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The Impact of the 2018 Trade War on U.S. Prices and Welfare

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The Impact of the 2018 Trade War on U.S. Prices and Welfare[1]

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Abstract:

This paper explores the impacts of the Trump administration's trade policy on prices and welfare. Over the course of 2018, the U.S. experienced substantial increases in the prices of intermediates and final goods, dramatic changes to its supply-chain network, reductions in availability of imported varieties, and complete passthrough of the tariffs into domestic prices of imported goods. Overall, using standard economic methods, we find that the full incidence of the tariff falls on domestic consumers, with a reduction in U.S. real income of $1.4 billion per month by the end of 2018. We also see similar patterns for foreign countries who have retaliated against the U.S., which indicates that the trade war also reduced real income for other countries.

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1. Introduction

Over the course of 2018, the Trump administration imposed import tariffs on approximately \$283 billion of U.S. imports, with rates ranging between 10% and 50%. In response, U.S. trading partners, especially China, have retaliated with tariffs averaging 16% on approximately \$121 billion of U.S. exports, plunging the U.S. into its first episode of large-scale competitive tariff protection since the Great Depression of the 1930s, and raising questions about the future of international trade integration. These kind of tit-for-tat exchanges of tariffs are typically characterized as a "trade war," a term that we adopt throughout this paper.

This paper aims to explore the impacts of this change in U.S. trade policy on prices and welfare. While the long-run effects are still to be seen, over the course of 2018, the U.S. experienced substantial increases in the prices of intermediates and final goods, large changes to its supply-chain network, reductions in availability of imported varieties, and complete passthrough of the tariffs into domestic prices of imported goods. Therefore, although in principle the effect of higher tariffs on domestic prices could be offset by foreign exporters lowering the pre-tariff prices that they charge for these goods, we find little evidence of such an improvement in the terms of trade up to now, which implies that the full incidence of the tariff has fallen on domestic consumers so far. Our results imply that the tariff revenue the U.S. is now collecting is insufficient to compensate the losses being born by the consumers of imports. We also see similar patterns for foreign countries who have retaliated against the U.S., which indicates that the trade war reduces real income for the global economy as well.

We argue that conventional trade models are a powerful framework for understanding what has happened to prices, quantities, and welfare. The deleterious impacts of the tariffs have been largely in line with what one might have predicted based on a simple supply and demand framework. We estimate the likely impact on U.S. consumers and find that by the end of 2018, import tariffs were costing U.S. consumers and the firms that import foreign goods an additional $3 billion per month in added tax costs and another $1.4 billion dollars per month in deadweight welfare (efficiency) losses. Tariffs have also changed the pricing behavior of U.S. producers by protecting them from foreign competition and enabling them to raise prices and markups. If we assume that the 2018 tariffs have not affected prices in sectors that do not use or compete with targeted imports, we estimate that the combined effect of input and output tariffs have raised the average price of U.S. manufacturing by one percentage point, which compares with an annual average rate of producer price inflation from 1990-2018 of just over two percentage points. We also see evidence of large impacts of the U.S. tariffs and the foreign retaliatory tariffs on supply chains. We estimate that if the tariffs that were in place by the end of 2018 were to continue, approximately $165 billion dollars of trade per year will continue to be redirected in order to avoid the tariffs. Given the fixed costs associated with the current supply chains, this reorganization of global value chains is likely to impose large costs on firms that have made investments in the U.S. and China, as they have to move their facilities to other locations or find alternative sources of import and export destinations.

2. Overview of the Trump Administration's Trade War

The Trump administration's trade war provides a natural experiment for evaluating the effects of trade policy. Since President Trump's election was a surprise to many observers, it is unlikely that the tariffs were anticipated in the affected industries. Most observers were expecting Hillary Clinton to win, with a presumably different approach to trade policy. A second feature of the Trump administration's trade war that makes it useful for social scientists is that the large magnitude of the tariffs creates meaningful variation across products, time, and countries. These large tariffs makes it relatively easy to discern their effects using conventional datasets.

As one can see in Figure 1, the 2018 U.S. tariffs were introduced in six main waves throughout the year.[1] Starting in January, the first wave of tariffs imposed import duties of 30 percent on solar panels and duties of 20-50 percent on washing machines. These two product categories accounted for approximately 10 billion dollars of imports and created a modest uptick in US average tariff rates as one can see in the figure. The second wave of tariffs was implemented in March on 18 billion dollars of steel and aluminum imports. In this wave, aluminum imports were hit with 10 percent tariffs and a 25 percent tariff was applied to steel imports. The low value of imports covered by the second wave stems from the fact that at least initially, many countries such as Canada, Mexico, and the countries in the European Union (E.U.) were exempt. This exemption ended as the third wave of tariffs was imposed on $22 billion of imports from these countries in June.

These early tariff waves were dwarfed in size by the tariffs that were applied to Chinese imports that summer. The China-specific tariffs began in July and were rolled out in three waves. The first tranche of 25 percent tariffs on 34 billion dollars of imports began in July (wave 4), followed by a second tranche of 25 percent tariffs on another 16 billion dollars of Chinese imports in August (wave 5). Finally, another tranche of 10 percent tariffs on an additional 200 billion dollars of Chinese imports was imposed at the end of September (wave 6). The tariffs included in this last wave were slated to rise in value by another 15 percentage points in January until President Trump and President Xi announced a temporary truce in December at the G20 meeting. In total, nearly 283 billion dollars of imports—about 12 percent of total imports—were hit by duties. While

[1] We do not count the imposition of aluminum tariffs on $0.1 billion of imports from South Korea on May 1 and $1.2 billion of Turkish imports on August 13, 2018 as separate tariff waves given their small magnitudes, however they are included in the analysis.

62 percent of U.S. imports continued to enter duty free, the fraction of U.S. imports facing duties of over 10 percent rose from 3.5 percent in December of 2017 to 10.6 percent by October of 2018.

It was not only U.S. tariffs that went up in 2018. Many foreign countries retaliated against the U.S. by applying tariffs of their own. In April, China began by levying tariffs on 3.3 billion dollars of U.S. exports of steel, aluminum, food, and agricultural products, followed by 50 billion dollars of U.S. exports in July and August, and another 60 billion dollars of exports in September. That summer, they were joined by the EU, Mexico, Russia, and Turkey, who all began levying retaliatory tariffs on U.S. exports. All told, approximately $121 billion of U.S. exports were affected by these retaliatory tariffs.

3. Conventional Price Impacts: Data

U.S. import tariffs had an almost immediate effect on prices in the U.S. economy. Figure 2 presents evidence of this for one of the first sectors targeted by the Trump administration: washing machines. The first panel shows what happened to the consumer price index (CPI) for major appliances, which is broad category of goods that includes washing machines. As one can see in the figure, despite the fact that the CPI for major appliances had been falling steadily for years prior to the trade war, it began rising sharply after the imposition of the new tariffs.

While it is impossible to match most import codes cleanly to the CPI because they appear in many CPI categories and many CPI categories contain a variety of imported products, we can obtain a clear sense of how the tariffs are being passed through into domestic prices by considering what has been happening to the prices paid by U.S. importers. U.S. customs data reports the foreign export values and quantities, i.e., the values and quantities of imports by source country at the 10-digit level of harmonized tariff system (HTS10 data). These data break up monthly U.S. imports from each country into approximately sixteen thousand narrowly defined categories. By dividing the import values by the quantities, one can compute unit values at a very disaggregated level (e.g., "baseball and softball gloves and mitts made in China"). These unit values are likely to contain a lot of information about the prices of these goods. Importantly, unit values are computed before tariffs are applied, so they correspond to foreign export prices. If we multiply these unit values by the duty rates available from the U.S. International Trade Commission, we can compute tariff-inclusive import prices.

These tariff-inclusive prices provide the first hint of what has been happening to the U.S. economy as a result of the Trump administration's tariffs. If we denote the unit value (price) of an HTS10 good i, from country j in month t by p_{ijt}, we can compute the 12-month relative change in prices for that good and country as $\hat{p}_{ijt} \equiv \left(p_{ijt}/p_{ij,t-12}\right)$. In working with these price relatives for each good, we difference out any constant choice of units for each good. We work with 12-month relative changes to avoid seasonality in the unit values. Letting w denote the set of HTS10-country varieties affected by a tariff change, we compute a price index for each wave as the following weighted average of these price relatives:

$$\hat{p}_{wt} \equiv \prod_{i,j \in w} \left(\hat{p}_{ijt}\right)^{s_{ij}^{w}},$$

where s_{ij}^{w} is the logarithmic mean of the import shares from country j in sector i in the relevant months from 2017 and 2018 among all HTS10 imports in the categories affected by tariff wave w.

Our use of the logarithmic mean import shares as weights ensures that we weight the price change for each good according to its relative importance in imports and that this price index corresponds to a Sato-Vartia price index that is exact for the constant elasticity of substitution (CES) demand system. We express these price indexes as proportional changes by subtracting one ($\hat{p}_{wt} - 1$). We compare these price changes relative to month zero, defined as the month before the tariffs were imposed. We also eliminate secular trends in price increases by subtracting the average price increase for each wave in month zero from all observations so that goods in all waves have a price increase of zero in month zero. [2]

Figure 3 plots the evolution of these prices for each of the six waves of tariffs. We see a number of important facts in this figure. First, the prices for sectors not subject to tariffs are fairly flat, which suggests that whatever price movements we observe in protected sectors are likely due to the tariffs. Second, we see large increases in prices of goods that were subject to tariffs, with unit values typically rising from 10 to 30 percent in the wake of the tariffs. Given that these numbers are comparable in magnitude to tariffs that were applied, it suggests that much of the tariffs were passed on to U.S. importers and consumers. Clearly, importers began feeling the full effects of the tariffs in the first month that they were implemented. Finally, although there seems to be some pre-trend in prices for the goods hit in waves 1 and 5, there does not appear to be a pre-trend for the goods in any of the other waves, which indicates that the price increases that we observe are likely due to the fact that much of the tariffs have been passed on to importers. To the extent that countries not targeted by each tariff wave (included in our untreated category of countries and products) also raised their prices in response to the higher tariffs imposed on their competitors, the full price impact of the tariffs could be even larger than suggested by these figures.

Figure 4 repeats the same plot using the total value of imports as the variable in place of unit values. In this plot, we normalize the import value in month zero to be one for all goods, so the import values are all relative to imports in the last month before the tariffs were applied. As one can see from the figure, there was a big surge in imports in the wave 1 products just before implementation and smaller surges for the goods in the other sectors. The run up in washing

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[2] We also do this for the "untreated" set of goods and countries—i.e., those goods and countries that faced no tariff changes in 2018—to have a sense of the baseline movement in prices. We drop petroleum imports from all plots and tables because of the volatility of these prices.

machine and solar panel (wave 1) imports prior to the imposition of tariffs was likely caused by importers moving forward import orders in order to obtain products before the imposition of the tariffs. For the remaining goods, it appears that on average their import levels were rising a little faster than for unaffected goods in the months prior to the imposition of the tariffs, but there was a steep decline in import values after the imposition of the tariffs. The drops in imports following the imposition of the tariffs are quite large in magnitude. We see import values falling 25 to 30 percent after the imposition of the tariffs. This drop is particularly striking given that the imports of unaffected sectors and countries *rose* by about 10 percent over the same period, where this rise could in part reflect some import substitution from affected to unaffected countries and products in response to tariff changes. These results suggest that the imposition of the tariffs had very large relative impacts on the amount of imports for affected countries and sectors.

4. Conventional Price Impacts: Theory

We can understand why we observe these patterns by considering the standard textbook model of import tariffs given in Figure 5. The horizontal axis plots the quantity of home imports (m) and the vertical axis corresponds to import prices (p) and foreign exporter prices (p^*). The foreign export supply curve (S^*) rises with prices, which reflects the fact that higher prices induce foreign producers to increase production and foreign consumers to decrease consumption. In contrast, home import demand (D) falls with prices, which captures the fact that higher prices also reduce demand by domestic consumers and increase production by domestic firms. In the absence of tariffs, markets will clear with an equilibrium price ($p_0 = p_0^*$) that equalizes import demand and export supply when imports equal m_0.

Within this simple framework, an *ad valorem* tariff on imports of τ raises the cost of the imported good in the domestic market from p^* to $p^*(1+\tau)$. As a result of this higher price, domestic consumers cut back demand for imports to m_1. At this import level, there is a wedge between the prices charged by foreign producers (p_1^*) and the prices paid by domestic consumers (p_1) that equals the per-unit tariff being collected ($p_1^*\tau$). Home consumers lose regions $A + B$, with A reflecting the higher prices paid on the imports purchased, and the triangular region B capturing the deadweight welfare loss (reduction in real income) from the distortion of domestic production and consumption decisions. The home government gains rectangular region $A + C$ in tariff revenue. Since rectangle A simply represents a transfer from consumers to the government (i.e., the amount of a tariff's costs consumers are forced to bear), whether the tariff benefits the country as a whole depends on the sign of $C - B$. This amount can be thought of as the difference between the gain in a country's "terms of trade" (i.e., its ability to extract rents from foreign producers by forcing them to drive their prices down in order to continue exporting to the home market) and the deadweight welfare loss given by B. The foreign country clearly loses in this setup, since an amount of their producer surplus equal to C is transferred in the form of tariff revenue to the home government, and the triangular region D constitutes the deadweight welfare loss from the distortion of foreign production and consumption decisions.

An important special case of the impact of tariffs on prices and welfare comes when imports are supplied perfectly elastically and so the foreign country has a horizontal export supply curve as shown in Figure 6. In this case, the imposition of a foreign tariff will have no impact on foreign prices. This means that the home country will necessarily lose because region C is zero and hence there is no terms of trade gain, leaving home only with the welfare loss due to the distortion of domestic production and consumption decisions. Although, to simplify the exposition, we have undertaken all of this analysis starting from zero tariffs (free trade), a directly analogous analysis goes through starting from an initial positive value for tariffs.

5. Estimating Price and Welfare Losses

The critical question for short-run impacts, then, is whether the price received by foreign exporters, p_1^*, falls in response to a tariff or not. A necessary condition for the U.S. to gain from these tariffs in the classical model is that foreign exporters absorb some of the tariff costs so that they are not fully born by home consumers (Figure 5 versus Figure 6). Thus, understanding how the price received by foreign exporters moves in response to a tariff increase is a first key step in understanding the welfare implications. We examine these effects by regressing the change in the log import unit value (measured without including the tariff change) over a twelve-month period (i.e., $\ln(p_t^*/p_{t-12}^*)$ on the change in one plus the applied tariff on imports (i.e., $\ln[(1+\tau_t)/(1+\tau_{t-12})]$) over the same period. Treating the Trump administration's tariffs as exogenous, and assuming that they are uncorrelated with unobserved shocks to unit values, the estimated coefficient in this regression captures the impact of the tariffs on the prices received by foreign exporters.

Column (1) of Table 1 shows the results from this regression. We obtain an estimate of tariffs on unit values of -0.003, which suggests that the tariff changes have had little-to-no impact on the prices received by foreign exporters. Moreover, because the standard error of this estimate is 0.024, the coefficient is precisely estimated, so we can reject the hypothesis that there is a substantial impact of tariffs on exporter prices. This finding that the Trump administration's tariff changes have been almost entirely passed through into domestic prices, leaving exporter prices unchanged, is consistent with the findings from a different estimation methodology in Fajgelbaum, Goldberg, Kennedy and Khandelwal (2018).[3] Thus, it appears that the supply elasticity of exports, at least in

[3] While much of the existing literature on the passthrough of cost shocks into prices focuses on exchange rate shocks (e.g. Amiti, Itskhoki, and Konings (2014)), Khandelwal, De Loecker, Goldberg and Pavcnik (2016) examine the effect of lower tariffs in India, while Edmond, Midrigan and Xu (2015) consider the effects using Taiwanese

the short-run, is close to perfectly elastic as portrayed in Figure 6, which means close to all of the cost of the 2018 U.S. tariffs has been born so far by U.S. consumers and importers.[4]

In Column (2) of Table 1, we replace the dependent variable with the 12-month change in imported quantities. Under the assumption that the Trump administration's tariffs are exogenous, and using our finding that there is no offsetting change in the prices received by foreign exporters, we can interpret the estimated coefficient on the tariff change as the import demand elasticity. Here we see that a one percent increase in tariffs is associated with a 1.3 percent decrease in imports. This decline is much smaller than the declines we observed in Figure 4, because prohibitive tariffs result in zero import quantities that are dropped from the regression. As a simple fix for this problem, we rerun the regression replacing the log of the quantity change with the inverse hyperbolic sine, which is defined for cases in which import quantities are zero.[5] The results from this exercise are reported in Column (3). As one can see from this specification, including the trade flows that go to zero results in a substantially higher estimate of the impact of tariffs on trade flows. We estimate that a one percentage point increase in tariffs is associated with a six percentage point fall in import quantities. This estimate is very much in line with standard estimates of trade elasticities (c.f., Broda and Weinstein 2006).[6]

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data. Amiti, Di, Feenstra, and Romalis (2017) estimate the effect of China lowering its own tariff's on the U.S. manufacturing price indexes.

[4] The absence of any terms-of-trade effects is particularly surprising given the work by Broda, Limão, and Weinstein (2008), who argue that export supply curves are often upward sloping, which means that U.S. optimal tariffs are not zero. One likely explanation for the difference between these two sets of results is the time horizon. Their work estimates these elasticities at an annual frequency, whereas we are working with monthly data and looking at the impact of tariffs over just a few months. It is possible that in the short run export prices are more sticky, so if we were to look at the impact of these tariffs over longer periods we would see exporters drop their prices.

[5] The inverse hyperbolic sine of some variable, x, is given by $\ln[x + (x^2 + 1)^{0.5}]$. It equals 0 when $x = 0$, and its slope tracks that of $\ln x$ more closely than $\ln(1 + x)$ when x is small.

[6] We find a similar pattern of results if we augment the specifications in Table 1 with a full set of fixed effects for HS-2-digit-sector-year, with marginally smaller coefficients in absolute value.

In Columns (4) and (5) of Table 1, we repeat this exercise using import values as the dependent variable, where these import values are again measured without including the tariff. We now have far more observations, because import values are more frequently reported than import quantities. We find quantitative similar results for values as for quantities, which is consistent with our earlier finding of no discernible effect on the prices received by foreign exporters. If we multiply the tariff changes by this elasticity estimate, we find that the 2018 U.S. tariffs through wave 6 reduced U.S. imports in the affected HTS10 categories relative to those in the unaffected categories by about 54 percent, which is in line with the steep relative drops in imports that we saw in Figure 4. U.S. total imports probably fell by much less than this because some of the declines in protected sectors were offset by increases in exports from countries not subject to tariffs. Based on our estimates in Column (5) of Table 1, the *relative* decline in imports from affected sectors amounts to $136 billion dollars in imports (on an annual basis).[7] Importantly, this relative decline in imports is consistent with any aggregate movement in imports as long as the imports of the affected sectors fell by $136 billion more than the unaffected. However, the estimate does imply a substantial shock to global supply chains, because it means that at least $136 billion dollars of trade was redirected as a result of the import tariffs. This potentially could imply very large costs for U.S. multinationals (and Chinese exporters) who have made irreversible investments in China. Indeed, given that Liang and Lovely (2018) found that in sectors like Machinery, Electrical equipment, appliances, and computer and electronic products, the share of exports from China that were made from non-Chinese firms ranged from 59 percent to 86 percent, it is reasonable to conjecture that U.S. firms may be forced to write off investments in China as their Chinese factories become uncompetitive and new facilities need to be opened elsewhere.

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[7] This number is calculated by computing the change in import values obtained by multiplying the coefficient on the tariff change in column 5 by the tariff change in each sector and summing across sectors.

We can also use these regression estimates to undertake a simple calculation of the reduction in real income for U.S. consumers as a result of these tariffs. If we assume that the import demand curve has a constant slope and approximate region B by a triangle, then we know that the height of this triangle is given by $p_1^*\tau$ and its base is given by $m_0 - m_1$. The deadweight welfare loss is then given by $\frac{1}{2}p_1^*\tau(m_0 - m_1) = \frac{1}{2}(p_1^*m_1)\tau(m_0 - m_1)/m_1$, where $p_1^*m_1$ is simply the value of imports after the imposition of tariffs, τ is the tariff rate, and $(m_0 - m_1)/m_0$ is the percentage change in the quantity of imports due to the imposition of the tariffs. As we observe both the tariff rate and the value of imports after the tariff, all we need to implement this calculation is an estimate of the percentage change in the quantity of imports.

We consider two main approaches to obtaining this estimate. First, we use the quantity regressions we ran earlier. In these regressions, negative one times the coefficient in the quantity regression (β) multiplied by the change in tariff $\ln\left(\frac{1+\tau_t}{1+\tau_{t-12}}\right)$ tells us the percentage change in imports due to the imposition of the tariff or $-\beta\ln\left(\frac{1+\tau_t}{1+\tau_{t-12}}\right) = -\ln(m_1/m_0) \approx (m_0 - m_1)/m_1$. Thus, the deadweight loss associated with the tariffs is given by $-\frac{1}{2}(p_1^*m_1)\tau\beta\ln\left(\frac{1+\tau_t}{1+\tau_{t-12}}\right)$.[8]

In Table 2, we compute the value of these deadweight losses for each month of 2018 and compare them to the value of the tariff revenue raised. Given that we find no effect of the tariffs on the prices received by foreign exporters, this tariff revenue is a pure transfer from domestic consumers to the government. If we assume that the U.S. government uses the tariff revenue to generate social welfare benefits equal to the tax burden, the reduction in welfare from the tariff for

[8] In principle, one could rewrite the deadweight welfare loss as $\frac{1}{2}(p_1^*m_0)\tau\beta\ln\left(\frac{1+\tau_t}{1+\tau_{t-12}}\right)$, which would be correct even if $m_1 = 0$, but it is not practical to work with this formulation because trade data often has sectors in which quantities are not reported, which means that m_1 and m_0 are missing. This explains why we used the formulation that is based on import values $(p_1^*m_1)$

the economy as a whole is captured by the deadweight loss, while the cost to the consumer and importer equals the sum of the deadweight welfare loss and the tariff revenue transferred to the government. As one can see, these losses mounted steadily over the year, as each wave of tariffs affected additional countries and products, and increased substantially after the imposition of the wave 6 tariffs on $200 billion dollars of Chinese exports. By November, these deadweight welfare losses reached $1.4 billion per month.[9] Over the course of the first year of the tariff war (through November), the cumulative deadweight (i.e., efficiency) losses amounted to $6.9 billion. If we were instead to assume that U.S. government cannot generate social welfare benefits equal to the tax payments they receive, the losses to taxpayers could rise by as much as the full value of their tariff payments: $12.3 billion through November.

One might be tempted to try to compare these losses to the stated objective of reducing the cost of intellectual property theft by China. Unfortunately, these costs are extremely hard to estimate. For example, one estimate prepared by the Commission on the Theft of Intellectual Property, stated the cost of intellectual property theft *from all sources* exceeded $225 billion "with the unknown cost of other types of IP theft certainly exceeding that amount and possibly as high as $600 billion annually."[10] These estimates are based on setting a lower bound for trade secrets theft equal to the economic costs of narcotics because "like the theft of trade secrets, the trafficking of narcotics inflicts a variety of economic costs," (create.org p. 9) and the upper bound equals total U.S.

[9] To put this number into perspective, Caliendo and Parro (2015) do a general equilibrium exercise to estimate the U.S. welfare gain from tariff reductions under NAFTA and find that it amounts to 0.08 percent of GDP or about $1.4 billion per month, close to our estimate of the monthly deadweight loss from the Trump administration tariffs.

[10] https://www.whitehouse.gov/wp-content/uploads/2018/06/FINAL-China-Technology-Report-6.18.18-PDF.pdf

spending on R&D (create.org p. 8) under the assumption that the worst case scenario is that all U.S. intellectual property is stolen every year. [11]

Since these oft-cited estimates are difficult to justify, a reasonable benchmark might be obtained by considering what a policy success might look like. In 2017, China paid the U.S. $8.3 billion in royalties for U.S. intellectual property: about 16 percent of total payments to the U.S. from all countries.[12] If we assume that a successful trade negotiation would increase the royalties that China pays by 25 percent, it would take three years of these higher royalties to pay off the deadweight welfare loss from the 2018 trade war. Alternatively, if we were to think that a successful outcome from the trade war would be the creation of 35,400 manufacturing jobs—the number of steel and aluminum jobs lost in the last ten years—then the deadweight welfare loss per job saved is $195,000, which is almost four times more than the annual wage of a steel worker: $52,500. These benchmarks suggest that the costs of the trade war are quite large relative to optimistic estimates of any gains that are likely to be achieved.

One potential concern about this approach of using the coefficient β to estimate the percentage change in the quantity of imports due to the tariff is that this coefficient captures the *relative* change in imports between targeted and untargeted countries and products. Therefore, it does not capture any effect of the tariffs on imports that is common to both. While these effects could either raise or lower the estimated impact of the tariffs, one reason for an overestimate is substitution away from the targeted countries and products to those that are untargeted. To address this concern, we also consider a second approach, in which we aggregate across countries within HTS10 sectors,

[11] The Commissions estimates (http://ipcommission.org/report/IP_Commission_Report_Update_2017.pdf) are largely based on a study by the Center for Responsible Enterprise and Trade (https://create.org/resource/economic-impact-of-trade-secret-theft/). The create.org study explains the methodology used to generate the estimates.

[12] https://research.stlouisfed.org/publications/economic-synopses/2019/02/08/a-closer-look-at-chinas-supposed-misappropriation-of-u-s-intellectual-property

and examine the relationship between import changes and weighted average tariff changes across HTS10 sectors (using 2017 import weights). The estimated elasticity of tariffs on sectoral imports is reported in column (6) of Table 1 and is smaller in magnitude (-3.8 vs. -6.5), suggesting that some of the decline in imports from targeted countries is offset by more imports from unaffected countries. However, the coefficient is still negative and significant, which implies that the application of tariffs even to a subset of countries is associated with substantial declines in imports in the sector.[13]

Of course, these numbers do not take into account the impact on U.S. exporters. Foreign countries have placed retaliatory tariffs on approximately $121 billion of U.S. exports. These tariffs have heavily hit U.S. agricultural exports as well as exports of steel, automobiles, and consumer goods. In Table 3, we estimate the same specifications we ran in Table 1, but using U.S. export data instead of import data. Thus, the unit values we construct are for exports by U.S. firms for each HS10 product (before applying the foreign tariffs). As apparent from Column (1) of Table 3, there also appears to be no decline in U.S. export prices in response to foreign tariffs, which implies that consumers and importers in foreign countries are bearing the full cost of their retaliatory tariffs as well.

However, this does not mean that U.S. exporters are not being affected by the retaliatory tariffs. As we can see in the last column of the table, the elasticity of U.S. export values with respect to foreign tariffs is -3.9, which means that a ten percent foreign tariff is associated with a 32 percent decline in the value of U.S. exports. In other words, by the end of 2018 foreign retaliatory tariffs were also costing U.S. exporters approximately $2.4 billion per month in lost exports. Once again,

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[13] We also redid our deadweight loss calculations with this elasticity and found that deadweight losses equaled 0.5 billion in the month of November alone. However, this number may underestimate the loss because it assumes that there is no welfare loss associated with U.S. importers switching import sources from one country to another.

to the extent that this means that U.S. firms have to find new export markets or offshore to avoid paying the tariffs, it is likely that the retaliatory tariffs are associated with substantial shifts in supply chains and possibly large depreciations in capital equipment based in the U.S. Summing together our estimates for lost exports and imports, we find that by the last month of 2018 approximately \$13.8 billion dollars of trade (\$2.4 billion of exports and \$11.4 billion of imports) per month was being redirected as a result of the tariffs, which amounts to \$165 billion on an annual basis.

6. Assessing the impact of tariffs on imported varieties

The standard textbook model used in the previous sections is based on the assumption that imported and domestic varieties of goods are perfect substitutes. However, in reality, the products produced in one country can be imperfect substitutes for those produced in other countries. Indeed, one of the distinguishing features of "new trade theory" is its emphasis on how increases in trade barriers can reduce welfare by restricting consumer's ability to purchase new imported varieties. In these models, consumers benefit from trade liberalizations because it gives consumers access to varieties of products—French wine, Colombian coffee, and Hungarian paprika—that might not be purchased if trade barriers were higher. If trade liberalization is associated with increases in varieties, one might well wonder whether the 2018 tariffs have resulted in a reduction in imported varieties and what the welfare costs of these variety losses have been.

Figure 7 presents some evidence on how the trade war has influenced imported varieties, where we define a variety as a country-HTS10-digit code (e.g. French red wine). For each set of HTS10-country codes that were affected by a particular wave of tariffs, we compute a count of the number of varieties imported. We use the same normalization as before, so month 0 corresponds to the last month before the new tariffs were implemented, and we normalize the number of varieties within the set of HTS10 codes in each tariff wave to be one in month 0. We see that for the three years prior to the imposition of these tariffs, all of the categories of goods experienced increases in the number of varieties. However, the imposition of the tariffs is associated with sharp drops in the number of imported varieties entering the U.S. in all sectors except the wave 1 products (washing machines and solar panels). This may reflect the fact that the wave 1 tariffs only affected a small number of product codes.

These results suggest that some of the tariffs were prohibitive, reducing imports to zero. This can create a measurement problem that can arise if we try to assess the price impacts of tariffs on goods that are no longer imported. For example, our welfare calculations in the previous section require us to be able to observe exporter prices after the imposition of the tariffs (p_1^*). Similarly, although we did make an *ad hoc* adjustment for the zero quantities in the previous regressions, it would be preferable to be able understand the impact of a loss of varieties within the framework of a model of consumer behavior.

Starting with Feenstra (1994), economists have developed rigorous tools to measure price movements when the set of products are changing. The key insight is that for some widely-used classes of preferences we can divide a price index into two components. The first is a "common-goods" component, which captures price changes for the set of goods that survive between a pair of time periods, and the second is a "variety adjustment" which captures the fact that whenever a good exits a sample we can think of it as if its price rose so much that it became prohibitively expensive. Similarly, the variety adjustment accounts for the fact that whenever a good enters the sample, it is as if its price fell from some prohibitively high level to a level at which consumers are willing to purchase the product.

While the algebra for deriving these expressions can be involved, the intuition for how one can go about doing this is straightforward. For many demand systems, the value of any variety of a good comes down to two terms. First, we need to know how substitutable a good is with other goods. The elasticity of substitution matters because consumers are more likely to appreciate being able to purchase new differentiated goods (e.g., French red wine) than highly substitutable ones (French wheat). Thus, all things equal, tariffs that cause varieties of differentiated products to disappear are likely to be more costly than tariffs that cause varieties of homogeneous products to disappear. Second, the quality of a product relative to its cost also matters. While one might think that this is a very hard number to measure, it turns out that it is quite simple in many demand systems. The market share of a product is a sufficient statistic for a product's quality relative to its cost in many common demand systems because any increase in quality or reduction in price will increase a product's market share by an amount determined by the demand system. In other words, products with low quality relative to their cost will have low market shares and products with high quality relative to their cost will have high market shares. For example, the market success of a German beer relative to Chinese beer tells us that U.S. consumers think that spending a given amount of money on a bottle of German beer yields more utility than spending the same amount on a Chinese beer. Consumers may still occasionally order Chinese beer because they sometimes like trying different beers, but they think German beer is better overall in terms of quality per dollar spent.

Operationally, this means that the entry or exit of a variety with a large market share is going to have a much bigger impact on consumer welfare than the entry or exit of a product with a small market share. The variety term in these price indexes captures the impact of the gains and losses of varieties by adjusting prices upwards by more when varieties with big market shares disappear (e.g., German beer) than when we lose varieties with low market shares (e.g., Chinese beer). Combining these market share terms with the substitutability parameter lets us evaluate the gains and losses due to entering and exiting products.

To evaluate the size of these effects, we compute variety-adjusted import price indexes for each HS-6-digit product. Following Feenstra (1994), the overall price index is simply the product of the common-goods price index and the variety adjustment term. We construct these indexes using prices inclusive of the tariff to capture the prices paid by importers. We also assume an elasticity of substitution between varieties of 6, which is a common value in the literature, and consistent with our estimate in the previous section.[14]

Table 4 presents the results from regressing the percent change in these indexes on a weighted average of the changes in tariffs in the sector where the weights reflect the import shares from each country at the HTS10 level in the previous year. Consistent with what we saw in the last section, the tariffs appear to be passed through completely in terms of domestic prices for common goods. When the average tariff in an HS6 sector goes up by ten percent, the average domestic price for common goods goes up by 9.95 percent. Once again, we cannot reject the hypothesis that pass through is complete, and U.S. importers bore the full cost of the tariffs.

The next column provides the adjustment for these price indexes taking into account that the tariffs may cause the entry and exit of varieties. We obtain a coefficient on the variety adjustment term of 0.049, which implies that a ten-percent tariff not only raises the tariff-inclusive price of goods that continue to be imported, but also raises import price indexes by an additional 0.5 percent because some goods became prohibitively expensive as a result of the tariffs. If we sum these two terms together to form the overall price index as in Column (3), we find that a ten percent increase in tariffs causes domestic prices to rise by 10.4 percent through both effects. These variety effects

[14] For comparability with Figure 1, we follow Feenstra (1994) in using the Sato-Vartia price index for common goods, which assumes constant quality for each surviving good. See Redding and Weinstein (2018a,b) for an alternative price index for common goods that allows for changes in quality within surviving goods over time.

imply that the impact of tariffs is actually somewhat larger than the simple pass-through regressions suggest.

7. The Impact of Tariffs on U.S. Domestic Producer Prices

A third channel through which tariffs affect firms and consumers is through their impact on markups. A large body of empirical work has demonstrated that as foreign firms enter a market, domestic firms drop prices and markups in response. More recently, Feenstra and Weinstein (2017) provide evidence that U.S. welfare gains through this channel are at least as large as through the variety channel. Amiti, Itskhoki and Konings (2019) have developed this idea further in a setup that takes into account how trade can affect domestic prices through increased competition in domestic firms' output markets as well as through firms' intermediate input costs. In their framework, a firm's price changes can be written as a log-linear relationship between intermediate input cost changes and changes in the prices of the firm's competitors.

While we do not have access to firm-level price data, we do have access to detailed data from the producer price index (PPI), so we can run analogous regressions at the industry level. Disaggregated NAICS6 PPI data contains information on the prices being charged by domestic producers. We merge these data with input-output tables to identify which products are used in each industry. We refer to the weighted-average tariffs protecting the output in any industry as "output tariffs," and the weighted-average tariffs applied to an industry's inputs as the "input tariffs" as they reflect the additional costs that producers in a given sector face because tariffs raise their input price.[15] We thus obtain a measure for each NAICS6 category of the output tariff on

[15] In order to link these data to the trade data, we matched the PPI for every NAICS 6-digit sector to the HTS10 codes associated with that NAICS sector. For any output sector i, we then took an import weighted average of the tariff changes in that sector, using 2017 annual import shares by country-HTS10. Mathematically, the output tariff for NAICS6 sector k in month t is given by $\text{Output Tariff}_{kt} = \sum_{i \in k} \sum_{j} s_{ijk}\, \tau_{ijt}$, where i denotes an HTS10 category; j indexes exporters; s_{ijk} is the 2017 value of any HTS10 export value from country j divided by the total

final goods and the import tariff on intermediate inputs.[16] We expect that output tariffs have a bigger effect on producer prices in sectors in which imports account for a larger share of domestic sales. Therefore, we adjust our output tariff measure by the share of imports in domestic consumption. Similarly, we expect that input tariffs have a larger impact on producer prices in sectors in which imported intermediate inputs account for a larger share of total variable costs. Therefore, we adjust our input tariff measure by the share of imported intermediate inputs in total variable costs. In Table 5, we present regressions of the 12-month change in the PPI in each NAICS6 on these adjusted output and input tariffs.[17]

We find that the 2018 U.S. tariffs increased the prices charged by U.S. producers through both of these channels. First, we obtain a coefficient of 1.8 on the weighted input tariff. This coefficient implies that for the average firm that imports 15 percent of its variable costs, a 10 percent higher input tariff causes it to raise its own prices by 2.7 (=0.15×1.8) percent. This tariff pass-through into domestic producer prices is incomplete because higher input costs often cause firms to reduce markups and absorb some of the higher costs in lower profits. Despite this adjustment in markups, there is a clear cost-push channel of the tariffs that causes domestic producer prices to rise because their input costs have risen.

Second, we also see a clear markup or competition effect of tariffs in the coefficient on output tariffs. The coefficient of 0.49 on the adjusted output tariff change implies that in a typical

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imports in the HTS10-digit sectors within k; and τ_{ijt} is the *ad valorem* tariff rate on goods in category i from country j in month t. We also have $\text{Input Tariff}_{kt} = \sum_{\ell \in k} w_{\ell k}\,(\text{Output Tariff}_{kt})$, where $w_{\ell k}$ is the value of inputs from sector ℓ used by firms in NAICS6 sector k based on the U.S. 2007 input-output table divided by the sum of total intermediate input and labor costs in sector k.

[16] Formally, we weight the output tariffs by $\text{Import Share}_k \equiv m_k,/(d_k + m_k - x_k)$, where m_k, d_k, and x_k are imports, shipments, and exports in sector k. We weight the import tariffs by $\text{Import Intensity}_k \equiv M_k/(N_k + W_k)$, where M_k, N_k, and W_k are imports of intermediates, total material costs, and labor costs in sector k.

[17] This builds on Amiti, Heise, and Kwicklis (2019).

sector in which a quarter of all domestic sales are by foreign firms, a ten percent tariff is associated with a 1.3 (=0.26×0.49) percent increase in domestic producer prices over 12 months. In other words, domestic producers raise their prices when their foreign competitors are forced to raise prices due to higher tariffs.

In Panel B of the table, we provide some sense of the economic magnitude of these effects. In particular, we multiply the actual tariff increases by the coefficients from Panel A to obtain a back-of-the-envelope estimate of the impact of the tariffs on domestic producer prices in manufacturing. This calculation is clearly a partial equilibrium exercise, because we implicitly assume that the changes in tariffs have no impact on sectors that do not use imports directly affected by the tariffs. This assumption could be violated for a number of reasons, including for example any effect of the changes in tariffs on aggregate wages. With these caveats in mind, we estimate that U.S. domestic prices were 1.1 percent higher in manufacturing industries in 2018 as a result of the new tariffs, which compares with an average annual rate of producer price inflation from 1990-2018 of just over two percentage points.

8. Conclusion

Economists have long argued that there are real income losses from import protection. Using the evidence to date from the 2018 trade war, we find empirical support for these arguments. We estimate the cumulative deadweight welfare cost (reduction in real income) from the U.S. tariffs to be around $6.9 billion during the first 11 months of 2018, with an additional cost of $12.3 billion to domestic consumers and importers in the form of tariff revenue transferred to the government. The deadweight welfare costs alone reached $1.4 billion per month by November of 2018. The trade war also caused dramatic adjustments in international supply chains, as approximately $165 billion dollars of trade ($136 billion of imports and $29 billion of exports) is lost or redirected in order to avoid the tariffs. We find that the U.S. tariffs were almost completely passed through into U.S. domestic prices, so that the entire incidence of the tariffs fell on domestic consumers and importers up to now, with no impact so far on the prices received by foreign exporters. We also find that U.S. producers responded to reduced import competition by raising their prices.

Our estimates, while concerning, omit other potentially large costs such as policy uncertainty as emphasized by Handley and Limão (2017) and Pierce and Schott (2016). While these effects of greater trade policy uncertainty are beyond the scope of this study, they are likely to be considerable, and may be reflected in the substantial falls in U.S. and Chinese equity markets around the time of some of the most important trade policy announcements.

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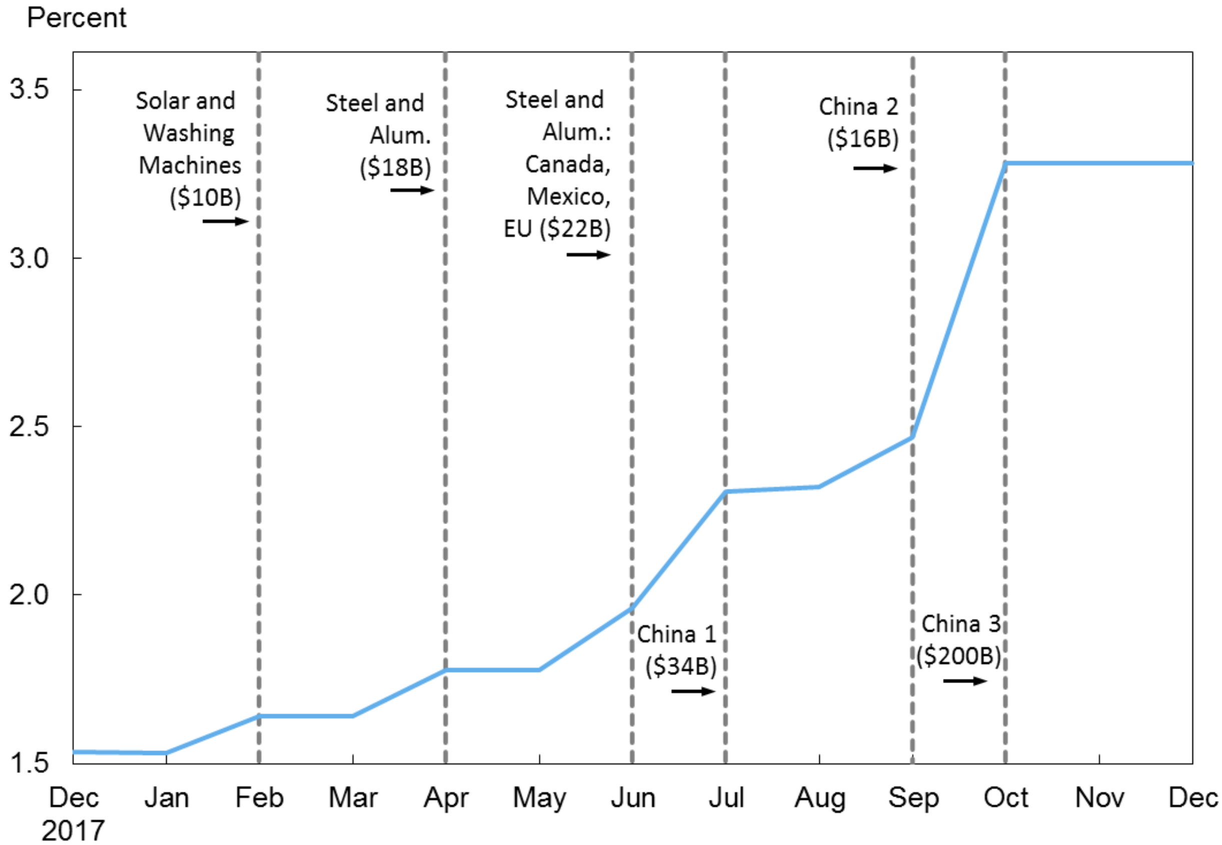
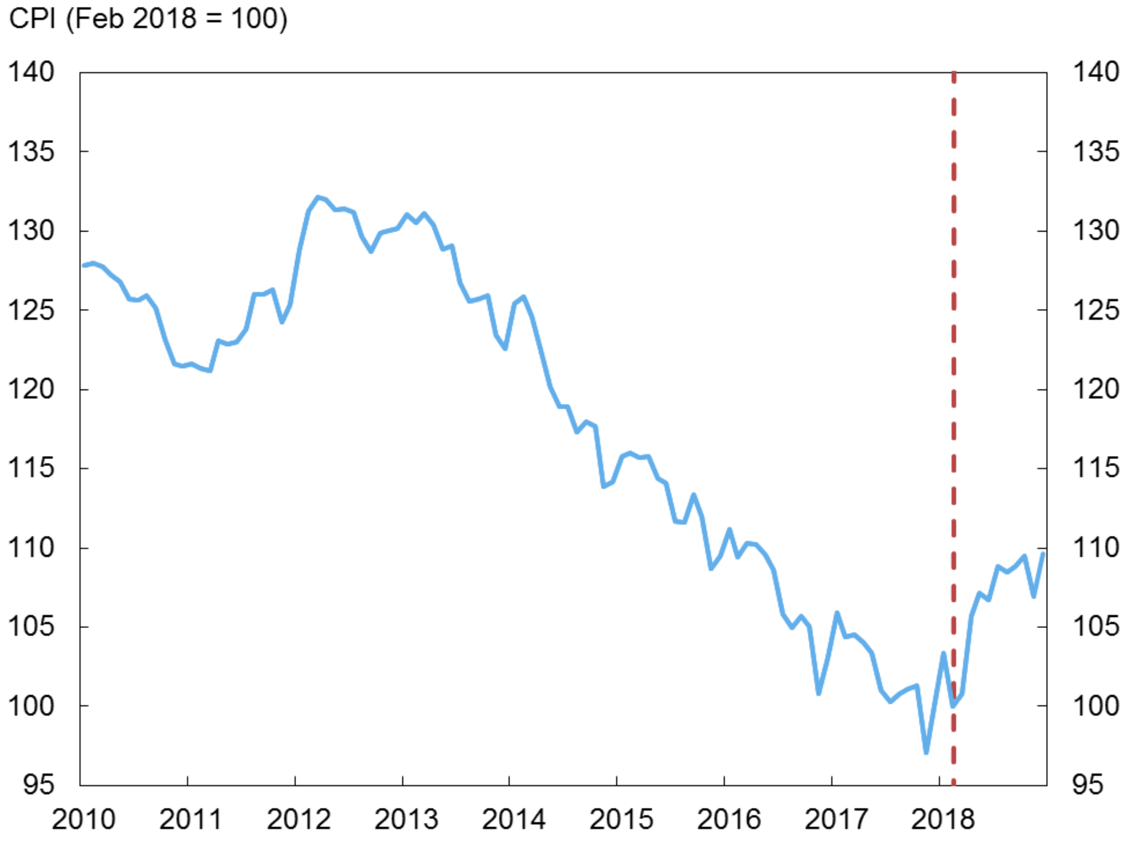
Figure 1: Average Tariff Rates



Source: US Census Bureau; USTR; USITC; authors' calculations.

Notes: Tariffs on the 10-digit Harmonized Tariff Schedule (HTS) product code by country, weighted by 2017 annual import value. Dashed vertical lines indicate the implementation of major new tariffs; tariffs implemented after the 15th of the month counted for the subsequent month. Three tranches of tariffs were imposed on China, designated by 1, 2, and 3.

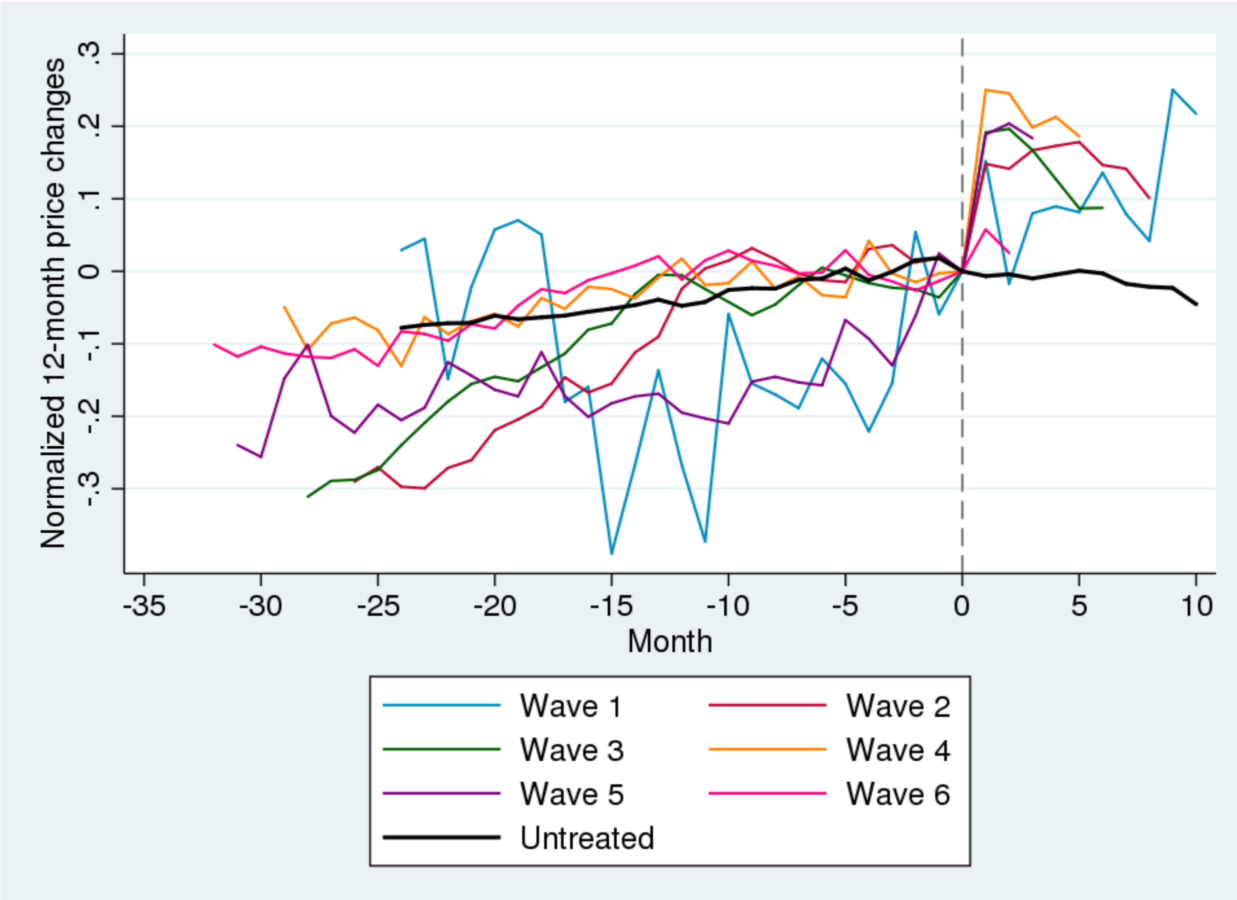
Figure 2: Major Appliance CPI



Source: BLS.

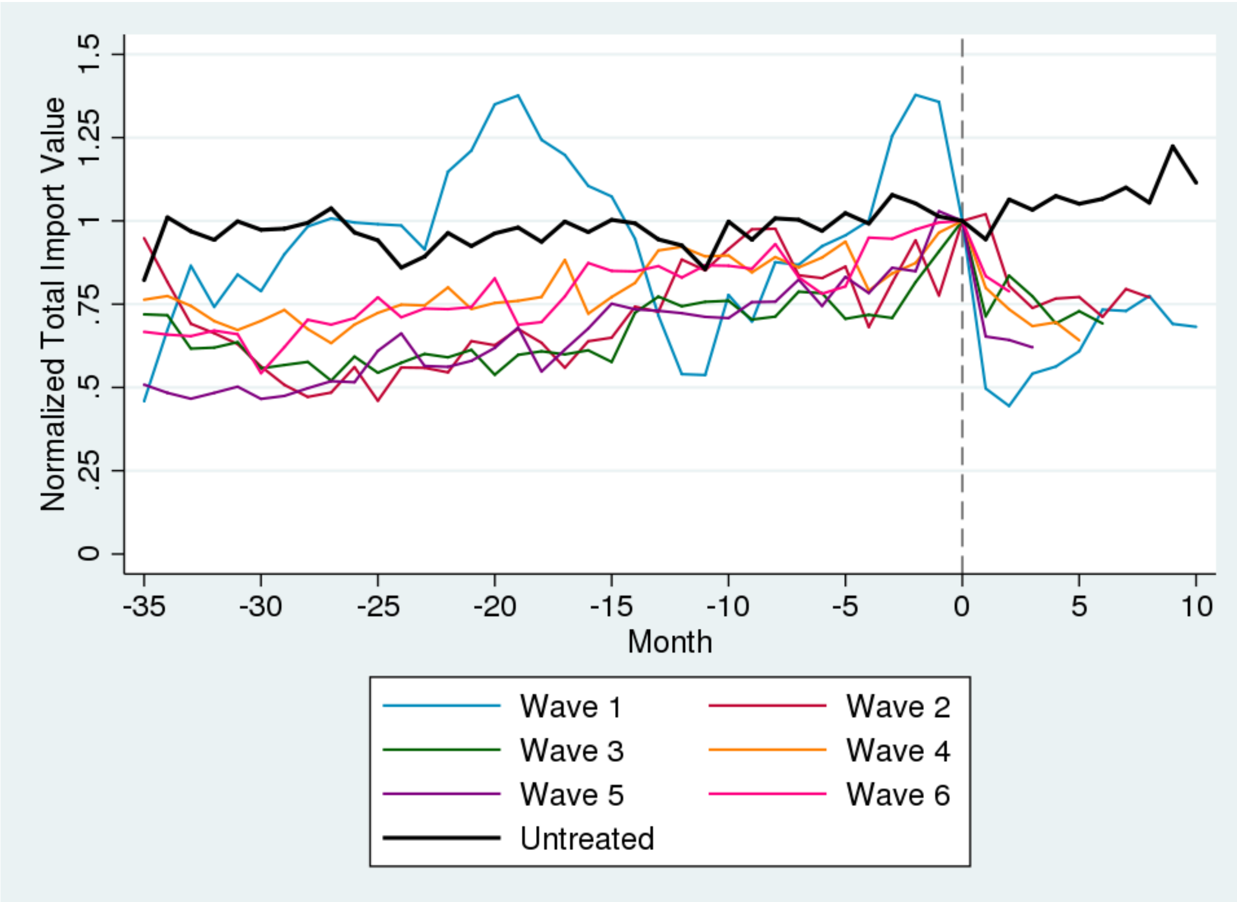
Notes: Monthly CPI of ELI HK01 – Major Appliances. Series indexed to 100 in February 2018. The red dashed line indicates the implementation of the January 22nd tariffs on washing machines.

Figure 3: 12-month Proportional Change in Import Prices by Tariff Wave



Notes: Proportional change in an import-share-weighted average of 12-month relative changes in U.S. import unit values inclusive of tariffs (import values divided by input quantities) for each tariff wave and for unaffected countries and products; proportional changes for each wave are normalized to equal zero in the month prior to the introduction of the tariff; tariff waves are defined in Section 2 of the paper.

Figure 4: Total Import Values by Tariff Wave



Notes: 12-month proportional changes in the value of U.S. imports by tariff wave and for unaffected products; each series is normalized to the value one in the month prior to the introduction of the tariff; tariff waves are defined in Section 2 of the paper.

Figure 5: Impact of a Tariff on Prices

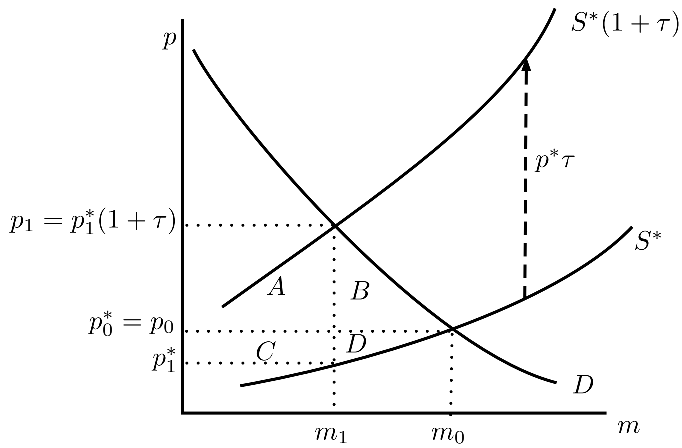


Figure 6: Impact of a Tariff on Prices with Perfectly Elastic Export Supply

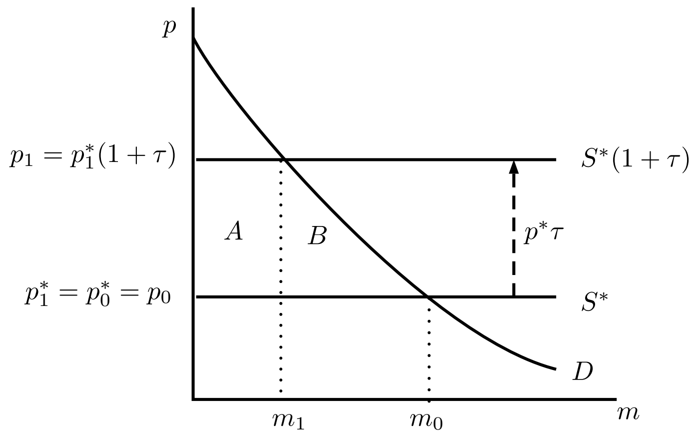
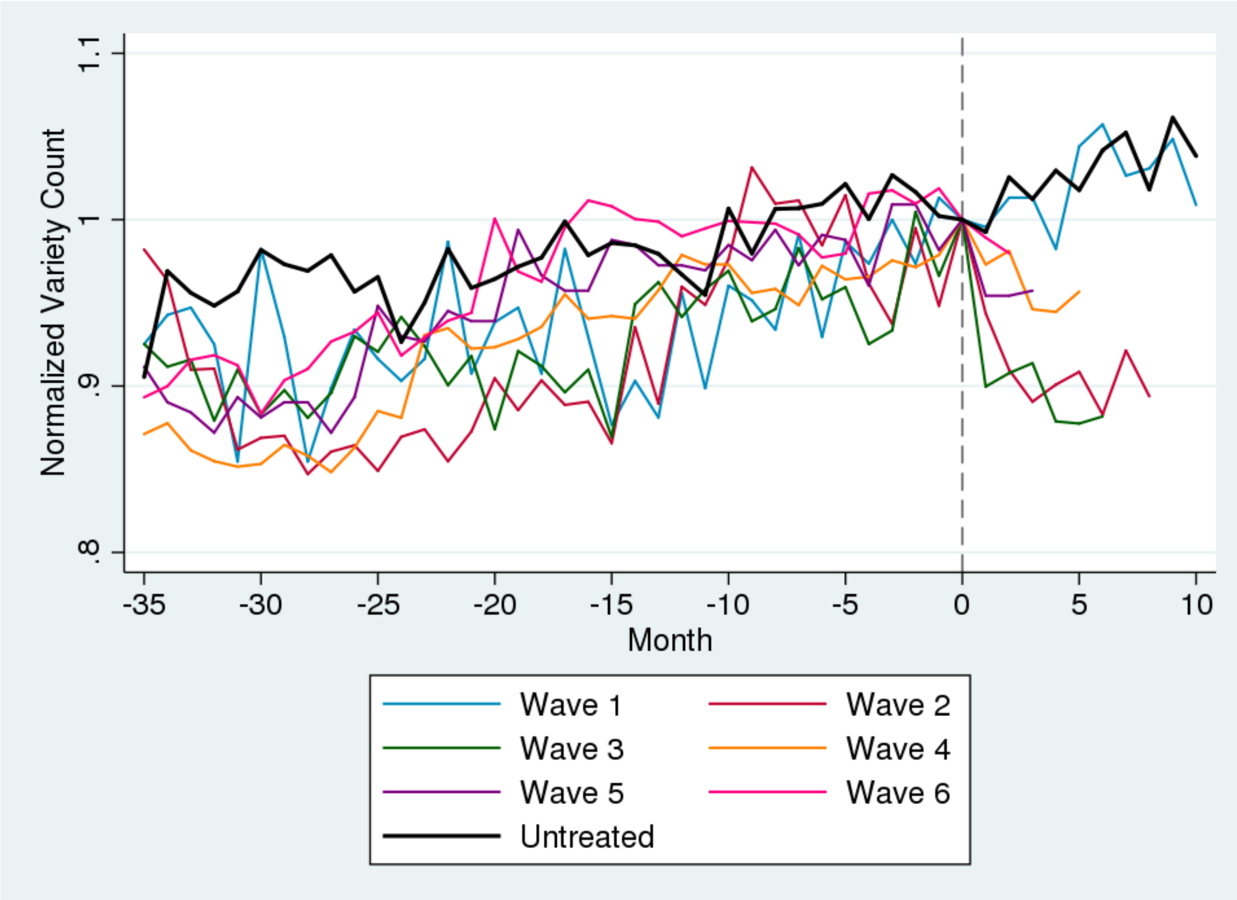


Figure 7: Number of Varieties by Tariff Wave



Notes: 12-month proportional changes in the number of import varieties, defined as an HTS10-country code, by tariff wave and for unaffected products; each series is normalized to the value one in the month prior to the introduction of the tariff; tariff waves are defined in Section 2 of the paper.

Table 1: Impact of U.S. Tariffs on Importing

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta\ln(p_{ijt})$	$\Delta\ln(m_{ijt})$	$\Delta\ln(m_{ijt})$	$\Delta\ln(p_{ijt}\times m_{ijt})$	$\Delta\ln(p_{ijt}\times m_{ijt})$	$\Delta\ln(p_{it}\times m_{it})$
$\Delta\ln(1+\text{Tariff}_{ijt})$	-0.003	-1.299***	-6.026***	-1.380***	-6.466***	-3.757***
	(0.024)	(0.094)	(0.597)	(0.090)	(0.791)	(0.760)
N	1,576,955	1,576,955	3,178,368	2,379,947	4,271,990	373,422
R^2	0.021	0.025	0.108	0.02	0.111	0.43

Notes: Observations are at the HTS10-country-month level for the period January 2017 to December 2018. Variables are in 12 month log change. Standard errors are clustered at the HTS 8-digit level. All columns include HTS10 product fixed effects and country x year fixed effects. The dependent variable in column (1) is the log change of prices (before U.S. duties are applied) charged by foreign exporters. The dependent variables in column (2) and (3) are the log change and the change in the inverse hyperbolic sine of U.S. import quantities. The dependent variables in column (5) and (6) are the log change and the change in the inverse hyperbolic sine of U.S. import values. We use the inverse of the hyperbolic sine transformation $[\log(x+(x^2+1)^{0.5})]$ to be able to estimate changes when import quantities or values are zero in t or t–12. Columns 1-3 drop any observations with a ratio of unit values in t relative to t–12 greater than 3 and less than 1/3. Column 6 collapses the country dimension, so an observation is an HTS10-month. Standard errors are reported in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

Table 2: Deadweight Welfare Loss and Tariff Revenue

Month	Deadweight Loss	Tariff Revenue	Total Cost to Importers
Jan	0	0	0
Feb	0.1	0.1	0.2
Mar	0.1	0.1	0.2
Apr	0.3	0.4	0.7
May	0.2	0.4	0.6
Jun	0.4	0.7	1.2
Jul	0.9	1.4	2.4
Aug	0.9	1.4	2.3
Sep	1.0	1.6	2.6
Oct	1.5	3.1	4.6
Nov	1.4	3.0	4.4
Total	6.9	12.3	19.2

Note: Deadweight welfare loss and tariff revenue measured in current prices in billions of dollars; see the text for the discussion of these calculations.

Table 3: Impact of Foreign Tariffs on U.S. Exporting

	(1) $\Delta\ln(p_{iUSt})$	(2) $\Delta\ln(m_{iUSt})$	(3) $\Delta\ln(m_{iUSt})$	(4) $\Delta\ln(p_{iUSt}\times m_{iUSt})$	(5) $\Delta\ln(p_{iUSt}\times m_{iUSt})$
$\Delta\ln(1+\text{Tariff}_{ijt})$	0.083**	-1.239***	-3.459***	-1.100***	-3.898***
	(0.036)	(0.152)	(0.742)	(0.132)	(0.870)
N	1,268,851	1,268,851	2,681,215	2,109,042	3,787,343
R^2	0.015	0.018	0.080	0.014	0.075

Notes: Observations are at the HTS10-country-month level for the period January 2017 to December 2018. Variables are in 12 month log change. Standard errors are clustered at the HTS 8-digit level. All columns include HTS10 product fixed effects and country-year fixed effects. Columns 1-3 drop any observations with a ratio of unit values in *t* relative to *t*–12 greater than 3 and less than 1/3. The dependent variable in column (1) is the log change of prices (excluding the tariff) charged by U.S. exporters. The dependent variables in column (2) and (3) are the log change and the change in the inverse hyperbolic sine of U.S. export quantities. The dependent variables in column (5) and (6) are the log change and the change in the inverse hyperbolic sine of U.S. export values. We use the inverse of the hyperbolic sine transformation $[\log(x+(x^2+1)^{0.5})]$ to be able to estimate changes when import quantities or values are zero in *t* or *t*–12. Standard errors are reported in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

Table 4: Import Price Indexes and Tariffs

	(1) Δln(Common Goods Price Index$_{jt}$)	(2) ln(Variety Adjustment$_{jt}$)	(3) Δln(Price Index$_{jt}$)
Δln(1+Tariff$_{j,t}$)	0.995***	0.049***	1.044***
	(0.040)	(0.009)	(0.041)
N	87321	87321	87321
R^2	0.183	0.096	0.183

Notes: A variety is defined at the HTS10-country, aggregated up to the HS6-month level for January 2017 to December 2018 in 12 month changes. All regressions include HS6 and time fixed effects Standard errors are clustered at the HS6 level. The elasticity of substitution in column 1 and 3 is set equal to 6, consistent with the results above. Price ratios are cleaned on top and bottom 1/3 and 3, and lambda ratios are cleaned on top and bottom 5 percentiles. Standard errors are reported in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

Table 5: Regressions of Non-Petroleum Merchandise Producer Price Index (PPI) onto Import Tariffs

Dependent Variable: $\Delta\log(PPI_{it})$	12-Month Change
Panel A: Regression Coefficients:	
Import $Share_i$ x $\Delta\ln(1+Output\ Tariff_{it})$	0.487**
	(0.210)
Input Import $Intensity_i$ x $\Delta\ln(1+Input\ Tariff_{it})$	1.798***
	(0.646)
Fixed Effects: Industry and Time	Yes
Panel B: Implied Aggregate Effects:	
Input Tariff Effect:	0.857
Output Tariff Effect:	0.230
Total Effect:	1.087
N	8350
#Industries	334
R^2	0.453

Notes: The dependent variable is the 12-month change in log PPI, while the tariffs are entered as the 12-month changes in $\log(1+Tariff_{it})$. The sample period is monthly data from January 2017 to December 2018. Standard errors in parentheses, clustered on BEA IO code. Input import intensities constructed using only tradable non-service inputs. Standard errors are reported in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.