 1$. Another sufficient condition is $\alpha\varepsilon > (1-\beta)$.[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.

B. *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 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 to 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

[26] In online 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

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

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

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 $\tau \in \left(w_B/w_A, \tau_c\right)$. 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 IIIA, 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 parentheses, 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 $a \in \left(0, a_B\right]$. 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 $1 - G\left(a_B\right)/G\left(\bar{a}\right)$ of their inputs. These searches each have an expected flow cost of $f/G\left[\bar{b}\left(\tau_c\right)\right]$. Tariff revenues collected by the home government exactly offset the tariff payments made by home producers. So, using Assumption 2, we can write

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

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 $\bar{b}^\tau = \bar{b}\left(\tau_c\right)$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

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

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 online 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

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

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 $\tau > [(\theta+1)/\theta][(\theta+1-\beta)/\theta]$. 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 online 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* $\tau_c > \tau > w_B/w_A$ *and for* $\tau > \max\{\tau_c, (\theta+1)/\theta\}$, $\rho(\tau)$ *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* $\tau < (\theta+1-\beta)/\theta$; (*ii*) *if Country B is the home country*, *welfare increases with* τ *if and only if* $\tau < [(\theta+1)/\theta][(\theta+1-\beta)/(\theta+\beta)]$.

IV. Application to the Trump Tariffs

In this section, we apply our model to the tariffs imposed on China 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 online 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 IVA by calibrating our model to match the estimated price and quantity responses to the Trump tariffs, and other empirical moments pertaining to the United States.[28] In Section IVB, 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 IVC examines the

[28] See online Appendix B for a more detailed discussion of the calibration of the model.

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.

A. *Parameter Calibration*

We interpret the home country as corresponding to the United States and Country A as representing China. Motivated by our empirical findings of a relocation of US imports toward other Asian countries in response to the Trump tariffs, we use Other Asia (as defined in the introduction) as the destination for new searches in our baseline specification (Country B).

We interpret the differentiated sector in the model as the manufacturing sector in the data. We map the outside sector in the model to the nonmanufacturing sector in the data and take the stance that wages in the home country (the United States) are pinned down in the nonmanufacturing sector, which is much bigger than the manufacturing sector as a share of US GDP. We choose the home wage as the numeraire. Thus, the home country's gross domestic product in the initial zero-profit equilibrium before the tariff is given by L, its manufacturing value added equals $n\ell$, and its manufacturing expenditure is given by PX. Although consumer expenditure equals consumer income, manufacturing value added can differ from manufacturing expenditure because of the outside sector.

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).

Tariff, Elasticities, and Wages.—In Table 2, we summarize the calibration of each of the model's parameters. We set the tariff 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, which yields $\tau = 1.1401$. We calibrate the elasticity of demand for the differentiated sector (ε) based on the estimated demand elasticity across four-digit NAICS sectors using the Trump administration tariffs in Fajgelbaum et al. (2020): $\varepsilon = 1.19$, which satisfies our assumption of elastic demand across sectors ($\varepsilon > 1$).

The elasticity of substitution across varieties within the differentiated sector (σ) determines the markup of prices over marginal cost. Therefore, we calibrate this parameter based on the estimated markup using US data of 1.61 from De Loecker et al. (2020), which implies $\sigma = 2.64$ and satisfies our assumption of a higher demand elasticity across goods within the differentiated sector than across sectors ($\sigma > \varepsilon$).

We choose the home labor supply such that home gross domestic product is equal to US GDP in 2017 before the Trump tariffs ($L = 19.4773$ trillion). We calibrate the wage in China (w_A) such that its income per capita equals one-fifth of that in home ($w_A = 0.2$), which is in line with relative gross domestic product

Table 2—Calibration of Model Parameters

Parameter	Notation	Value	Source
Tariff	τ	1.14	Imported–weighted average tariff imposed on China by the Trump administration
Sector elasticity	ε	1.19	Estimated sector elasticity from Fajgelbaum et al. (2020)
Variety elasticity	σ	2.64	Estimated markup from De Loecker et al. (2020)
Home wage		1	Numeraire
Labor supply	L	19.48	US GDP in 2017
Country A wage	w_A	0.20	Relative China-US GDP per capita 2017 before the Trump tariffs (purchasing power parity)
Bargaining power	β	0.50	Central value
Productivity dispersion	θ	9.6993	Estimated log change in US imports from China in response to the Trump tariffs by October 2019 from the event-study estimates in Amiti et al. (2020) of −34.23 percent $(\log(M_A^\tau/M_A))$.
Country B cost disadvantage	w_B/w_A	1.1155	Estimated log change in Chinese export prices in response to the Trump tariffs by October 2019 from the event-study estimates in Amiti, Redding, and Weinstein (2020) of −2.14 percent $(\log(\rho_A^\tau/r_A))$.
Imported input share	α	0.1791	Initial share of imports from China in US manufacturing value added in 2017 before the Trump tariffs 22.95 percent (M_A/nwl).
Fixed operating cost	f_o	0.0007	Initial share of manufacturing value added in US GDP in 2017 before the Trump tariffs of 11.3 percent (nl/L).
Fixed search cost	f	$f_o/100$	Institute of Supply Management (2018)
Fixed entry cost	f_e	$\tau_c < \tau < \tau_{ex}$	Condition for relocation of import sourcing

Notes: 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. Relative changes in productivity ($\bar{b}^\tau/\bar{a}$ and $\bar{a}^\tau/\bar{a}$) and welfare ($(V^\tau - V)/npx$) are invariant to the fixed costs as long as the theoretical restrictions in equations (36) and (37) are satisfied. We calibrate the fixed entry (f_e) and search costs (f) to ensure that these theoretical restrictions are satisfied. We choose a central value for the bargaining parameter ($\beta = 0.5$) for our baseline specification and report robustness tests for alternative values of this parameter.

per capita in purchasing power parity (PPP) terms in China and the United States in 2017.

For the empirically relevant range of parameters in which there is a partial relocation of supply chains to Other Asia ($\tau_c < \tau < \tau_{ex}$), we show below that the responses of US-China import values and Chinese export prices to the tariff are invariant with respect to the parameter β that controls the relative bargaining power of buyers and suppliers. Nevertheless, this bargaining parameter influences the estimated welfare effects of the tariff because it affects the wedge between the perceived marginal cost of inputs ($[\sigma/(\sigma-1)]\phi^\tau$) and expected input prices (ρ^τ) and hence shapes employment, input use, and search costs in the differentiated sector. Since this bargaining parameter is hard to determine using the available data, we choose a central value of $\beta = 0.5$ for our baseline specification and report robustness tests for alternative values of this parameter.

Price and Quantity Responses to the Trump Tariffs.—We calibrate the four parameters $(\theta, w_B/w_A, \alpha, f_o)$ in the bottom half of Table 2 to exactly match the following four empirical moments: (i) the initial share of imports from China in US manufacturing value added in 2017 before the Trump tariffs $(M_A/n\ell)$; (ii) the initial share of manufacturing value added in US GDP before the Trump tariffs $(n\ell/L)$; (iii) the estimated log change in US imports from China in response to the Trump tariffs by October 2019 from the event-study estimates in Amiti, Redding, and Weinstein (2020) $(\log(M_A^\tau/M_A) = -0.3423)$; (iv) the estimated log change in Chinese export prices in response to the Trump tariffs by October 2019 from the event-study estimates in Amiti, Redding, and Weinstein (2020) $(\log(\rho_A^\tau/\rho_A) = -0.0214)$.[29]

In the model, all inputs are imported from China in the initial equilibrium before the tariff, which implies that the initial share of imports from China in manufacturing value added $(M_A/n\ell)$ is largely determined by the share of inputs in production costs (α). Therefore, by controlling this parameter, we can ensure that the model exactly matches this first moment. In contrast, the initial share of manufacturing value added in GDP before the tariff $(n\ell/L)$ is heavily influenced by the fixed operating cost (f_o), which affects the size of the differentiated sector. Hence, by controlling this parameter, we can ensure that the model also exactly matches this second moment.

The log changes in US imports from China $(\log(M_A^\tau/M_A))$ and Chinese export prices $(\log(\rho_A^\tau/\rho_A))$ are closely related to the productivity dispersion parameter (θ) and the cost disadvantage of Country B (w_B/w_A). In particular, for the empirically relevant range of parameters $(\tau_c < \tau < \tau_{ex})$, we have the following closed-form solutions for these two moments:

$$\log\left(\frac{M_A^\tau}{M_A}\right) = \log\left(\left(\frac{w_B}{w_A}\right)^\theta \frac{1}{\tau^{\theta+1}}\right), \tag{33}$$

$$\log\left(\frac{\rho_A^\tau}{\rho_A}\right) = \log\left(\frac{\tau_c}{\tau}\right), \tag{34}$$

$$\tau_c = \left(\frac{w_B}{w_A}\right)^{\frac{\theta}{\theta-\alpha(\varepsilon-1)}}, \tag{35}$$

as shown in Section 5 of online Appendix A.

From equations (33)–(35), we can solve in closed form for the parameters θ and w_B/w_A given our event-study estimates of $\log(M_A^\tau/M_A) = -0.3423$ and $\log(\rho_A^\tau/\rho_A) = -0.0214$, and our calibrated values of α and ε. To match the combination of a sharp drop in US-China imports and a small drop in Chinese export prices, we require a relatively large value for the productivity dispersion parameter $(\theta = 9.70)$ and a relatively small value for the cost disadvantage of Country B $(w_B/w_A = 1.12)$. In online Appendix B.8, we show how the model's predictions for

[29] We use the event-study estimates from Amiti, Redding, and Weinstein (2020) because the sample includes two additional waves of US tariffs on China in June and September 2019. Both import values and export prices are expressed in dollars. The event-study specification controls for exporter-product, exporter-year, and product-year fixed effects. We also use data on US GDP (US Bureau of Economic Analysis 2023a), US manufacturing value added (US Bureau of Economic Analysis 2023b), and aggregate US imports from China (US Census Bureau 2023).

these two moments vary for alternative values of the productivity dispersion (θ) and cost disadvantage (w_B/w_A) parameters.

Fixed Entry and Search Costs.—Under our assumption of a Pareto productivity distribution, we show in Section 5 of online Appendix A that *relative changes* in productivity ($\bar{b}^{\tau}/\bar{a}$ and $\bar{a}^{\tau}/\bar{a}$) and welfare ($(V^{\tau} - V)/npx$) in response to the tariff are *invariant* to the fixed costs (f_o, f_e, f). Therefore, the values of these fixed costs do not matter for the quantitative predictions of relative changes that interest us.

Nevertheless, the model does impose some theoretical restrictions on the empirically relevant values of the fixed costs (f_o, f_e, f). First, for an interior equilibrium in which firms only accept suppliers with sufficiently low cost draws ($\bar{a} < 1$), we require the fixed search cost to be sufficiently large relative to the fixed operating and fixed entry costs so that the following inequality holds:

$$\bar{a}^{\theta} = \frac{f}{f_o + f_e} \frac{\theta - \alpha(\sigma - 1)}{\beta\alpha(\sigma - 1)} < 1. \tag{36}$$

Second, for the tariff to lead to a reorganization of supply chains to other Asian countries with no exit by domestic firms we require that the relative value of the fixed operating and entry costs satisfies the following inequality:

$$\left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}} < \frac{1}{1 + f_e/f_o} < \frac{\theta - (1-\beta)\alpha(\sigma - 1)}{\theta - \alpha(\sigma - 1)} \left(\frac{w_A}{w_B}\right)^{\frac{\theta\alpha(\varepsilon-1)}{\theta-\alpha(\varepsilon-1)}}, \tag{37}$$

where $0 < w_A/w_B < 1$, $0 < 1/(1 + f_e/f_o) < 1$, and $1 < [\theta - (1-\beta)\alpha(\sigma - 1)]/[\theta - \alpha(\sigma - 1)] < \infty$.

Since the values of the fixed costs (f_o, f_e, f) do not matter for our key objects of interest, which are the *relative changes*, we just need to ensure that (36) and (37) are satisfied. Given the value of the fixed operating cost (f_o) from above, we choose the fixed entry cost (f_e) such that $1/(1 + f_e/f_o)$ lies midway between its lower bound of $(w_A/w_B)^{[\theta\alpha(\varepsilon-1)]/[\theta-\alpha(\varepsilon-1)]} < 1$ and its upper bound of one, which ensures that the inequality (37) is satisfied. We set the fixed search cost equal to $f = f_o/100$ based on the evidence from Institute of Supply Management (2018), which ensures that the inequality (36) is satisfied.

Model Fit.—Our calibrated model exactly matches the estimated decline in US-China imports of 34.23 percent from the event-study estimates of Amiti, Redding, and Weinstein (2020). The corresponding estimated elasticity of US imports with respect to the Trump tariffs from this event-study specification is −2.15 (see column 4 of Table B.3 in online Appendix B.4). This estimated elasticity is close to the estimated partial trade elasticity of −2.53 in Fajgelbaum et al. (2020) and lies within the 95 percent confidence interval around that parameter estimate (from −3.02 to −1.75).

Our calibrated model also exactly reproduces the estimated decline in Chinese export prices of 2.14 percent from the event-study estimates of Amiti, Redding, and Weinstein (2020). The corresponding estimated elasticity of foreign export prices with respect to the Trump tariffs from this event-study specification is $0.96 - 1 = -0.04$ (see column 3 of Table B.3 in online Appendix B.4). This estimated elasticity is comparable with the estimated elasticity of zero in Fajgelbaum et al. (2020) and lies within the 95 percent confidence interval around that parameter estimate (from -0.14 to 0.10).

Although not directly targeted in our calibration, our model also predicts a reallocation of imports from China to Other Asia that is of a similar magnitude to that observed in the data. In the empirically relevant range of the parameter space ($\tau_c < \tau < \tau_{ex}$), we have the following closed-form solution for this import reallocation in the model:

$$\frac{M_B^\tau}{M_A^\tau - M_A} = \frac{\left[1 - \left(\frac{\tau_c}{\tau}\right)^\theta\right]}{\left(\frac{\tau_c}{\tau}\right)^\theta - \tau\left(\tau_c \frac{w_A}{w_B}\right)^\theta}. \tag{38}$$

From October 2017 to October 2019, the observed change in Other Asia's share of US imports relative to the change in China's share of US imports is $\left(M_B^\tau/\left(M_A^\tau - M_A\right)\right) = -0.96$, as shown in Figure 1. In comparison, the predicted import reallocation in the model is $\left(M_B^\tau/\left(M_A^\tau - M_A\right)\right) = -0.64$. Whereas the observed change of -0.96 reflects the influence of all the economic shocks that occurred over the period from October 2017 to October 2019, the predicted change in the model of -0.64 reflects the impact of the Trump tariffs on China alone. Nevertheless, the predicted import reallocation in the model in response to these tariffs goes a long way toward explaining the observed import reallocation in the data.

B. *Effects of the Trump Tariffs on US Terms of Trade and Welfare*

Using the calibrated parameters from the previous section, we now evaluate our model's predictions for the impact of the Trump tariffs on China on the US terms of trade and welfare.

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_A^τ/ρ). Both terms of trade are invariant with respect to the bargaining parameter (β), as shown in online Appendix B.8.3.

For small tariffs in the range $\tau \in \left(1, w_B/w_A\right)$, the model predicts an upward-sloping relationship between ρ_A^τ and τ due to renegotiation with extant suppliers under the shadow of the tariff. However, for our calibrated parameter values with a relatively small cost disadvantage of Country B (w_B/w_A), we find that this effect is small in magnitude, such that at $\tau = w_B/w_A$, we have $\rho^\tau/\rho = 1.0002$ close to one. 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.

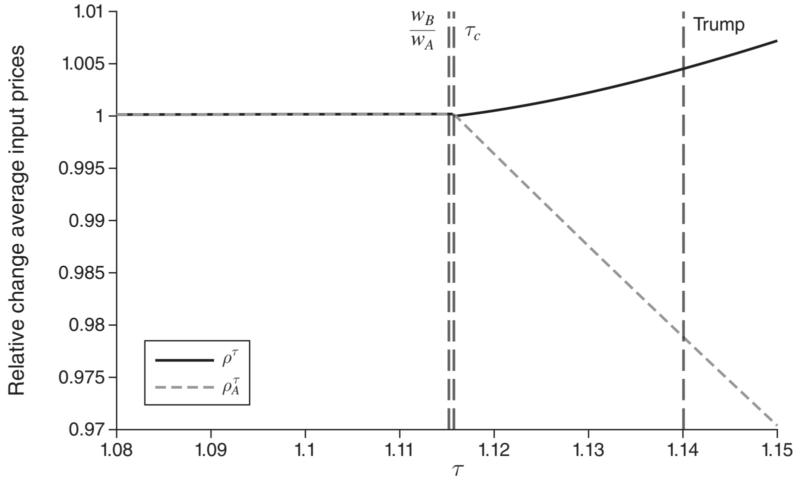

Figure 4. Effects of Tariffs on Average Input Prices (Inverse Terms of Trade)

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_A^τ/ρ); vertical black dashed lines show w_B/w_A, τ_c, and our calibrated Trump tariff on China 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. In this narrow interval, the solid black line is downward sloping (improving terms of trade), until at τ_c, 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 (ρ_A^τ/ρ), 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 toward an overall deterioration in the terms of trade.

Proposition 4 states that the Vinerian effect dominates the renegotiation effect if and only if $\tau > \max\{\tau_c, (\theta+1)/\theta\}$. For our calibrated parameter values, we have $(\theta+1)/\theta = 1.10$, 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.

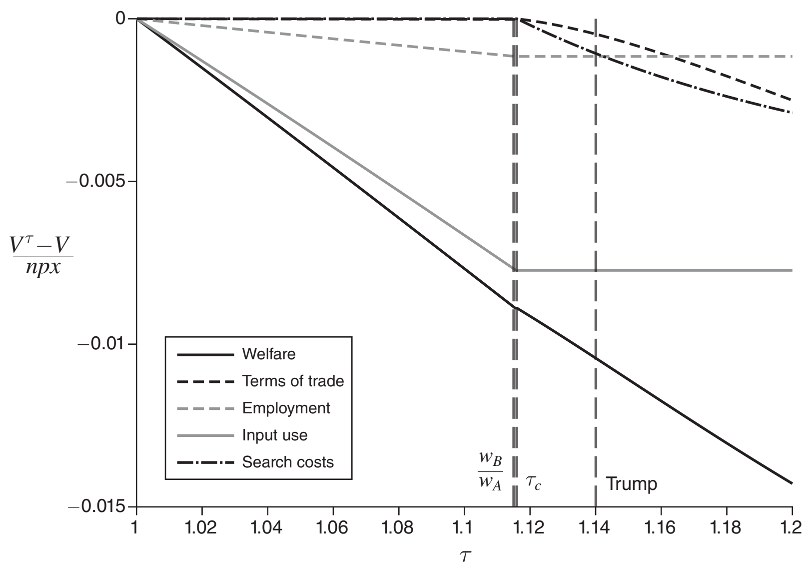

FIGURE 5. DECOMPOSITION OF WELFARE COSTS OF THE TRUMP TARIFFS

Notes: 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 $((V^\tau - V)/npx)$; black dashed line shows the change in the terms of trade $((\rho^\tau - \rho)/npx)$; gray dashed line shows the change in employment $((l^\tau - l)/npx)$; gray solid line shows the change in input use $((m^\tau - m)/npx)$; 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 on China of $\tau = 1.14$.

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 0.45 percent, despite a 2 percent fall in the price of imports from China.

Welfare.—In Figure 5, the solid black line shows the percentage change in home welfare relative to differentiated sector expenditure $((V^\tau - V)/npx)$.[30] 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). The relative contributions of these terms are endogenous and affected by the strength of buyer-supplier bargaining power and search costs. We report results here for our baseline value of the bargaining parameter $(\beta = 0.5)$ and present results for lower $(\beta = 0.35)$ and higher $(\beta = 0.65)$ values in online Appendix B.6.2. We report a further robustness test varying this bargaining parameter from 0.1 to 0.9 in online Appendix B.8.3.

In Proposition 3, 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

[30] 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)).

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, for our calibrated parameter values with a relatively small cost disadvantage of Country B (w_B/w_A), this effect is small in magnitude and not discernible visibly. We find that the welfare loss from the reduction in input use (gray solid line) is substantially larger than the welfare loss from the reallocation of employment away from the differentiated sector (gray dashed line), highlighting that our results are not simply capturing a change in the size of the differentiated sector. As the tariff rises to τ_c, we find a reduction in welfare of 0.89 percent of pre-tariff spending on differentiated products or 0.10 percent of pre-tariff GDP.

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 $\tau \in \left(\tau_c, \tau_{ex}\right)$, 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 the tariff on welfare through employment in the differentiated sector. 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 zero), 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 tariffs on China ($\tau = 1.14$), this welfare loss is around 1.04 percent of pre-tariff spending on differentiated products or 0.12 percent of pre-tariff GDP. This predicted welfare loss is larger than existing empirical findings for the Trump tariffs. Amiti, Redding, and Weinstein (2019) and Fajgelbaum et al. (2020) estimate welfare losses from the Trump tariffs of \$8.2 billion and \$7.2 billion, respectively, which correspond to around 0.04 percent of GDP.

While our predicted welfare losses are larger than those in Fajgelbaum et al. (2020), there are several differences between the two papers. First, we consider a longer sample period, which includes two additional waves of tariffs on China in June and September 2019.[31] Second, they examine the welfare effects of both US tariffs and foreign retaliatory tariffs, whereas our analysis does not include foreign retaliatory tariffs. Third, their quantitative model allows for general equilibrium changes in relative wages (and hence the terms of trade), whereas our assumption of an outside sector implies that relative wages are exogenously fixed. Fourth, we develop a new model of buyer-supplier search and bargaining, which highlights a novel source of changes in the terms of trade through buyer-supplier bargaining in the shadow of the tariff. Therefore, there is no reason for the estimated welfare losses to be the same in the two papers.

[31] We report a robustness test for a shorter sample period ending in December 2018 in online Appendix B.9.2.

C. *Robustness*

We next probe the robustness of our quantitative conclusions to variations in our assumptions, as discussed in further detail in online 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 US-China import values and Chinese export prices vary from 39.24 to 17.46 percent and from 2.15 to 1.99 percent, respectively. Nevertheless, we continue to find welfare losses from the Trump tariffs on China, with the percentage change in welfare relative to spending on differentiated products ranging from 1.11 to 0.59 percent of differentiated sector expenditure (0.13 to 0.07 percent of GDP).

Second, we recalibrate the model after excluding consumer goods from the set of imports that we consider to be part of US 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 in the event-study estimation of 4.26 percent. Nevertheless, since the terms of trade component in the welfare decomposition is relatively small, we find an estimated total welfare loss from the Trump tariffs on China of 0.79 percent of differentiated sector expenditure or 0.09 percent of GDP, compared with 1.04 and 0.12 percent in our baseline specification, respectively.

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 US firms, we find a welfare loss from the Trump tariffs on China of 0.94 percent of differentiated sector expenditure or 0.11 percent of GDP.

Therefore, across a range of specifications, we find that our calibrated model predicts significant welfare losses from the Trump tariffs on China.

V. 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 (World Bank 2020). 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 to match initial import shares and the estimated price and quantity responses to the Trump tariffs. 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 on China led to overall welfare reduction of 0.12 percent of GDP, with substantial contributions from changes in import sourcing and search costs.

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 multicountry sourcing, as in Blaum, Lelarge, and Peters (2017) and Antràs, Fort, and Tintelnot (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.

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