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The Production Relocation and Price Effects of US Trade Policy: The Case of Washing Machines[†]

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We estimate the price effect of US import restrictions on washers. The 2012 and 2016 antidumping duties against South Korea and China were accompanied by downward or minor price movements along with production relocation to other export platform countries. With the 2018 tariffs, on nearly all source countries, the price of washers increased nearly 12 percent. Interestingly, the price of dryers—not subject to tariffs—increased by an equivalent amount. Factoring in dryer prices and price increases by domestic brands, the 2018 tariffs on washers imply a tariff elasticity of consumer prices of above one.
(*JEL* F13, F14, F23, L68, 019, P33)

To an extent not seen in nearly a quarter century, trade policy occupied the forefront of economic policy debates in the United States in 2018. In that year, the United States imposed a series of tariffs on a wide range of goods—largely from China—using a variety of trade policy measures that have little precedent. The economic impacts of these tariffs on trade flows, prices, and production are highly uncertain because the magnitude of these tariff changes is extraordinary for an advanced country integrated with the global economy. On the one hand, increases in production sharing across global value chains and the corresponding decline in the value-added share of a given country's exports have led tariffs to become more punitive, as they are levied on the gross value of an imported good. On the other hand, given the prominence of multinational firms in global production, it may be easier than ever to relocate production across country borders, undoing the effects of tariffs.

Set against the uncertainties of how trade policy plays out in an integrated global economy are long-standing questions of international trade theory with little or conflicting empirical evidence. One such question is the incidence of tariffs: whether the amount of import taxes is passed on to consumers in the form of higher prices

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or absorbed by foreign producers by lowering their export price. Irwin (2019) notes that direct evidence on the consumer price effect of tariffs is scarce, particularly for a large economy such as the United States with potential monopsony power. Although new tariffs offer many possibilities for study, most are placed on intermediate goods where tracking price effects through the economy is particularly challenging. This paper focuses on a final consumer good (washing machines) and provides evidence of the effects of recent trade policies on trade flows, domestic production, and, most notably, prices.

The study of washing machines offers useful lessons for how trade policies affect the economy for several reasons. First, washing machine imports have been subject to wide-ranging trade policies in recent years. The contrasting effects of these policies offer lessons for how the characteristics of any particular trade policy (specifically, whether it's multilateral or unilateral) will alter their impact. Second, the new tariffs on washing machines in early 2018 were the first of a long string of subsequent trade policy actions enacted by the Trump administration, and therefore the full effect of these tariffs is more readily evident than the effect of those imposed later on, specifically on China. Finally, features of the product in question—relatively simple means of classification, clear channels for complementarities (washers and dryers), and a reasonable concentration of production—make this episode relatively straightforward for detailed study.

The first round of trade policy measures against imported washing machines consisted of country-specific antidumping duties, targeting specific companies producing in particular locations. These antidumping duties, first imposed on Mexican and South Korean production in 2012 and later on Chinese production in 2016, resulted in a shift in production to other countries, while keeping the overall magnitude of US imports roughly the same. Such "country-hopping" behavior is intuitive from existing theories of tariff avoidance and models with export platform foreign direct investment (FDI). The second round utilized a little-used area of US trade law, enacting "safeguard" tariffs on virtually all source countries for washing machine imports to the United States. Apart from notable shifts in the timing of imports based on when these tariffs went into effect (i.e., anticipatory increases—or front-running—of imports before the tariffs were first applied), the so-called Section 201 tariffs coincided with new domestic production, as both LG Electronics and Samsung Electronics opened plants in the United States in 2018. To summarize, firms shifted production following each new trade policy—first from Korea/Mexico to China, then to Thailand/Vietnam, and finally to the United States—to avoid paying import tariffs.

Coincident with these changes in production and trade flows were significant price movements, as measured by the published consumer price index (CPI). In the 12 months following the Korea/Mexico antidumping duties, the CPI for laundry equipment actually declined by about 5 percent, reversing the previous trend of moderate increases in the years before. The 12 months after the China antidumping duties saw the CPI continuing on its prior trend. Conversely, the index jumped in the months following the Section 201 safeguard tariffs and was up by about 9 percent by February 2019.

To more fully assess the price impacts of these tariffs, we use detailed weekly retail price data on major appliances. A concern with comparing the prices of

washing machines before and after trade policy changes is the presence of other shocks that changed the price of washers independently of the trade policy under study. For example, washer prices may respond to changes in the price of steel or general changes in retail markups. We therefore use other appliances as control products for the change in washing machine prices. In addition, a diverse set of product features in the data allow us to remove non-tariff-related price movements based on the life cycle feature of product pricing and also account for product characteristics and brand- or model-specific differences in pricing. The approach of using untreated appliance products as controls has been used before by Ashenfelter, Hosken, and Weinberg (2013) in their study of the effects of the Maytag-Whirlpool merger in 2006.

The implications of the 2016 antidumping duties on Chinese imports were strikingly different from the safeguard tariffs on many countries in 2018. Although China accounted for a whopping 80 percent of washing machine imports to the United States prior to the application of tariffs, we find little evidence of any meaningful consumer price changes due to the 2016 China-specific tariffs. This difference could be explained by the relative ease with which large foreign brands (Samsung, LG) appeared to subsequently shift production to Thailand and Vietnam, with coinciding increases in washing machine parts exports from Korea to these countries. By contrast, washer prices in the months following the new 2018 global safeguard tariffs notably spiked: about 12 percent more than the corresponding change in our control group. Moreover, prices of a complementary good—clothes dryers—also jumped at the same time by a similar magnitude, even though these products were not subject to any new tariffs during this period.

A key metric for evaluating the effects of tariffs is the degree of tariff pass-through to consumer prices. Yet, data limitations have made it difficult to capture the complicated effects on prices due to production relocation, complementary goods, and the responses by domestic producers. With our available data, we calculate the tariff elasticity of consumer prices, which measures the price changes encompassing the overall bundle of goods available to consumers (both imported and domestically produced) relative to the average change in tax applied to these goods via import tariffs. Although our sample of microlevel prices does not overlap with the Korea/Mexico antidumping duties, we report evidence—a drop in import prices from subsequent production in China, along with declines in the CPI index—pointing to a *negative* pass-through of tariffs, and hence, increased consumer surplus from these duties. Our estimates of the tariff elasticity of consumer prices for the country-specific antidumping duties on Chinese production, though positive, are small. Production relocation plays a prominent role in the differences in these estimates. Indeed, we show theoretically in online Appendix A that the potential for production relocation by multinationals to other export platform countries leads to a non-monotonic response of prices to tariff changes.

We find a much higher tariff elasticity of consumer prices for the global 2018 safeguard tariffs. Due to the price increases by domestic brands, and incorporating the additional effect on dryer prices, our estimates imply a pass-through of the safeguard tariffs to consumer prices of above 100 percent with estimates ranging between 108 and 225 percent. Our estimates indicate that the safeguard tariffs raised the median price of washing machines and clothes dryers by about US$86

and US$92 per unit, respectively. Using the level of shipments to construct an aggregate, we calculate that these tariffs resulted in increased consumer costs of just over US$1.5 billion annually. By comparison, the total amount of tariff revenue collected was relatively small, aggregating to about US$82 million annually. Absent additional factors, the reports of increases in domestic employment attributed to this policy of roughly 1,800 workers would result in an average annual cost to consumers of over US$815,000 per job created (after netting out tariff revenues).

Our analysis contributes to the literature on the incidence of tariffs. Irwin (2019) studies the sugar price response to import tariffs from 1880 to 1930, finding a roughly 40 percent pass-through to consumer prices of import tariff *increases* and a complete pass-through of import tariff *reductions*. Huber (1971) and Bernhofen and Brown (2004) compare nineteenth-century autarky price levels of several goods in Japan with price levels after trade liberalization. Bai and Stumpner (2019) and Jaravel and Sager (2019) measure the US consumer gains from Chinese imports using retail price data. Dating back to at least Feenstra (1989), several papers have analyzed the response of import prices to tariff changes (e.g., Winkelmann and Winkelmann 1998; Trefler 2004; Broda and Weinstein 2006; Broda, Limao, and Weinstein 2008; Spearot 2012; Ludema and Yu 2016; Fitzgerald and Haller 2018). In an analysis of the 2018 trade policies enacted by the United States, the comprehensive reviews of both Amiti, Redding, and Weinstein (2019) and Fajgelbaum et al. (2020) find complete pass-through of tariffs to import prices.

Availability and coverage of retail price data offer a number of advantages in analyzing the economic effects of policy. The US retail prices we study capture the impacts of tariffs on domestic competitors, production relocation, and complementary goods—channels that would be more difficult to assess using import prices alone.[1] For example, we find either flat or increasing import prices of imported washers from Korea in response to the 2012 antidumping duties. Domestic prices in the United States, however, fell as foreign production relocated to China.

Our paper also contributes by providing evidence on the response of multinational firms to tariff changes. A large literature on the proximity concentration trade-off documents the ratio of foreign affiliate sales to exports rises in the import tariff level (e.g., Brainard 1997; Helpman, Melitz, and Yeaple 2004). Horstmann and Markusen (1992) show that in response to an import tariff, a foreign multinational may set up a plant in the home country which could lead to lower domestic prices than without the tariff. Blonigen (2002) studies the tariff-jumping behavior of foreign firms to US antidumping measures in the 1980s. He finds an economically small increase in the probability that a foreign firm establish US production in response to the antidumping rulings. Consistent with the predictions of models of export platform FDI (e.g., Yeaple 2003; Ekholm, Forslid, and Markusen 2007; Tintelnot 2017), our findings illustrate the relocation of production to third markets as export platforms in response to bilateral tariff changes.[2]

[1] Using Belgian manufacturing data, Amiti, Itskhoki, and Konings (2016) document that large firms respond to competitors' cost changes induced by exchange rate changes. Using the 2015 Swiss Franc appreciation as a natural experiment, Auer, Burstein, and Lein (2018) find that prices of Swiss-produced goods fell by more in product categories with larger reductions in border prices.

[2] These findings reflect a third-country effect from trade policy discussed in various works by Bagwell and Staiger (see Bagwell, Bown, and Staiger 2016, for a review). Our findings are also related to work by Ruhl (2014),

I. Import Restrictions and Changes in Trade Flows

Throughout the latter half of the twentieth century, a series of major domestic brands of washing machines—including Maytag, Whirlpool, G.E., and Kenmore—competed for market share in the United States. In 2006, the Whirlpool Corporation ("Whirlpool") cemented its position as the dominant domestic producer after acquiring Maytag, its main competitor. This merger substantially increased the concentration of both washing machines and clothes dryers: according to research on the effects of this merger in Ashenfelter, Hosken, and Weinberg (2013), Whirlpool and Maytag together (pre-merger) accounted for 60 percent of total revenue for washing machines and 65 percent for clothes dryers.

Imported washing machines occupied a small share—less than 10 percent—of US sales during this time. Around the same time as the Whirlpool/Maytag merger, however, two large South Korean electronics companies, LG Electronics and Samsung, were beginning to enter the US appliance market.[3]

A. *Antidumping and Global Safeguard Investigations*

Following steady gains in US market share by the two South Korean companies, in December 2011, Whirlpool filed an antidumping petition (as part of Section 731 of the Tariff Act of 1930) with the US International Trade Commission (USITC), alleging that imports of large residential washers from Mexico and South Korea were being sold in the United States at less than fair value and that the US industry was being "materially injured or threatened with material injury as a result." In this form of investigation, the petitioning firm must prove a particular type of unfair pricing behavior as well as actual (or threat of) material injury resulting from that behavior. Any remedial measures—meant to be corrective rather than punitive—are then applied to the US imports of the importing firm, but only on imports from the particular country in question. In February 2012, the USITC issued a ruling recommending antidumping measures; in July, the US Department of Commerce announced firm-specific import duties ranging from 9.3 to 82.4 percent—see online Appendix Table B2 for details.[4]

After LG and Samsung maneuvered production around the antidumping duties, in December 2015 Whirlpool filed another antidumping petition with the USITC, this time against the imports of washing machines produced in China. In February 2016, the USITC issued another ruling in favor of antidumping measures; final antidumping duties announced by the commerce department ranged from 32.1 percent (LG) to 52.5 percent (Samsung).[5]

Following additional "country-hopping" responses to these localized antidumping duties, in May 2017 Whirlpool petitioned for a global safeguard investigation into large residential washing machines. Known colloquially by

who finds a large aggregate impact of US antidumping policies. For a literature survey on the effects of trade policy, see Goldberg and Pavcnik (2016).

[3] Indeed, Ashenfelter, Hosken, and Weinberg (2013) note that competitive forces from increased foreign entry into this market was a key argument by the US Department of Justice in approving the merger.

[4] Preliminary antidumping duties were first applied in August of 2012 (first dashed line in Figure 1).

[5] The new antidumping duties on Chinese imports began five months later in July 2016 (second dashed line in Figure 1).

its section number of the Trade Act of 1974, a "Section 201" global safeguard investigation is not required to prove unfair trade practices; rather, the USITC simply determines "whether an article is being imported in such increased quantities that it is a substantial cause of serious injury, or threat thereof, to the US industry producing an article like or directly competitive with the imported article" (US Code: Title 19, Code 2252). Moreover, the global safeguard remedy differs from antidumping and countervailing duties in that it is generally applied on a global basis.[6] Use of this trade measure has been rare; Section 201 safeguard tariffs were last implemented in 2002 on steel and steel products.

The USITC issued a positive determination in the case in October 2017 and published recommendations for temporary safeguard tariffs in December. The final result, published as a presidential proclamation in January 2018, was a tariff rate quota: a tariff rate of 20 percent on the first 1.2 million imported units (per year) entering the United States, with all subsequent units subject to a 50 percent tariff. Select imported components of washing machines were also subject to a tariff rate quota: in the first year, any imported parts above 50,000 units would be subject to an additional tariff of 50 percent. These tariff rates went into effect in February 2018 (for washing machines and their component parts) and are scheduled to expire after three years. Online Appendix Table B1 provides a summary of the key dates associated with the three rounds of import restrictions against washing machine imports.

B. *Trade Policy Effects on Production and Trade Flows*

Panel A of Figure 1 shows the striking response of US imports to the series of trade restrictions on washing machines. In the two years following the antidumping duties on Korean imports, the quantity of these imports fell by roughly 75 percent (blue line in panel A). Contemporaneous with the drop in imports from Korea (and to a lesser extent, Mexico) was a substantial increase in imports from China (red line). The results of the later antidumping duties on Chinese imports were nearly identical to the 2012 ruling: imports from China fell from 3 million units per year in 2015 to roughly 300,000 units in 2017. This time, imports of washing machines produced in Thailand and Vietnam (purple and yellow lines) increased sharply, from essentially zero in 2015 to nearly 3.3 million units (combined) in 2017.

As expected, the Section 201 safeguard tariffs in 2018 had differing effects given their global nature. In the midst of the global safeguard investigation of 2017, both Samsung and LG announced plans to begin US production of large residential washing machines. The Samsung factory in Newberry, South Carolina, opened in January 2018 with plans to produce 1 million washing machines that year; Samsung claims the plant will create around 1,000 new jobs by 2020 (Samsung 2017). An LG Electronics factory in Clarksville, Tennessee, opened in May 2019 with an advertised creation of roughly 600 new jobs (LG Electronics 2017). Similarly, Whirlpool reported adding 200 workers in 2018 explicitly due to the new tariffs.

[6] There were ultimately a few country exclusions to the Section 201 safeguard tariffs. Canada was excluded, as well as imports from a set of developing countries were also excluded from the tariff, provided that the country's share of total imports remains below a certain threshold. The Section 201 safeguard tariffs are imposed in addition to the standard MFN rates under Chapter 84 of the tariff schedule (which, in 2019, were 1 percent for washing machines).

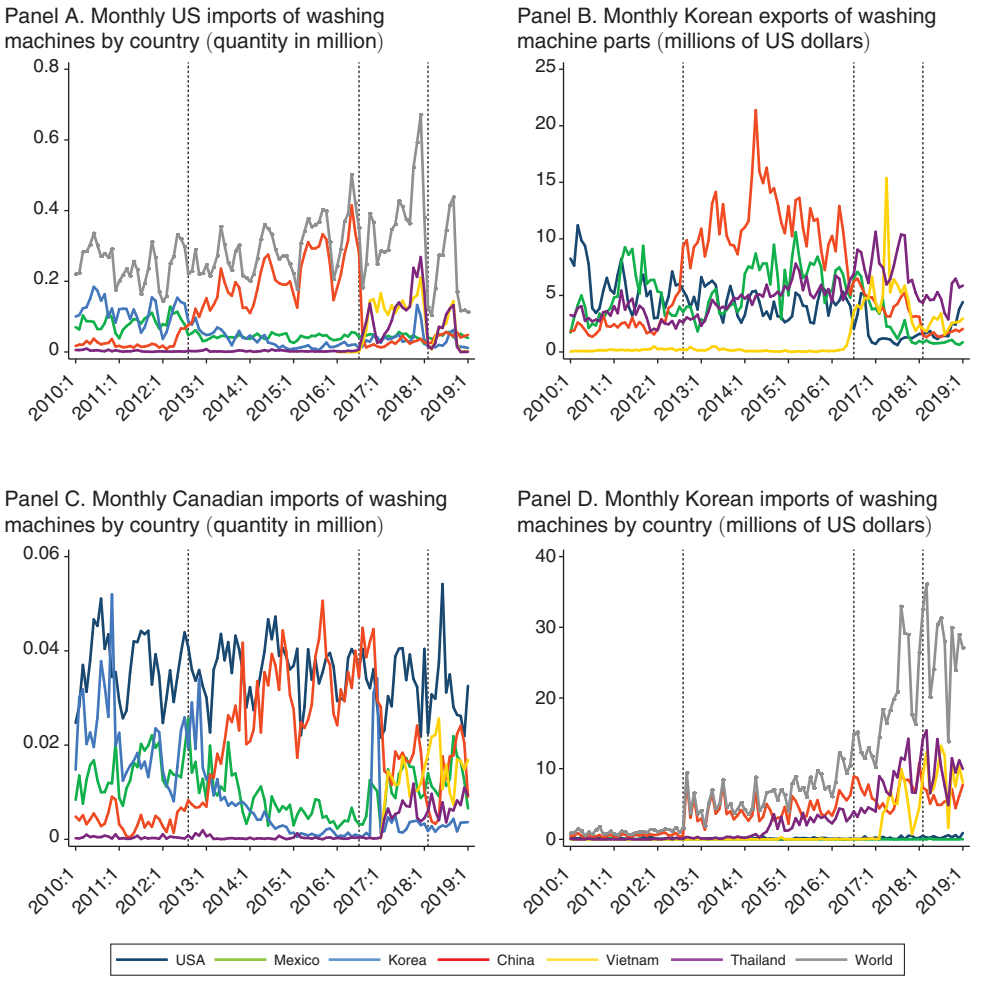

FIGURE 1. TRADE FLOWS OF WASHING MACHINES AND WASHING MACHINE PARTS

Notes: Residential washing machines are classified under HS8450110040, HS8450110080, HS8450200040, HS8450200080, and HS8450200090. Washing machine parts are classified under HS845090. The seasonally adjusted version of panel A is shown in online Appendix Figure D1.

Sources: US International Trade Commission (2010–2019), Korea Customs Service (2010–2019), Canadian International Merchandise Trade Database (2010–2019)

As shown in panel A of Figure 1, imports surged in late 2017 and early 2018 as foreign producers rushed to ship washing machines to the United States before the Section 201 tariffs went into effect. Imports subsequently fell sharply in February and March of 2018, rising again through September 2018 just before the quota limit of 1.2 million imported units was reached and subsequent tariffs rose to 50 percent.[7] Imports fell sharply again through the remaining months of 2018.[8]

[7] According to Commodity Status Reports published by the US Customs Bureau, the quota limit on washers was reached on October 22, 2018.

[8] Panel A of Figure 1 may understate the responsiveness of import quantities to the Section 201 safeguard tariffs; at Whirlpool's request, not all washers within the selected HS product codes were included as within-scope for the investigation. See online Appendix C.2.

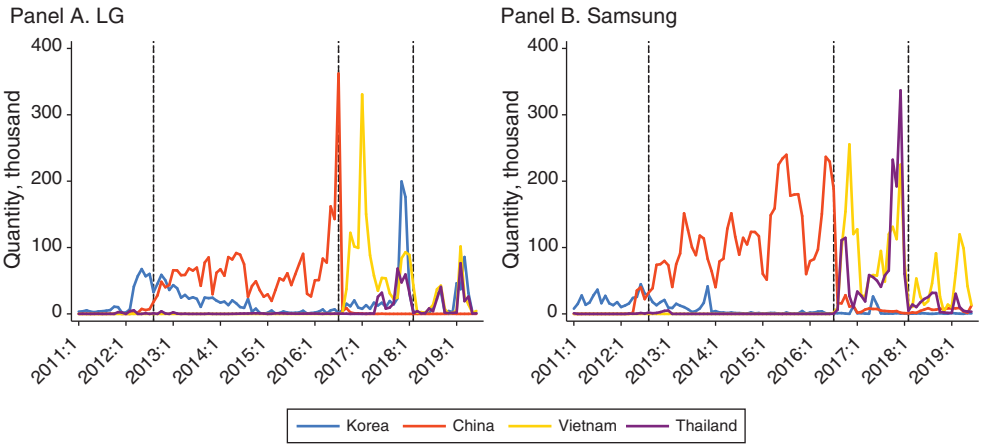

FIGURE 2. FIRM-LEVEL IMPORTS OF WASHING MACHINES

Note: See online Appendix C.14 for more details.

Source: PIERS (2012–2019) bill of lading data

To confirm the country-hopping and front-running patterns in panel A are the result of adjustments by existing manufacturers in response to the tariff actions, we turn to the PIERS dataset derived from detailed bill of lading documents. From this shipment-level dataset we identify the quantity of imported washing machines and the relevant producer from variables such as the "shipper," "consignee," or "notify" fields. Figure 2 demonstrates that US imports by LG and Samsung follow the pattern evident in panel A of Figure 1, with sharp changes in the prevailing country of production.[9]

These changes in sourcing locations can also be viewed through the lens of Korean exports of washing machine parts, given that both Samsung and LG have their global headquarters in Korea. Panel B of Figure 1 plots the value of Korean exports of washing machine parts (under HS845090) to the various countries highlighted above. Panel B shows that exports of parts to China jump in 2013 and 2014 before falling in 2016 and 2017 as exports of parts to Thailand and Vietnam rise. Overall Korean washing machine parts exports (not shown) rise nearly 60 percent between 2010 and 2016, consistent with the reduced amount of parts used in Korea for washing machine production for export.[10] Together, panel A and panel B of Figure 1 illustrate the changes in supply chains induced by US tariffs.

Beyond supply chain effects, US policy also had notable implications for third-country trade flows. Panels C and D of Figure 1 show that Canadian and Korean consumers were affected by US trade policy; the pattern of imports of

[9] The greater lumpiness evident in the PIERS data are likely due to differences in the timing between when the bill of ladings are submitted and the imports are processed by US Customs. Indeed, this lumpiness (and subsequent degree of misalignment between PIERS and official statistics) appears to be greatest when an uncharacteristically large mass of US imports occurs directly before the application of the China antidumping and Section 201 tariffs. See online Appendix C.14 for more details.

[10] Panel B of Figure 1 highlights that imported components may lower the domestic value-added share of washer exports. For Thailand and Vietnam, imported washing machine parts (HS845090) accounted for 12 to 17 percent of the value of washing machine exports.

washers largely follows that of the United States.[11] During the period shown, Korea went from being a net exporter to a net importer of washing machines (see online Appendix Figure C6a for Korean washer exports). One might also suspect spillovers in the production location of clothes dryers, but there is little change in the dryer import patterns; the production locations for dryers do not closely align with those of washers (see online Appendix Figure C5).

II. Effects of Trade Policy Measures on Prices

The overall impact of tariffs depends on the extent to which they are passed on to consumers. In this section, we use detailed, high-frequency microdata from retail stores to study the effect of these tariffs on consumers.

A. *Evidence Using Import Prices*

Figure 3 reports the pattern of import prices for the main trading partners during our sample. Unit values decreased following the Korea/Mexico antidumping duties as production relocated to China; import prices from China (red line) tend to be lower than import prices from Korea (blue line). With the Chinese prices not subject to the tariff, this negative price response to tariff changes is consistent with a *negative* tariff pass-through.[12]

In contrast, import prices tend to be roughly equivalent during the switch from China to Thailand/Vietnam (the purple line). Similarly, no systematic changes in the behavior of import prices are evident following the Section 201 safeguard tariffs. Figure 3 illustrates the shortcomings of inferring the tariff elasticity based on a regression evaluating the relationship between changes in import prices and tariff rates at the country-product level. We describe the differences between this approach and our elasticity calculations below, using retail prices in greater detail in online Appendix C.8.

B. *Data and Price Trends of Washers and Dryers*

Properly identifying the consumer price impact of the US tariffs on washing machines requires data on final point-of-sale prices that are both high frequency and include details on brand, features, and retailer. We obtain data with these features from Gap Intelligence (2013–2018), a market research firm that gathers data across a wide range of products and markets in the United States. The raw dataset contains weekly data entries of price and product characteristics at the retailer-model level from March 2013 to December 2018.

[11] These third country effects also allay suspicion that the increase in US imports from Thailand and Vietnam was due to trans-shipments rather than true production relocation. See online Appendix C.4.

[12] We demonstrate the theoretical underpinnings of a negative price response to tariff changes (or negative rate of tariff pass-through) in online Appendix A, but the evidence from import prices for the Korea/Mexico antidumping case is more suggestive than conclusive. Changing product composition, transfer pricing strategies, and unaccounted for cost information may influence the evidence from reported values and quantities used in this calculation. But as Figure 4 shows, the CPI for laundry equipment declines considerably just after the production relocation from Korea/Mexico to China in mid-2012, consistent with the negative pass-through interpretation of the changes in unit values.

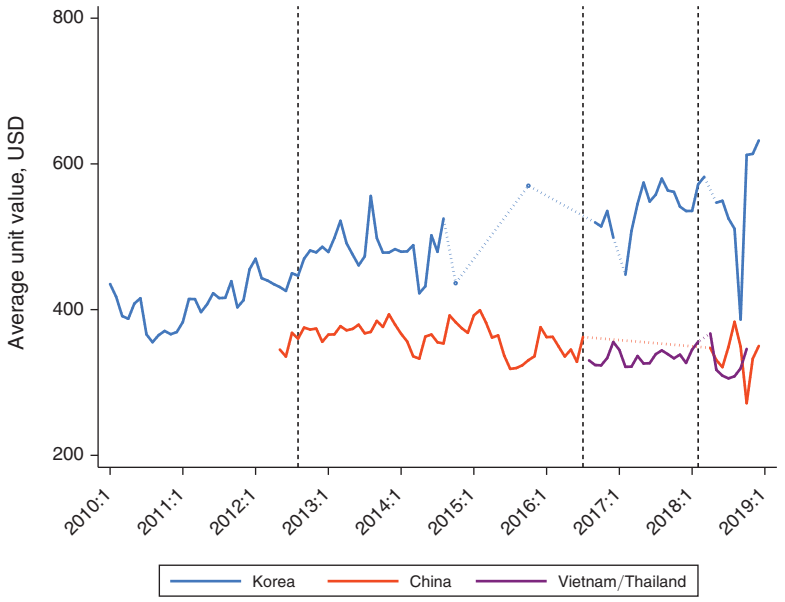

Figure 3. Average Unit Values (Exclusive of Tariffs and Duties) by Production Location

Notes: Includes residential washing machines classified under HS8450200040, HS8450200080, and HS8450200090. Solid lines display country-level unit values with at least 10,000 unit imports in the data. Dotted lines represent periods that did not satisfy a threshold of at least 10,000 unit imports.

Source: US International Trade Commission (2010–2019)

We have information on five major household appliances: washers, dryers, ranges, dishwashers, and refrigerators. In addition to the posted retail price, we observe the brand, model, date of first appearance in the market, and various other product characteristics such as capacity, color, load type, and energy efficiency rating. The dataset contains records from both brick-and-mortar and online stores (separately for stores with an online and physical presence); the data also contain the number of each retailer's brick-and-mortar stores in a given quarter. Gap Intelligence pays weekly visits to major retailers in 22 metropolitan areas and records the availability and price of each product. The company provides two price variables: the sticker price and the net price after applying promotions or discounts. We work with the net price in our analysis throughout. Some heterogeneity in prices across retail locations may exist, but the provided weekly retailer-product specific price information is what Gap Intelligence considers the nationally representative price.[13] The Gap Intelligence data contain no product-level quantities purchased, so we corroborate our analysis with annual, brand-level market share data by Traqline Market Research (2010–2018), another market research firm.

We apply several sample restrictions to the Gap Intelligence data. To account for the life cycle effects of appliances we calculate each product's age from the initial debut date in our data. The initial debut date is truncated by the first week

[13] Nakamura (2008); Hitsch, Hortacsu, and Lin (2017); and DellaVigna and Gentzkow (2019) report evidence suggesting chain-level pricing across stores located in different geographic markets.

in which the retail price data was collected. As this introduces large measurement error in products' ages for dates near March 2013 and we find particularly strong price discounts of appliances in the first few months, we start our price analysis from mid-July 2014 onward. We remove laundry machines with both washing and drying functions (all-in-one or laundry center) and focus attention on the five major brands of washing machines: LG, Samsung, Whirlpool, Maytag, and G.E. These brands account for more than 80 percent of the total observations on washers and dryers in the raw data. We further concentrate our analysis on the five national retailers in the United States: JC Penney, Best Buy, Lowes, Sears, and Home Depot, which together account for more than 50 percent of the observations in the data. In the online Appendix we show results where we include all available brands and retailers.

As a first step to document the trends in prices of washers and dryers, we first filter out changes in price that are accounted for by changes in the product mix, product features, and timeline of the product life-cycle. To do so, we apply the following hedonic regression of log prices of washers and dryers:

$$(1) \qquad p_{irt} = \lambda_{C(i)t} + \mathbf{X}_i\beta + b_{B(i)C(i)} + \sum_{a=2}^{25} \alpha^a_{C(i)} \mathbf{1}(age_{it} = a) + \gamma_r + \epsilon_{irt},$$

where subscripts i, r, t stand for model, retailer, and time (measured by week) respectively. The notation $C(i)$ refers to the product category (e.g., washer, dryer) whereas $B(i)$ refers to the brand (e.g., Samsung, Whirlpool) of product i. The $\mathbf{X}_i$ term is a vector of specifications for model i, which includes characteristics such as total capacity, energy star, smart appliance, and load type (see online Appendix Table C8 for a full list of characteristics by product category). The $\lambda_{C(i)t}$ term refers to a product category week fixed effect, and the $b_{B(i)C(i)}$ term captures a brand and product category specific fixed effect.[14] The term γ_r denotes a retailer fixed effect. To account for life cycle effects of product pricing, the age_{it} variable captures the age of a product measured in months. We omit a dummy variable for the first month of the product after initial debut in our dataset and then include dummies for the following 23 months, as well as a dummy for whether the product has debuted more than two years ago.

Figure 4 plots the $\lambda_{C(i)t}$ fixed effects, which depict trends in washer and dryer prices during our sample period. The red line displays the washer-week fixed effect from the log price regression in equation (1) (averaged by month), the blue line the dryer-week fixed effect (again averaged to its monthly level). These fixed effects summarize the average (log) price level in those periods after controlling for life-cycle factors and product/brand characteristics. The dashed line represents the CPI for laundry equipment from the Bureau of Labor Statistics (2010–2019). The residualized price series patterns align well with the CPI during our sample. For example, from July 2014 to January 2018 (shortly before the introduction of the safeguard tariffs in February 2018), the Gap Intelligence data suggests a decline in washer prices of about 20 percent and a decline in dryer prices of about 7 percent. The CPI for laundry equipment (a price index for washers and dryers combined)

[14] Note that any linear age effects of washer/dryer models will be captured by the $\lambda_{C(i)t}$ term.

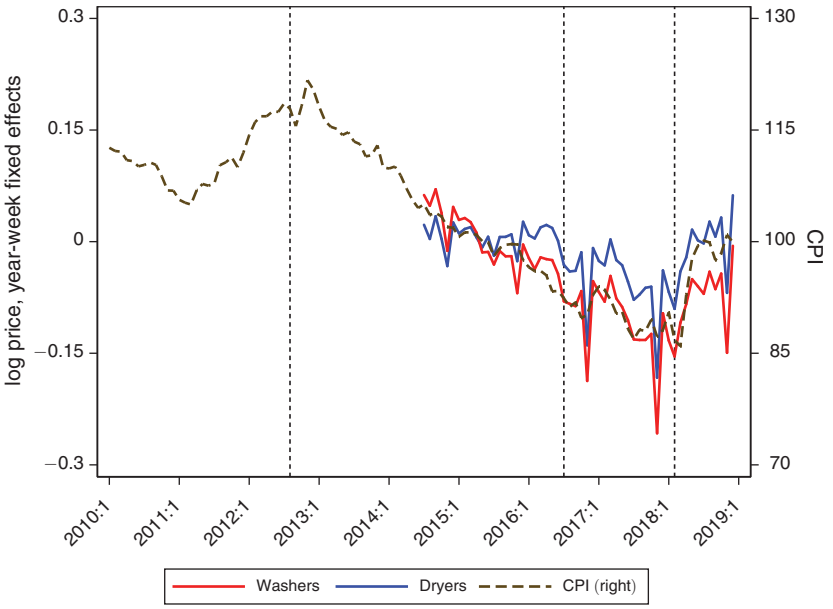

FIGURE 4. TIME FIXED EFFECTS FROM LOG PRICE REGRESSION, CPI FOR LAUNDRY EQUIPMENT

Notes: We plot the year-week fixed effects for washers or dryers, averaged over each month, obtained from estimating equation (1). We omit the week dummy for the week of April 1, 2015. In that month, the CPI for laundry equipment was close to 100 points and therefore the left and right axes are simple to compare. The dates of the three vertical lines are August 2012, July 2016, and February 2018, discussed in the text.

declined by about 15 percent during this period. One noticeable difference is that our series contains more seasonality, whereas the CPI for laundry equipment is seasonally adjusted. However, we find similar seasonal patterns for all five household appliances, so seasonality will not drive our estimates of the tariff effects discussed below. The product-category-time fixed effects for all five appliances are shown in Figure D2 in the online Appendix.

Figure 4 demonstrates that prices of washing machines jump shortly after the safeguard tariffs were applied. A more striking feature of Figure 4, however—and one that would not be evident without the more disaggregated data at our disposal—is that the price of dryers jumps by a similar magnitude as washers, despite not being directly affected by tariffs during this period. We explore this feature of the data in greater detail below.

C. *Estimating the Price Effects of Washing Machine Import Restrictions*

We now turn our attention to estimating the price effects of US trade policy. Although our sample is not long enough to evaluate the first antidumping duties (on Mexican and Korean imports), we can separately assess the effects of the 2016 China antidumping duties and the 2018 safeguard tariffs.

By leveraging the additional appliances in our data, we can account for other factors influencing costs and demand conditions in the overall appliance market in the United States. One important factor during this time period was new import

restrictions affecting steel and aluminum. Using the rarely invoked "Section 232" trade remedy based on national security considerations, in March of 2018 the United States imposed tariffs of 25 percent on steel and 10 percent on aluminum. The result of these measures, however, was a jump in the domestic prices of steel and aluminum—which together represent a significant input cost in US production of washing machines. Our strategy allows us to isolate the particular effects of washing machine tariffs given that all appliances were similarly affected by these changes in input costs. The product category closest to washers and dryers with respect to steel content is ranges; therefore we choose it as the control product group. This appliance also has the most similar import share (see online Appendix C.5 for a discussion of the metals content and import share of appliances).

To estimate the price effect of the antidumping duties against China (effective from July 2016) and the safeguard tariffs (effective from February 2018), we regress the log price on product and brand controls, a retailer fixed effect, year-week fixed effects, and the interaction of each product category with weekly fixed effects. As ranges are the omitted product category, all estimates of the interaction terms are relative to the average log price of ranges before and after the event:

$$(2) \quad p_{irt} = \lambda^{d}_{C(i)t} + \mathbf{X}_i\beta + b_{B(i)C(i)} + \sum_{a=2}^{25} \alpha^{a}_{C(i)} \mathbf{1}(age_{it} = a) + \gamma_r + \ell_t + \epsilon_{irt}.$$

Most of the coefficients in equation (2) are the same as in equation (1), the difference being that $\lambda^{d}_{C(i)t}$ measures the product category week fixed effect relative to the week fixed effect from ranges.[15] To better illustrate our results, we estimate equation (2) twice, once with the week effect of the antidumping duties against China (week of July 17, 2016) normalized to zero and again with the week fixed effect of the safeguard tariffs ($t = -1$ of January 28, 2018) set to zero. The term ℓ_t absorbs price shocks that commonly affect all household appliances, such as changes in the price of steel.

Panel A of Figure 5 reports the estimates of $\lambda^{d}_{C(i)t}$ for the categories of washers, dryers, refrigerators, and dishwashers before and after the 2016 China antidumping duties. Panel B reports equivalent estimates for the Section 201 safeguard tariffs. We include refrigerators and dishwashers in the analysis as placebo effects—a check for the plausibility of our estimates. Though the patterns for both washers and dryers are striking in panel B in particular, we report 48 weeks of estimates before the policy dates to illustrate the effects of any pre-trends in the estimates. For example, refrigerator prices (panel A) appear to be growing differentially from ranges before and after July 2016. As we know from Figure 4, over a long horizon, the prices of washers have fallen more than the prices of dryers or other appliances (see online Appendix Figure D2 for price changes in all five appliances). Hence, though the patterns evident in Figure 5 are informative, we must factor in the different trends (e.g., Finkelstein 2007) to arrive at the true effect of tariff changes on prices. To do this, we calculate the estimated change in prices after the introduction of import restrictions

[15] Additional details on the other covariates in regression (2) are available in online Appendix Table C8. Standard errors are clustered by model.

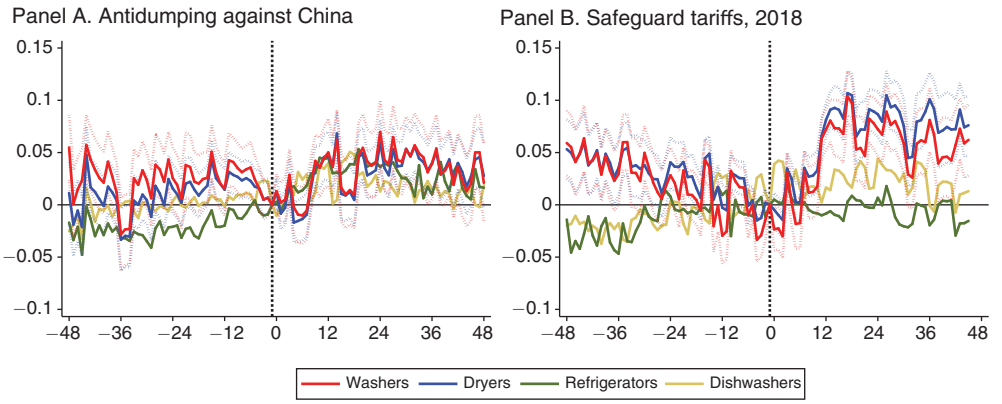

FIGURE 5. PRICE EFFECTS OF SAFEGUARD TARIFFS AND ANTIDUMPING DUTIES AGAINST CHINA

Notes: These figures report the regression coefficients $\lambda_{C(i)t}$ from equation (2). In panel A the estimates are relative to the week of July 17, 2016, and in panel B the estimates are relative to the week of January 28, 2018. The dotted lines denote 95 percent confidence intervals for the coefficient estimates for washers and dryers, based on standard errors clustered by model.

relative to the change in prices prior to the import restrictions. Specifically, we calculate the four-month effect of a tariff/antidumping event as

$$\Delta^{4m}_{event}\bar{p}_C = \left(\bar{\lambda}^d_{C,\,-28\ to\ -20\ weeks\ from\ event} - \bar{\lambda}^d_{C,\,-8\ to\ 0\ weeks\ from\ event}\right) - \left(\bar{\lambda}^d_{C,\,-8\ to\ 0\ weeks\ from\ event} - \bar{\lambda}^d_{C,\,+12\ to\ +20\ weeks\ from\ event}\right), \tag{3}$$

and an eight-month effect analogously, where we define the end points using periods −44 to −36 weeks and +28 to +36 weeks relative to the policy date.

Our baseline specification includes controls for product characteristics and an interaction of brand and product category fixed effects. We also present results with model fixed effects. In that specification the estimated policy effect is identified from the price changes of the products existing both before and after the policy change, whereas the baseline specification estimates price effects including price level changes for new products.

As shown in Table 1, after accounting for differential pre-trends, we find only modest price changes caused by the antidumping case against China. Our baseline estimates in columns 1 and 2 suggest a price increase of only 1.5 to 3.5 percent for washers and dryers in the 4- and 8-months periods. Columns 3 and 4 show the specification using model fixed effects, which show slightly higher estimates; though the price estimates of the two placebo appliances suggest that not all of this increase was due to tariffs.[16]

[16] In columns 3 and 4, when compared with dishwashers and refrigerators, the price increases for washers and dryers are comparable to columns 1 and 2. See Tables C6 and C7 in the online Appendix for analogous tables when refrigerators or dishwashers are used as the control group; the coefficients are identical to the difference between the washer or dryer coefficients and the other appliance category from Table 1.

Table 1—Difference-in-Difference Estimates: Price Effects of Washing Machine Tariffs

	Antidumping against China				Safeguard tariffs 2018			
	4-month (1)	8-month (2)	4-month (3)	8-month (4)	4-month (5)	8-month (6)	4-month (7)	8-month (8)
Washers	0.026	0.034	0.046	0.058	0.109	0.115	0.110	0.119
	(0.015)	(0.017)	(0.012)	(0.013)	(0.014)	(0.018)	(0.011)	(0.012)
Dryers	0.016	0.023	0.033	0.047	0.111	0.114	0.112	0.119
	(0.012)	(0.014)	(0.009)	(0.010)	(0.013)	(0.017)	(0.009)	(0.009)
Refrigerators	0.025	0.008	0.039	0.028	0.001	−0.035	−0.002	−0.018
	(0.010)	(0.013)	(0.007)	(0.007)	(0.010)	(0.015)	(0.006)	(0.007)
Dishwashers	0.012	−0.006	0.035	0.024	−0.010	−0.021	−0.012	−0.017
	(0.013)	(0.014)	(0.008)	(0.008)	(0.012)	(0.018)	(0.007)	(0.009)
Model characteristics	✓	✓			✓	✓		
Model FE			✓	✓			✓	✓
Observations	1,637,298		1,637,298		1,637,298		1,637,298	

Notes: The table reports estimates for $\Delta^{4m}_{event}\bar{p}_C$ and $\Delta^{8m}_{event}\bar{p}_C$ defined in equation (3) and the text below it. The right hand side of equation (3) is a linear combination of the estimates from equation (2). Standard errors in parentheses.

By contrast, and consistent with the preliminary evidence from panel B of Figure 5, the estimated price effects of the Section 201 safeguard tariffs are much more striking. We find that the price of washers jumps by around 11 percent four to eight months following the application of these tariffs. As noted above, equally dramatic is the relative price estimate for dryers which rises by an equivalent amount. In this case the estimates pertaining to the alternative specification are essentially unchanged.

The price effects on dryers are initially puzzling as these appliances were not subject to any new tariffs during this time. Residential washing machines are typically sold together (often, as paired models) with clothes dryers. Indeed, a prominent counterargument from respondents to the Section 201 investigation was that paired washer and dryer units are often sold at essentially identical prices; dryers are substantially less costly to produce, so considering profits on washers alone would understate the overall margins these companies expect to make on the laundry equipment market as a whole (see US International Trade Commission 2017a).

To explore this point further, we identify the set of matched washer-dryer models within each brand, as discussed in online Appendix C.9. Roughly three-quarters of the washers in our data have a matched dryer model (often with either gas or electric versions). Focusing solely on the electric models, we find that in over 85 percent of our weekly observations, these matched models report the *exact same dollar price*. Hence, the price correlation between these matched models is very high—over 0.95—while the correlation of price changes is 0.82.[17] These facts are consistent across all major brands in our data.

For another perspective, we scrape major online retailer websites and capture the "best selling" sales rank for both washers and dryers, in addition to the model name and number. We use these data to calculate the correlations of sales rank

[17] The correlation of average prices across all models within a brand/merchant is 0.87. The washer-dryer correlation of average price changes across all models within a brand/merchant is 0.74.

for washers and dryers for the major brands we study. The correlation of sales ranks for a brand's washers and dryers at a given retailer is quite high, 0.9 to 0.95, and typically lower, 0.3 to 0.9, for other appliance pairs (online Appendix C.10 and online Appendix Figure C10). As a whole, our data offer clear evidence of complementarities between washers and dryers. As such, the firms in our sample may have chosen to split the effects of new tariffs on prices between washers and dryers, maintaining the convention of identical prices. Nevertheless, this behavior raises significant questions. If dryers are indeed significantly less costly to produce, why doesn't competition drive down the price? One possibility is that consumers might be more informed about (and thus, have a more elastic demand for) the washer unit, while treating the dryer as an "add-on" good, for which demand is less elastic, as in Ellison (2005) and Gabaix and Laibson (2006). In addition, the aesthetics of similar design and style features of matched washer-dryer pairs is likely an important component of consumer behavior as well.

Reassuringly, in Table 1 we find little evidence of any differential price effects for refrigerators and dishwashers for the results pertaining to the 2018 safeguard tariffs. It is worth pointing out that some of the other appliances used in our analysis were subsequently subject to new tariffs later in 2018. A third round of tariffs imposed on Chinese imports included refrigerators and electric/gas ranges; household dishwashers were not subject to new tariffs. These tariffs went into effect in September (roughly $t = 28$ in panel B of Figure 5) at a rate of 10 percent. Although one might wonder whether these Section 301 tariffs may affect our results, the scope of impact of these China-specific tariffs on refrigerators and ranges was quite small by comparison. Prior to these tariffs, the Chinese import share for refrigerators was around 15 percent, leading to an increase in the trade-weighted tariff rate of less than 2 percentage points. For ranges, the Chinese import share was about 10 percent, and hence the increase in the effective tariff rate was less than 1 percentage point. See online Appendix C.5 for more details.

The evidence in Table 1 demonstrates that, as a whole, washers and dryers experienced notable price increases following the safeguard tariffs of 2018. Multiplying these estimates by the median pre-period price of washers (US$749 per unit) and dryers (US$809 per unit) yields that the dollar price increase attributable to these tariffs on washers and dryers was US$86 per unit and US$92 per unit, respectively.

Because the tariffs under consideration were not evenly applied across all models in the data, these estimates could mask much larger price changes by foreign producers (primarily LG and Samsung) with little to no price changes by domestic producers. To explore this heterogeneity, we rerun specification (2) but allow for separate coefficients for each brand. Specifically, we estimate

$$p_{irt} = \lambda'_{C(i)B(i)t} + \mathbf{X}_i\beta' + \sum_{a=2}^{25} \alpha'^{a}_{C(i)} \mathbf{1}(age_{it} = a) + \gamma'_r + \ell'_{B(i)t} + \epsilon'_{irt}, \tag{4}$$

where now $\lambda'_{C(i)B(i)t}$ denotes a product category × brand-week fixed effect and ℓ'_{Bit} denotes the brand-specific week fixed effect applied to all product categories. The product category of ranges does not have a separate product category × brand-week fixed effect. We then apply a suitably modified equation (3) to arrive at price change estimates that vary by both appliance and brand.

Table 2—Difference-in-Difference Estimates: Brand-Specific Price Effects of Washing Machine Tariffs

	Washers		Dryers		Refrigerators		Dishwashers	
	4-month	8-month	4-month	8-month	4-month	8-month	4-month	8-month
Antidumping against China								
Whirlpool	−0.031	−0.034	−0.034	−0.003	0.007	−0.012	−0.030	−0.046
	(0.028)	(0.036)	(0.025)	(0.034)	(0.017)	(0.024)	(0.021)	(0.028)
Maytag	0.142	0.190	0.114	0.148	0.031	−0.014	0.012	−0.011
	(0.044)	(0.053)	(0.037)	(0.046)	(0.049)	(0.053)	(0.043)	(0.048)
LG	0.010	−0.011	−0.008	−0.036	0.042	0.036	0.012	−0.024
	(0.039)	(0.049)	(0.029)	(0.042)	(0.028)	(0.042)	(0.058)	(0.069)
Samsung	0.083	0.057	0.093	0.060	0.116	0.030	0.026	−0.054
	(0.041)	(0.050)	(0.036)	(0.041)	(0.037)	(0.044)	(0.061)	(0.070)
G.E.	−0.002	0.024	−0.017	−0.018	−0.015	−0.008	0.012	0.011
	(0.018)	(0.024)	(0.017)	(0.023)	(0.016)	(0.022)	(0.015)	(0.018)
Safeguard tariffs, 2018								
Whirlpool	0.174	0.129	0.175	0.142	0.008	−0.029	0.041	−0.001
	(0.033)	(0.037)	(0.028)	(0.033)	(0.023)	(0.029)	(0.024)	(0.032)
Maytag	0.146	0.137	0.169	0.201	0.030	0.148	0.018	0.009
	(0.035)	(0.050)	(0.031)	(0.047)	(0.028)	(0.048)	(0.029)	(0.058)
LG	0.081	0.131	0.082	0.125	0.040	0.022	0.136	0.158
	(0.022)	(0.031)	(0.020)	(0.028)	(0.021)	(0.030)	(0.036)	(0.072)
Samsung	0.153	0.175	0.104	0.099	0.008	−0.071	−0.016	0.054
	(0.031)	(0.039)	(0.028)	(0.035)	(0.021)	(0.028)	(0.024)	(0.050)
G.E.	0.072	0.051	0.123	0.108	−0.035	−0.064	−0.052	−0.066
	(0.023)	(0.031)	(0.023)	(0.030)	(0.017)	(0.026)	(0.017)	(0.029)

Notes: The table reports results analogous to Table 1, based on separate estimates for each brand. Specifically, first equation (4) is estimated (with model characteristics as controls) and then a linear combination of these estimates is used to compute the left hand side of equation (3), separately for each brand and product category. Figure D3 in the online Appendix displays the corresponding weekly price estimates by brand. Standard errors are in parentheses.

Our estimates, reported in Table 2, show that all major brands increased prices following the safeguard tariffs. There is no clear distinction between domestic and foreign brands in these results, all within a range of 5 and 17 percent. Depending on the time horizon, Whirlpool increased washer prices between 13 and 17 percent; dryer prices increased at least as much. Maytag raised washer prices by about 14 percent, dryer prices between 17 and 20 percent. G.E. had lower price increases: around 5 and 11 percent for washers and dryers, respectively. LG raised prices over four months by 8 percent and over eight months by about 13 percent for both washers and dryers. Samsung increased prices by 15 to 17 percent for washers and about 10 percent for dryers.

Why did the price of domestic brands increase in line with foreign brands, despite being excluded from the additional costs of tariffs? One possibility is that the domestic brands are expanding their market shares and have rising marginal costs (the standard argument in most undergraduate textbook treatments of tariff analysis). To consider this possibility, we utilize data on annual brand-level market shares from Traqline. Following the China antidumping and safeguard tariffs, brand market shares were roughly stable and even declined slightly in 2017 and 2018 for Whirlpool and Maytag. Moreover, the observed differences in market shares between 2017 and 2018 align well with the estimated changes in relative prices

reported in Table 2. The firm with the lowest price increase (G.E.) experienced the largest gain in market share between 2017 and 2018. Annual shipment data from the Association of Home Appliance Manufacturers (AHAM) indicate that total sales of both washers and dryers declined by 3 percent during this period.

The Section 201 safeguard investigation also included new tariffs on washing machine parts. This could have raised the cost of domestic production, with subsequent pass-through to retail prices of washing machines. Further inspection reveals that the effective tariff rate on parts hardly changed following the Section 201 tariffs, consistent with this provision being a targeted measure to prevent foreign firms from importing semi-assembled pieces to get around the tariffs on fully assembled machines. Further details on washing machine parts is available in online Appendix C.6. The effect of the increase in steel prices is differenced out, as it also applies to ranges (the control group) and the other appliances. In light of these results, a more plausible explanation is that the domestic brands are using their market power to raise prices. Indeed, as shown by Pierce (2011) for a broader set of industries, domestic plants protected from antidumping duties tend to exhibit increased prices and markups.

Finally, we explore whether the increase in prices following the Section 201 safeguard tariffs reflected increased prices by wholesalers or changes in margins by retailers. We turn to proprietary data from AHAM, which includes monthly aggregate value and quantity (and, hence, a calculated average unit value) for shipments of broad categories of appliances (e.g., top-load washers and side-by-side refrigerators). Replicating the analysis above on this data, we find similar wholesale price changes for washers and dryers: an increase of roughly 10 percent in both washers and dryers following the Section 201 safeguard tariffs. Further details are available in online Appendix C.7.

D. *Robustness*

Online Appendix D contains additional results indicating that our findings from Section IIC are robust to alternative assumptions. We modify the sample to include all available stores and brands and to restrict to only brick-and-mortar stores. We have tried alternative specifications for how we treat the age of a model in our specification and run versions that remove the life cycle effects completely. We also run a specification using weights based on the number of brick-and-mortar stores for each retailer.

Our results are robust to these alternative assumptions. Focusing on our results pertaining to the safeguard tariffs, we see that the smallest estimate of price changes comes from the sample including all brands and retailers, with 8-month price increase estimates for washers and dryers of 8 percent. Our largest estimate of price changes comes from the weighted sample restricted to only brick-and-mortar stores, with eight-month price increase estimates for washers and dryers of 13 percent.

E. *The Tariff Elasticity of Consumer Prices*

The tariff elasticity of prices (or tariff pass-through) is a useful metric for policymakers attempting to understand the likely consequences of increased

tariffs on economic activity. In an environment pertaining to worldwide tariffs on a homogeneous goods market with a competitive retail sector, this elasticity would follow directly from the changes in import prices following a tariff change. A number of features, however, such as imperfect competition, changes in wholesaler/retailer margins, production relocation (including to the domestic market), and complementary goods, complicate the calculation of this metric.

We construct a measure of the tariff elasticity of *consumer* prices that can accommodate these complications. Formally, let $\Delta_t \ln P_C(\Delta\tau)$ denote the log change in the consumer price index of product category C *in response to a tariff change*. The measure is meant to capture the change in expenditure required to obtain the same utility as under pre-tariff prices (i.e., $\big(e(p_1,u_0) - e(p_0,u_0)\big)/e(p_0,u_0)$). Then, we define the tariff elasticity of consumer prices (*TECP*) as

$$TECP_{C,t} = \frac{\Delta_t \ln P_C(\Delta\tau)}{\left[\frac{M_{C,t-1}}{D_{C,t-1}}\right]\sum_K s^k_{C,t-1}\,\Delta\tau^k_{C,t}}, \tag{5}$$

where $M_{C,t-1}$ and $D_{C,t-1}$ are aggregate imports and consumption of product category C, measured in period $t-1$ before tariffs are applied. The term $s^k_{C,t-1}$ denotes lagged import shares of country k to apply to the country-specific tariff rate changes $(\Delta_t \tau^k_C)$. Equation (5) more accurately captures the indirect price effects of tariffs by measuring the aggregate price and tariff changes separately while using lagged import weights to reflect the effective tariff burden facing firms and therefore applicable to the initial price level. The focus on the overall consumer prices—made possible by our data—and an adjustment for the share of domestic production facing no tariff changes (the $M_{C,t-1}/D_{C,t-1}$ term in the denominator) ensure that the measure reflects an overall elasticity for products consumed.[18] Finally, the measure allows one to identify the product category C to assess whether broader categories of products experience price changes.

The *TECP* measure has intuitive properties. If import prices on the selected countries subject to tariffs rise proportionally with the tariff change and prices of goods from other countries do not change, the *TECP* measure takes a value of one, indicating a full pass-through of tariffs to consumers.[19] If firms substitute their import locations to other countries and increase prices by less than the tariff change, and domestic competitors do not change their prices, the *TECP* measure will be less than one. Finally, if competitors not subject to tariffs themselves increase their prices as well, the *TECP* measure can be larger than one.

To implement equation (5) in our data, we require two adjustments. First, as a measure of the price index, we are effectively taking the average log change of prices from our data. While this may insufficiently capture the substitution possibilities of consumers across brands, our brand-level analysis demonstrates

[18] For washing machines, we measure aggregate consumption using shipments data from AHAM.

[19] To see this, consider a first-order approximation of the expenditure function. Applying Shephard's lemma, one obtains $\big(e(p_1,u_0) - e(p_0,u_0)\big)/e(p_0,u_0) \approx \sum_k s^k_0\big((p^k_1 - p^k_0)/p^k_0\big)$. Hence, under these conditions, the numerator and denominator of the *TECP* formula will be the same.

similar price changes and stable market shares during the periods we study.[20] And, as shown in Figure 4, our estimates mirror the CPI quite well. Second, to capture the causal impact on prices (defined as $\Delta_t \ln P_C(\Delta\tau)$ above), we follow our approach from Section C and utilize our estimates $\widehat{\Delta_t^{8m}\bar{p}_C}$ in equation (3), which uses a set of control group (J) products. This is to difference out factors apart from tariffs that could be influencing consumer prices for product category C during this time period. This leads to the modified expression

$$\widehat{TECP}_{C,t} = \frac{\widehat{\Delta_t^{8m}\bar{p}_C}}{\left[\frac{M_{C,t-1}}{D_{C,t-1}}\right]\sum_{K_C} s^k_{C,t-1}\Delta_t\tau^k_C - \left[\frac{M_{J,t-1}}{D_{J,t-1}}\right]\sum_{K_J} s^k_{J,t-1}\Delta_t\tau^k_J}. \tag{6}$$

Implementing equation (6) in our data presents a number of complications. First, calculating the statutory tariff rate change is complicated. For the two antidumping cases in which the application of antidumping duties is firm specific, there is the question of how to aggregate. In order to best approximate the aggregate change in duties we utilize the firm-level bill of lading data (see online Appendix C.14) to construct pre-period firm-level shares to use as weights. For the Section 201 safeguard case, the complication comes from a number of product-level exclusions (within HS-10 codes) which we are unable to identify in the retail price data (see online Appendix C.2). Online Appendix Figure C3 demonstrates that imports identified under the Section 201 rate provision code display an applied tariff rate that matches those specified in the statute, while the average effective tariff rate across all washer imports is significantly lower. Because it is unclear which washers were excluded, and to what brands/models they belong, we adopt the conservative convention and simply apply the statutory rate in our calculations in equation (6).

In addition, the Section 201 safeguard measure is a tariff-rate quota and therefore exhibits multiple tariff rates during the sample period we study. As mentioned, the quota of 1.2 million units subject to the lower (20 percent) additional tariff rate was reached in October 2018, and all relevant units thereafter paid a higher rate of 50 percent. In our results below we report two estimates based on whether we use the trade-weighted average of these two rates or the maximum rate. The maximum rate may be appropriate if companies perceive the opportunity cost of selling a washer imported under the lower rate to be importing it at the higher rate in the future.

Finally, a third issue is how to account for the price changes of dryers, which had no tariff change during this period. We found that prices of dryers rose in line with washers, consistent with evidence for broader complementarities between these products. Firms likely spread out the increase in prices across both washers and dryers to keep the retail prices similar between matching models sold as pairs. To add the dryer effect to equation (6), we modify the product category C to include both washers and dryers. Because we estimate the price change to be nearly

[20] One would ideally estimate a structural model of demand across washers and dryers to estimate substitution parameters, and to calculate the consumer welfare effect of the policy induced prices changes. Although we lack the quantity data for this exercise, we will use the observed decline in the aggregate consumption of washers for our quantification of the consumer cost increases due to the 2018 safeguard tariffs on washers in Section III.

Table 3—Calculation of the Tariff Elasticity of Consumer Prices

	Antidumping		Safeguard Tariffs[a]	
	Korea and Mexico (1)	China (2)	Trade-weighted average (3)	Maximum (4)
Panel A. Average consumer price change(%)[b]				
Washers only	N/A	3.40	11.50	11.50
Washers and dryers	−8.55	2.85	11.45	11.45
Panel B. Pre-period trade-weighted average statutory tariff rate change(%)				
Washers only	9.57	16.32	9.18	19.94
Washers and dryers	5.27	9.15	5.09	10.64
Panel C. Tariff elasticity of consumer prices				
Washers only	N/A	0.21	1.25	0.58
Washers and dryers	−1.62	0.31	2.25	1.08

Notes: Panels A and B follow the numerator and denominator of equation (6), respectively. The denominator calculates import shares in a pre-period defined as July–December 2011, July–December 2015, and February–August 2017 for the Korea/Mexico antidumping, China antidumping, and safeguard tariffs, respectively. Statutory tariff rate changes for antidumping duties use firm-level weights from PIERS Bill of Lading data (see online Appendix Table B2).

[a] The two columns pertaining to the Section 201 safeguard tariffs correspond to the method of accounting for the heterogeneity in tariff rates over time. The *Trade-weighted average* uses import shares as weights during the period of study, and the *Maximum* column uses the maximum (50 percent) rate.

[b] Columns 2, 3, and 4 in panel A are calculated based on estimates presented in column 2 of Table 1, where the estimates for washers and dryers are the simple average of the two coefficients. Column 1 is calculated using changes in the CPI for "laundry equipment" relative to "other appliances" during the relevant period (following equation (3)).

identical (the numerator), the main difference arises in a smaller average tariff rate change (a smaller denominator, reflecting a zero tariff rate change for dryers).

Panel C of Table 3 presents the estimates of the tariff elasticity of consumer prices for the three tariff changes we study. (We separate out the numerator and denominator components in panels A and B, respectively, and report estimates for both washers and washers including dryers.) Although we lack detailed micro-level retail prices for the first Korea/Mexico antidumping duties, we provide an estimate of price changes using the published CPI for laundry equipment relative to the CPI for "other appliances." For the Section 201 safeguard tariffs, we report estimates separately based on whether we use the trade-weighted average or the maximum value of the tariff rate applied during the 12-month period following tariffs being implemented.

Evident in Table 3 is a wide range of the consumer elasticity of tariffs. Our suggestive estimate for the 2012 antidumping duties against Korea and Mexico indicates a *decline* in prices and hence a *negative* elasticity. (See online Appendix A for a theoretical discussion.) Consistent with this estimate, the brand-level market share data in online Appendix Table C12 indicate that both LG and Samsung gained market share in 2013 and 2014 (whereas their combined market shares were flat in the two years prior to the Korea antidumping case). However, the small price increase we estimate for the 2016 antidumping duties against China results in a modest elasticity of 0.21 (washers only) to 0.31 (washers and dryers combined). Finally, the estimates for the Section 201 safeguard tariffs are considerably higher: 1.25 to 2.26 using the trade-weighted average tariff increase or 0.58 to 1.08 using

the maximum tariff rate. Our results demonstrate markedly different consumer price effects between single- and multi-country tariffs. They further highlight that price increases by domestic competitors and for complementary goods can push this elasticity well above one.

III. Discussion and Conclusions

A common summary measure for evaluating the effects of a policy combines the impact on consumer prices with the added domestic employment into an estimate of the consumer cost per domestic job created in that industry. In the period following the 2018 safeguard tariffs, US employment rose as existing producers claimed an additional 200 jobs and foreign producers added 1,600 jobs from new US production.[21] As shown, these job gains were accompanied by substantially higher consumer prices. To arrive at an overall cost increase to consumers, we multiply the dollar value increases in washer/dryer prices by the annual level of washer/dryer shipments. We use the average level of shipments between 2017 and 2018, based on AHAM numbers indicating that washing machine sales fell in 2018. These numbers are roughly 10 million washing machines and 7.7 million clothes dryers, indicating an annual cost to consumers of US$1.55 billion.[22]

Tariff revenues offset these costs to a small extent. According to USITC records, calculated duties from February 2018 to January 2019 amounted to just under US$82 million for washing machines and about US$355,000 for washing machine parts. After netting out the tariff revenue from the annual costs to consumers, the consumer cost per job for the 2018 safeguard tariffs amounts to roughly US$817,000 annually. This number is of the same order of magnitude as in other similar exercises. Hufbauer and Lowry (2012) calculate such a metric from the Section 421 tariffs on Chinese tire imports, finding a cost of roughly US$900,000 per job. These calculations are made in partial equilibrium and focus only on the direct effects of these policies on the washing machine sector. Upstream linkages to domestic suppliers could create a multiplier effect on the number of domestic jobs created from this policy. But higher prices of appliances at retail stores may reduce available income for expenditures on other goods, leading to job losses in other industries.

Three broader lessons regarding firm behavior following new import tariffs emerge from our study. First, we find that complementary goods complicate the measurement of the tariff elasticity of prices, as dryer prices rose markedly in 2018 despite not being subject to new tariffs. Spillovers from complementarities across goods could operate more broadly, as complementary goods (mattresses and box springs; tables and chairs; printers and ink cartridges; and video game consoles, games, and accessories) are common and widespread. Firms being increasingly sophisticated in their models of pricing such goods (e.g., bundling, subscription

[21] Of course, the effect on overall employment from these policies depends in large degree on the extent of slack in the economy. In February 2018, the unemployment rates in Newberry County, South Carolina (Samsung plant), Montgomery County, Tennessee (LG plant), and Sandusky County, Ohio (main Whirlpool plant) were 3.7, 3.8, and 5.1 percent, respectively.

[22] Hence, US$86 $\times$ 9.78 million $\approx$ US$841 million plus US$92 $\times$ 7.72 million $\approx$ US$710 million. Together, they equal US$1.552 billion.

plans), so tariff policies for a particular good may lead to unexpected price changes in other products unaffected by tariffs.

Second, production relocation plays a large role in the extent of tariff pass-through to prices. The large shifts in production and trade following the two sets of antidumping duties imply that duties were ultimately not applied to a significant share of imports. Retail prices rose only modestly after the 2016 China antidumping duties; more strikingly, import prices even *declined* following the 2012 Korea/Mexico antidumping duties (see Figure 3). But what conditions govern whether production will relocate in response to a change in trade policy? Any response will necessarily rely on idiosyncratic features of the particular firms and policies, but the experience of washing machines offers several useful lessons. First, the product specificity of capital and the structure of existing production networks appear to play important roles. During the transitions from Korea to China and China to Thailand/Vietnam, both LG and Samsung utilized existing plants used previously for other products in the destination countries to adjust production of washing machines while keeping overall trade flows to their large markets roughly unchanged. In contrast, the shift of production to the United States following safeguard tariffs took comparatively longer as both firms opened new facilities (online Appendix C.12). Whether and when relocation occurs may also depend on the magnitude of import duties, the timing of when they are implemented, and the expectations for how long they will last.[23]

Finally, domestic producers increase prices following the global safeguard tariff by a similar margin to importers. Price increases by domestic brands are consistent with a model of oligopoly in which prices are strategic complements (see Amiti, Itskhoki, and Konings 2016). The extent of competition is a key determinant for how domestic producers will respond following an increase in import tariffs. Using the Traqline data to calculate the Herfindahl-Hirschmann index (HHI), we find the washing machine industry would be classified as "Moderately Concentrated" (an HHI between 1,500 and 2,500). Similar calculations for industries subject to new tariffs would be a useful exercise to better understand the overall impact of changes in trade policy on consumer prices.

REFERENCES

Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2016. "International Shocks and Domestic Prices: How Large Are Strategic Complementarities?" NBER Working Paper 22119.

Amiti, Mary, Stephen J. Redding, and David Weinstein. 2019. "The Impact of the 2018 Trade War on U.S. Prices and Welfare." *Journal of Economic Perspectives* 33 (4): 187–210.

Ashenfelter, Orley C., Daniel S. Hosken, and Matthew C. Weinberg. 2013. "The Price Effects of a Large Merger of Manufacturers: A Case Study of Maytag-Whirlpool." *American Economic Journal: Economic Policy* 5 (1): 239–61.

Association of Home Appliance Manufacturers. 2013–2019. "Factory Shipments Database." Confidential dataset.

Auer, Raphael, Ariel T. Burstein, and Sarah M. Lein. 2018. "Exchange Rates and Prices: Evidence from the 2015 Swiss Franc Appreciation." BIS Working Paper 751.

[23] As shown in online Appendix Table B1, there were effectively five months in between the USITC initial report and preliminary duties for the two antidumping cases and a slightly shorter lead time (four months) for the safeguard duties. Antidumping duties are subject to sunset reviews after five years, whereas safeguard tariffs are typically granted for a period of four years or less.

Bagwell, Kyle, Chad P. Bown, and Robert W. Staiger. 2016. "Is the WTO Passé?" *Journal of Economic Literature* 54 (4): 1125–1231.
Bai, Liang, and Sebastian Stumpner. 2019. "Estimating US Consumer Gains from Chinese Imports." *American Economic Review: Insights* 1 (2): 209–24.
Bernhofen, Daniel M., and John C. Brown. 2004. "A Direct Test of the Theory of Comparative Advantage: The Case of Japan." *Journal of Political Economy* 112 (1): 48–67.
Blonigen, Bruce A. 2002. "Tariff-Jumping Antidumping Duties." *Journal of International Economics* 57 (1): 31–49.
Brainard, S. Lael. 1997. "An Empirical Assessment of the Proximity-Concentration Trade-Off between Multinational Sales and Trade." *American Economic Review* 87 (4): 520–44.
Broda, Christian, Nuno Limao, and David E. Weinstein. 2008. "Optimal Tariffs and Market Power: The Evidence." *American Economic Review* 98 (5): 2032–65.
Broda, Christian, and David E. Weinstein. 2006. "Globalization and the Gains from Variety." *Quarterly Journal of Economics* 121 (2): 541–85.
Canadian International Merchandise Trade Database. 2010–2019. https://www5.statcan.gc.ca/cimt-cicm/home-accueil?lang=eng (accessed July 19, 2019).
DellaVigna, Stefano, and Matthew Gentzkow. 2019. "Uniform Pricing in US Retail Chains." *Quarterly Journal of Economics* 134 (4) : 2011–84.
Ekholm, Karolina, Rikard Forslid, and James R. Markusen. 2007. "Export-Platform Foreign Direct Investment." *Journal of the European Economic Association* 5 (4): 776–95.
Ellison, Glenn. 2005. "A Model of Add-On Pricing." *Quarterly Journal of Economics* 120 (2): 585–637.
Fajgelbaum, Pablo D., Pinelopi K. Goldberg, Patrick J. Kennedy, and Amit K. Khandelwal. 2020. "The Return to Protectionism." *Quarterly Journal of Economics* 135 (1): 1–55.
Feenstra, Robert C. 1989. "Symmetric Pass-Through of Tariffs and Exchange Rates under Imperfect Competition: An Empirical Test." *Journal of International Economics* 27 (1): 25–45.
Finkelstein, Amy. 2007. "The Aggregate Effects of Health Insurance: Evidence from the Introduction of Medicare." *Quarterly Journal of Economics* 122 (1): 1–37.
Fitzgerald, Doireann, and Stefanie Haller. 2018. "Exporters and Shocks." *Journal of International Economics* 113: 154–71.
Gabaix, Xavier, and David Laibson. 2006. "Shrouded Attributes, Consumer Myopia, and Information Suppression in Competitive Markets." *Quarterly Journal of Economics* 121 (2): 505–40.
Gap Intelligence. 2013–2018. "Weekly Consumer Appliance Retail Price Series." Confidential dataset.
Goldberg, Pinelopi K., and Nina Pavcnik. 2016. "The Effects of Trade Policy." In *Handbook of Commercial Policy*, Vol. 1A, edited by Kyle Bagwell and Robert W. Staiger, 161–206. Amsterdam: North-Holland.
Grant, Matthew. 2020. "Why Special Economic Zones? Using Trade Policy to Discriminate across Importers." *American Economic Review* 110 (5): 1540–71.
Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple. 2004. "Export versus FDI with Heterogeneous Firms." *American Economic Review* 94 (1): 300–16.
Hitsch, Günter, Ali Hortaçsu, and Xiliang Lin. 2017. "Pricing in US Retail Chains." Chicago Booth Research Paper 17-18.
Horstmann, Ignatius J., and James R. Markusen. 1992. "Endogenous Market Structures in International Trade (Natura Facit Saltum)." *Journal of International Economics* 32 (1): 109–29.
Huber, J. Richard. 1971. "Effect on Prices of Japan's Entry into World Commerce after 1858." *Journal of Political Economy* 79 (3): 614–28.
Hufbauer, Gary C., and Sean Lowry. 2012. "US Tire Tariffs: Saving Few Jobs at High Cost." Peterson Institute for International Economics Policy Brief 12-9.
Irwin, Douglas A. 2019. "Tariff Incidence: Evidence from U.S. Sugar Duties, 1890–1930." *National Tax Journal* 72 (3): 599–616.
Jaravel, Xavier, and Erick Sager. 2019. "What Are the Price Effects of Trade? Evidence from the US and Implications for Quantitative Trade Models." Center for Economic Policy Research DP-13902.
Korea Customs Service. 2010–2019. "Trade Statistics." http://www.customs.go.kr/english/cm/cntnts/cntntsView.do?mi=8042&cntntsId=2724 (accessed July 12, 2019).
LG Electronics. 2017. "LG Electronics to Build U.S. Factory for Home Appliances in Tennessee." Press Release, https://www.lg.com/us/press-release/lg-electronics-to-build-us-factory-for-home-appliances-in-tennessee.
Ludema, Rodney D., and Zhi Yu. 2016. "Tariff Pass-Through, Firm Heterogeneity and Product Quality." *Journal of International Economics* 103: 234–49.
Nakamura, Emi. 2008. "Pass-Through in Retail and Wholesale." *American Economic Review* 98 (2): 430–37.

Pierce, Justin R. 2011. "Plant-Level Responses to Antidumping Duties: Evidence from U.S. Manufacturers." *Journal of International Economics* 85 (2): 222–33.

Port Input/Export Reporting Service (PIERS). 2012–2019. "Bill of Lading Database." Confidential dataset.

Ruhl, Kim J. 2014. "The Aggregate Impact of Antidumping Policies." Unpublished.

Sales Rank Dataset. 2019. "Online Sales Rank by Retailer." Compiled from http://www.bestbuy.com, http://www.homedepot.com, and http://www.jcpenney.com (accessed January 30, 2019 and February 1, 2019).

Samsung. 2017. "Samsung to Expand U.S. Operations, Open $380 Million Home Appliance Manufacturing Plant in South Carolina." Press Release, https://news.samsung.com/us/samsung-south-carolina-home-appliance-manufacturing-plant-investment-newberry/.

Spearot, Alan C. 2012. "Firm Heterogeneity, New Investment and Acquisitions." *Journal of Industrial Economics* 60 (1): 1–45.

Tintelnot, Felix. 2017. "Global Production with Export Platforms." *Quarterly Journal of Economics* 132 (1): 157–209.

TraQline Market Research. 2010–2018. "Brand-Level Retail Market Share Series." Confidential dataset.

Trefler, Daniel. 2004. "The Long and Short of the Canada–US Free Trade Agreement." *American Economic Review* 94 (4): 870–95.

United Nations. 2010–2019. "Comtrade Database." https://comtrade.un.org/ (accessed July 15, 2019).

United States Bureau of Labor Statistics. 2010–2019. "Consumer Price Index." https://www.bls.gov/cpi/ (accessed May 20, 2019).

United States Census Bureau. 2000–2019. "Related Party Trade Database." https://relatedparty.ftd.census.gov/ (accessed December 15, 2018).

United States International Trade Commission. 2010–2019. "DataWeb." https://dataweb.usitc.gov/ (accessed April 20, 2019).

United States International Trade Commission. 2017a. "Large Residential Washers." USITC, Investigation No: TA-201-076 Report 4745.

United States International Trade Commission. 2017b. "Large Residential Washers: Pre-Hearing Report." USITC, Investigation No: TA-201-076 Report Doc ID: 621175.

Winkelmann, Liliana, and Rainer Winkelmann. 1998. "Tariffs, Quotas and Terms-of-Trade: The Case of New Zealand." *Journal of International Economics* 46 (2): 313–32.

Yeaple, Stephen R. 2003. "The Complex Integration Strategies of Multinationals and Cross Country Dependencies in the Structure of Foreign Direct Investment." *Journal of International Economics* 60 (2): 293–314.