The Long-Term Impact of Steel Tariffs on U.S. Manufacturing

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Abstract

In this paper, I study the long-term effects that temporary upstream tariffs have on downstream industries. Even temporary tariffs can have cascading effects through production networks when placed on upstream products, but to date, little is known about the long-term behavior of these spillovers. Using a new method for mapping downstream industries to specific steel inputs, I estimate the effect of steel tariffs enacted by President Bush in 2002 and 2003 on downstream industry outcomes. I find that upstream steel tariffs have highly persistent negative impacts on the competitiveness of U.S. downstream industry exports. Persistence in the response of exports is driven by a restructuring of global trade flows that does not revert once the tariffs are lifted. I use a dynamic model of trade to show that the presence of relationship-specific sunk costs of exporting can generate persistence of the magnitude that I find in the data. Finally, I show that taking both the contemporaneous and persistent downstream impacts into account substantially alters the welfare implications of upstream tariffs.

Keywords: Trade policy, tariff, global value chains, gains from trade, sunk cost, welfare.

JEL Codes: F10, F12, F13, F14

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1 Introduction

U.S. trade policy under the Trump administration sparked renewed attention to the fact that globally integrated supply chains complicate the traditional cost-benefit analysis of tariffs. Tariffs and other emergency safeguards are often justified as temporary measures designed to relieve struggling domestic industries. When placed on upstream products, however, this protection comes at a cost: Tariffs on upstream products raise input costs for downstream manufacturers, making them more vulnerable to foreign competition. While the tariffs themselves are temporary, little is known about the long-term behavior of these spillover effects. This is the primary focus of my paper.

While the breadth and scale of the Trump administration's protectionist efforts was unprecedented in recent history, protectionist policy for certain U.S. industries is not a new phenomenon.[1] In this paper, I use a case study of the steel tariffs levied by George W. Bush in 2002 and 2003 to provide new empirical evidence on the long-term effects that temporary upstream tariffs have on downstream industries. Because steel is a broadly used input—Cox and Russ (2020), for example, find that the number of jobs in industries that use steel as an input outnumber the number of jobs that produce steel by about 80 to 1—tariffs on steel are particularly prone to having broad downstream effects. This feature, along with the fact that the Bush tariffs were a sizable but temporary shock to steel tariff rates, makes the episode useful for studying both the contemporaneous and long-term downstream impacts of temporary upstream tariffs. To generalize my empirical findings outside of this context and understand the underlying mechanisms, I calibrate a dynamic model of trade, consistent with my findings.

A key empirical challenge in estimating the causal impacts of upstream tariffs through supply chains is linking protected upstream inputs to the downstream industries that use them. Tariffs are placed on highly disaggregated products, rendering publicly available input-output tables too coarse to provide the required mapping. A key innovation in this paper is the creation of a highly detailed, steel-specific input-output table that links disaggregated steel products to specific downstream industries. I create this new table using exclusion requests for steel products that were submitted by firms in response to the Trump steel tariffs. I take advantage of the fact that, by definition, exclusion requesting firms are downstream users of very specific upstream products. With these data, I create a detailed mapping that allows me to leverage the variation in tariff rates imposed by Bush in 2002 and 2003 to causally estimate the impacts of higher tariff rates on downstream industry outcomes.

[1] Upstream products—like steel, aluminum, lumber, and sugar—that are central inputs to many U.S. manufacturing industries have enjoyed spurts of protectionist policy since this nation's founding, according to Irwin (2017).

My primary empirical findings are threefold. First, I find that upstream steel tariffs have highly persistent negative impacts on the competitiveness of U.S. downstream industry exports. A 1 percentage point increase in an industry's upstream steel tariff rate causes a relative decline in the U.S. share of that industry's world exports—or the industry's global market share—of 0.1 percentage points at its peak (0.2 percentage points for steel-intensive industries). To put the magnitude of the impact into perspective, shifting an industry from the 25th to the 75th percentile of the tariff burden distribution (an increase of 13.5 percentage points) results in a decline in global market share of 1 percentage point relative to pre-tariff levels (2 percentage points for steel-intensive industries). Declines in the competitiveness of U.S. exports due to the tariffs are highly persistent—global market share remains depressed relative to pre-tariff levels for at least 8 years after the tariffs are lifted. Likely a result of this loss in market share, I also find that steel-intensive industries suffered persistent declines in employment in response to relatively high steel tariff rates.

Second, I find that the persistence of the impact of steel tariffs on downstream exports stems from a restructuring of global trade flows that does not revert once the tariffs are lifted. Downstream industries that faced higher steel tariffs suffered persistent relative declines in both export prices and quantities after the tariffs were lifted, consistent with an inward shift of world demand for U.S. downstream products. I show that higher steel tariffs in the U.S. led to relative *increases* in the downstream export shares of other top producing countries. Germany, Japan, and France, in particular, experienced increases in their export shares relative to pre-tariff levels that persisted after the tariffs were removed. This pattern suggests that the U.S. steel tariffs induced a shift in sourcing patterns for foreign buyers in downstream industries that did not revert when the tariffs were removed.

Third, I find that the impact of the steel tariffs on downstream domestic production is more transitory than the impact on exports. U.S. imports of downstream products that faced a 1 percent higher steel tariff increased by 1 percent relative to pre-tariff levels, suggesting that U.S. consumers substituted toward foreign sources when the tariffs were in place. Imports revert to pre-tariff levels within two years of the tariffs being removed, however, indicating a much quicker rebound in production for the domestic market than for exports.

In the last part of the paper, I use a dynamic model of trade to show that the presence of relationship-specific sunk costs of exporting can generate a persistent response of downstream exports to an input tariff that is consistent with the patterns I find in the data. The model features asymmetric countries, an upstream steel sector, heterogeneous Melitz-style downstream steel users, and a relationship-specific sunk cost of trade that drives the key results. Intuitively, because it is costly for countries to change sources of imports, if an input tariff induces a change in sourcing patterns, those patterns will not immediately revert when the tariffs are lifted. Using the model, I estimate the aggregate welfare implications of a two-year shock to steel tariffs in the Home country that matches my empirical setting. I find annual welfare losses equivalent to an average of 2.8 percent of exports that continue to accrue for 8 years after the tariffs are removed. The model-implied estimates are in line with reduced-form estimates that I calculate using a partial-equilibrium framework. A counterfactual simulation in which I double the amount of time the tariffs are in place (from 2 to 4 years) leads to a doubling of aggregate welfare losses,[2] suggesting that the longer input tariffs are in place, the more distortionary they become.

My paper contributes to the growing empirical literature on the many channels through which trade policy can affect the domestic economy. Among others, this literature includes the work of Amiti et al. (2019), Cavallo et al. (2019), and Fajgelbaum et al. (2020), who estimate the impacts of the Trump tariffs on prices and welfare. A subset of this literature focuses, as I do, on the effect of tariffs through supply chains. Handley et al. (2020), for example, find that downstream industries that were more exposed to increases in tariffs imposed by the Trump administration experienced a relative slow-down in export growth. Flaaen and Pierce (2019) find that industries more exposed to upstream tariff increases experience relative reductions in employment, driven by rising input costs and retaliatory tariffs. There are a handful of studies that use other periods of tariff implementation to estimate the effects of tariffs through supply chains. Blonigen (2016) focuses on the steel industry in particular, leveraging variation across countries to show that the presence of steel-sector industrial policy has a negative impact on the export competitiveness of downstream manufacturing sectors. Bown et al. (2020) find that tariffs and anti-dumping duties against China since the 1980s have led to job-losses in downstream industries.

My findings are broadly consistent with these results, but my work departs from existing studies in several ways. First and foremost, the aforementioned studies of the Trump tariffs are, by nature, only able to provide evidence of short-term effects.[3] By focusing on an earlier period of temporary tariff implementation, I provide new evidence on the persistence of these effects. In addition, due to the complexity of the trade war induced by Trump's policies, the Bush tariffs provide a cleaner setting to isolate the impact of upstream tariffs on downstream industries. Second, because many of the Trump tariff rates were uniform across product types (e.g., 25 percent for all types of protected steel), studies with similar empirical setups like Handley et al. (2020) and Flaaen and Pierce (2019) use estimates of downstream industry *exposure* to tariffs as the primary source of variation. The Bush tariffs were varied across steel products, meaning that different downstream industries faced different taxes on their inputs

[2]That is, changes in the sum of discounted utility (i.e., not on a per-year basis).

[3]Amiti et al. (2019), Cavallo et al. (2019), Fajgelbaum et al. (2020), Flaaen and Pierce (2019).

depending on which inputs they use. This feature combined with my newly constructed steel-specific input-output table allows me to leverage variation in tariff rates themselves for causal inference. Third, with the exception of Handley et al. (2020) and Blonigen (2016), recent work focuses primarily on the impact of tariffs on domestic outcomes. In contrast, I place more emphasis on the broader impacts of upstream tariffs on the export margin, and provide new evidence of their effects on downstream global sourcing patterns.

The study most closely related to this one is that of Lake and Liu (2021), who also implement a case study of the Bush steel tariffs to study long-term effects on local employment. The authors find that the tariffs led to a persistent depression in employment in local labor markets that relied on steel more heavily as an intermediate input. My findings on employment are consistent with theirs. In addition to employment, I focus on a broader set of results, including U.S. and foreign exports and domestic production, and my results focus on industry-level outcomes rather than local effects. Finally, I provide a theoretical motivation for the persistence found in the data, and an estimate of the welfare implications.

My findings also contribute to our knowledge of the hysteretic effects of temporary shocks. There is very little direct empirical evidence of hysteresis in response to temporary shocks. One of the few papers that provides causal evidence from an exogenous shock is Xu (2021), who studies the 1866 London banking crisis to show that temporary financial shocks have a persistent impact on exports. On the theoretical side, seminal work by Baldwin (1988), Baldwin and Krugman (1989), and Dixit (1989) showed that the presence of sunk costs of exporting can generate hysteresis in trade flows in response to temporary shocks. More recent papers, for example Das et al. (2007), Burstein and Melitz (2013), Atkeson and Burstein (2010), and Alessandria and Choi (2014), have embedded sunk costs of exporting into both partial- and general-equilibrium models to show how they impact trade dynamics. I rely on features of this existing theory to build a model that fits my setting and allows me to simulate the dynamic impacts of temporary upstream tariffs on the economy. In doing so I introduce a new framework for estimating the welfare impacts of temporary upstream tariffs that incorporates both the contemporaneous and persistent downstream effects.

Overall, my findings highlight the complicated nature of tariff policy in a world with global production networks. Even temporary tariffs on a small subset of imports can have vast, persistent effects on a broad swath of the economy. The rest of the paper will proceed as follows: In Section 2, I provide a brief background on the policy setting. In Section 3, I describe a key innovation of this paper—the creation of a highly detailed, steel-specific input-output table. In Sections 4 and 5, I present my empirical strategy and results, and in Sections 6 and 7, I present reduced-form and model-simulated estimates of the welfare implications.

2 Background: The Bush Steel Tariffs

In this section I provide a brief overview of the Bush steel tariffs, show that they were a meaningful shock to steel imports in the United States, and discuss some advantages of using the setting to estimate the impact of a temporary shock to upstream inputs on downstream industries.

2.1 The Policy

While protection for the steel industry had been renewed or extended by almost every president since the 1970s, the practice was phased out in the late 80s and early 90s under Presidents (George H. W.) Bush and Clinton.[4] Immediately upon taking office in January 2001, however, President George W. Bush faced intense pressure from the steel lobby and Congress to take action to protect the struggling domestic steel industry. In June 2001, President Bush announced his Administration would self-initiate a Section 201 investigation for 33 types of imported steel. Under a Section 201 investigation, if the International Trade Commission (ITC) determines that the volume of a particular import constitutes a "substantial threat of serious injury" to a domestic industry, the president has the authority to impose temporary import relief. The investigation began on June 22, 2001, and in October 2001 the ITC announced its findings that imports were injuring U.S. steel producers in almost half of the categories under investigation.

In March 2002, President Bush announced that the U.S. would impose three-year safeguards on 171 steel products (8-digit Harmonized System (HS) codes). The tariffs, which ranged from 8 to 30 percent on top of existing legislated rates, went into effect on March 20, 2002 and were slated to phase down in each year of the three-year period. Countries with free trade agreements with the United States at the time (Canada, Mexico, Israel, and Jordan) were exempt from the new tariffs, as were a list of developing nations with imports to the United States totaling less than 3 percent of the domestic market.[5]

Domestic steel consumers, free trade advocates,[6] and foreign trading partners[7] were outraged at the announcement. Many countries announced their intentions to retaliate against U.S. exports, and the European Union and seven other countries issued a complaint to the

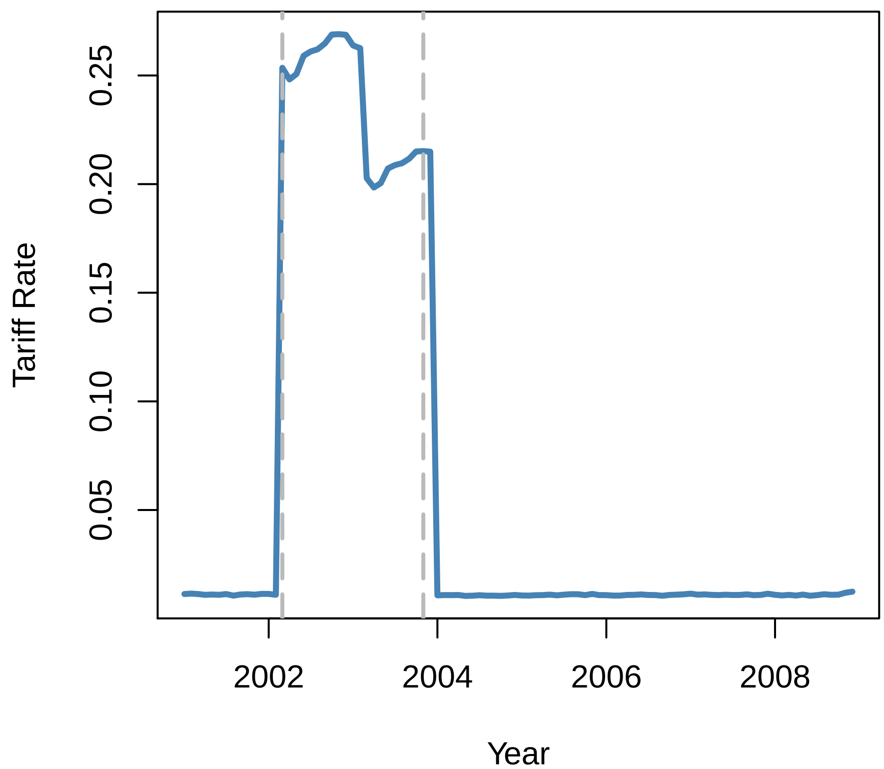
[4]See, for example, Irwin (2017).

[5]In accordance with WTO rules.

[6]`https://www.nytimes.com/2002/01/23/business/steel-users-campaigning-against-curbs-on-imports.html?searchResultPosition=83`

[7]According to the New York Times, "Within minutes of the White House announcement, America's European allies and Japan said they would most certainly challenge the action before the World Trade Organization." (March 6, 2002) `https://www.nytimes.com/2002/03/06/us/bush-puts-tariffs-of-as-much-as-30-on-steel-imports.html?searchResultPosition=96`

Figure 1: Trade-Weighted Average Tariff Rate on Protected Steel Products



Source: Tariff rates collected from Presidential Proclamation 7529 and are weighted by trade flows in 2001.

WTO about the legality of the Section 201 investigation under which the tariffs had been implemented. In November 2003, the WTO ruled that the safeguards were illegal, and before other countries were able to retaliate, President Bush announced on December 4, 2003 that he was terminating the Section 201 action. Ultimately the tariffs remained in place for almost two years. The sharp increase in tariff rates on the protected products during the period of implementation can be seen in Figure 1. The trade-weighted average statutory (legislated) ad valorem rate increased to around 25 percent in the first year and stepped down to around 20 percent in the second year, before the tariffs were eventually removed.[8]

2.2 Impact on Steel Imports and Import Prices

The extent to which downstream industries are affected by the steel tariffs depends in large part on the extent to which the tariffs are passed through to domestic import prices. If,

[8] Legislated tariff rates are collected from President George W. Bush's Presidential Proclamation 7529 and its appendix. `https://www.federalregister.gov/documents/2002/07/08/02-17272/to-provide-for-the-efficient-and-fair-administration-of-safeguard-measures-on-imports-of-certain`

in response to tariffs imposed by the United States, foreign countries reduce the prices of their steel exports to the United States—that is, there is little pass-through—downstream exporters may feel little effect. On the other hand, if tariffs are passed through to domestic import prices, downstream steel users in the U.S. will bear the cost of the tariffs in the form of higher input prices.

Figure 2 shows the response of steel import values, prices, and quantities to higher statutory tariff rates relative to their 2001 (pre-tariff) levels.[9] These responses are estimated using the specification in equation 1, where $y_{ij,t}$ is the log value, log price, or log quantity of imports of steel product i from country j in year t. The independent variable of interest is $(\tau_{i,2003} - \tau_{i,2001})$, the change in the statutory tariff rate on steel product i as a result of the Bush tariffs. Regressions include country-year fixed effects.[10]

$$y_{ij,t} - y_{ij,2001} = \alpha_{j,t} + \beta_t(\tau_{i,2003} - \tau_{i,2001}) + \Sigma_{ij,t} \tag{1}$$

Figure 2a shows that there was a relatively large decline in imports of steel products that faced higher tariff protection. In response to a one percent increase in tariffs, import values fell by an average of 4.3 percent in 2002 and 2003, with little evidence of any persisting effects post-2003. Figure 2b shows that there was no measurable impact of higher statutory tariff rates on steel import prices. Consistent with these results, Figure 2c shows a drop in imported quantities during the 2002-2003 period. A one percent increase in the statutory rate is associated with a 4.4 percent decline in imported quantities. This implies a trade elasticity at the low end of standard estimates in the literature which typically lie between 4 and 8.[11]

The lack of persistence in the response of steel imports to the tariffs provides some insights into the potential production relocation effects of tariffs. If the steel tariffs had induced more entry into the U.S. steel sector (as in the theoretical work of Venables (1987) and Ossa (2011)), this could have been beneficial for downstream producers if it gave them easier access to cheaper steel inputs. The rest of my results will suggest that these relocation effects only occur in the downstream sector, limiting the potential for upstream tariffs to be beneficial. Antràs et al. (2021) explore the impact of the production relocation effects of tariffs on optimal trade policy, and show that trade policy featuring higher tariffs on inputs

[9] I use data on import values and quantities from U.S customs at the HS8-digit level. Import prices are calculated as import value divided by import quantity.

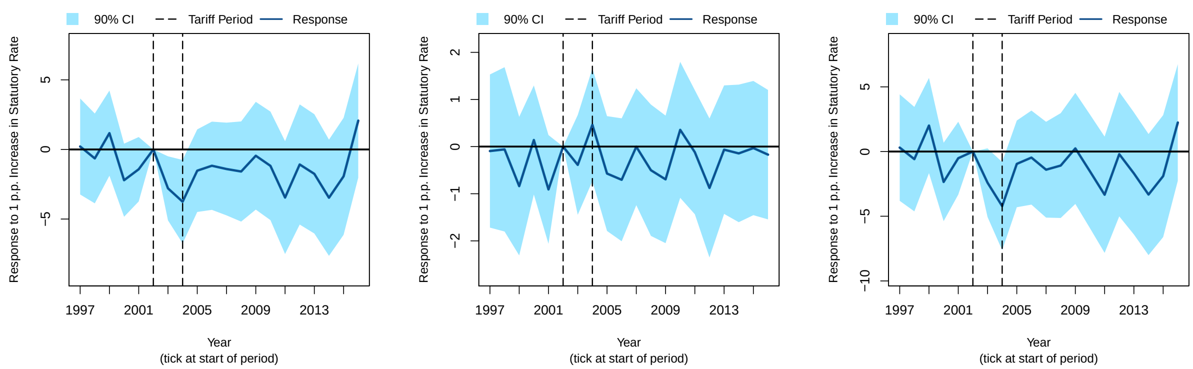
[10] I run these regressions at the individual country level to account for the fact that many countries were exempt from the tariffs. In the specification described, an exempt country faces a change in tariff of 0. For the downstream part of the analysis I will study aggregate trade flows.

[11] See, for example, Simonovska and Waugh (2014), and Eaton and Kortum (2002).

is sub-optimal.[12]

Together, the response of upstream inputs that U.S. consumers of imported steel, not foreign suppliers, bore the cost of the steel tariffs. Recent papers on the pass-through of the Trump tariffs to consumer prices (Amiti et al., 2019; Cavallo et al., 2019) find similar results. The rest of this paper will be devoted to examining the resulting impact of the steel tariffs on downstream industry outcomes.

Figure 2: Effect of Higher Statutory Rates on Steel Imports and Import Prices



(a) Steel Import Values (b) Steel Import Prices (c) Steel Import Quantities

2.3 Advantages of this Policy Setting

There are several advantages to using the Bush Steel Tariffs to examine the effects of upstream tariffs on downstream industry outcomes. First, because steel is a broadly used input—Cox and Russ (2020) estimate that the number of jobs in steel-using industries outnumber the number of jobs in steel-producing industries by 80 to 1—distortions in the steel industry are particularly prone to having widespread downstream effects. I show evidence in Section 3.1 that the Bush steel tariffs were placed on steel products used by a large swath of U.S. manufacturing industries.

Second, the tariffs were a "shock," in more ways than one. As noted in Section 2.1, the two Administrations prior to George W. Bush had phased out protection for the steel industry to the point where tariffs on most steel products were near zero at the beginning of 2002. When the steel tariffs went into effect, rates on these products increased substantially for a short (two-year) period of time, and then returned back to their near-zero levels, providing a clean setting for studying the dynamic impacts of a temporary shock. The tariffs were also a shock in a more literal sense—because Bush was a newly elected Republican president who had campaigned on a free-trade platform, his imposition of trade safeguards was politically

[12]They find that instead, tariff escalation—higher tariffs on downstream goods—is first-best.

unexpected. I discuss in detail in Section 4.3 how the nature of this shock to the steel industry created plausibly exogenous variation in input costs for downstream producers.

My empirical strategy will also take advantage of several features of the Bush steel tariffs that differ from the Trump trade war that has been the subject of several recent papers that seek to empirically estimate the effects of tariffs. First, unlike the Trump Tariffs, which were uniform within most product categories (e.g., 25 percent for all types of protected steel), there was variation in the tariff rates Bush applied to different types of steel. This means that different downstream industries faced different taxes on their inputs, depending on which inputs they used. This allows for causal inference using variation in actual tariff rates, rather than exposure to tariffs—the more common source of variation in similar studies like those of Lake and Liu (2021) for the Bush steel tariffs and Flaaen and Pierce (2019) and Handley et al. (2020) for the Trump steel tariffs. Second, since steel was the only target of the Bush tariffs, it is easier to discern the effects of the steel tariffs, without having to disentangle them from the effects of tariffs on other products, both domestic and retaliatory.[13] Lastly, and most importantly, while studies of the effects of the Trump tariffs are necessarily short-term due to data availability,[14] studying the Bush tariffs allows for the estimation of long-term effects—something largely missing from the literature until now.

3 Steel-Specific Input-Output Table

My identification approach will leverage both the variation in tariffs on upstream products and the varied composition of upstream inputs used by downstream industries to causally estimate the impact of those tariffs on downstream industry outcomes. I face one primary challenge in carrying this out: identifying which of the 171 protected steel products are inputs to which downstream industries. Traditional input-output tables like the ones published by the Bureau of Economic Analysis (BEA), are too coarse to aid in creating this mapping. Tariffs are placed on very specific products, for example:

> *Flat-rolled products of iron or nonalloy steel, of a width of 600 mm or more, hot-rolled, not clad, plated or coated, not in coils, not further worked than hot-rolled, with patterns in relief of a thickness of 4.75mm or more.*

Even the most detailed BEA input output table, however, provides data on industry use of only two broad categories of steel input: *Iron and Steel Mills and Ferroalloy Manufacturing*

[13]While there were threats of retaliation from foreign countries in response to the Bush steel tariffs, none was enacted.

[14]It is worth noting that because of the COVID-19 crisis, it will be difficult to ever discern long-term effects using the Trump tariffs, even as a longer time series becomes available.

and *Steel Product Manufacturing from Purchased Steel*. To take advantage of the fact that different downstream industries use different steel inputs that faced different tariff rates requires a much more detailed mapping of steel inputs to downstream industries. The first innovation of this paper is the creation of a new, highly-detailed, steel-specific input output table that provides a detailed enough mapping to accomplish the task at hand. The rest of this section is devoted to describing the creation of this new input-output table and illustrating its effectiveness.

3.1 Identifying Steel Product to Downstream Industry Linkages

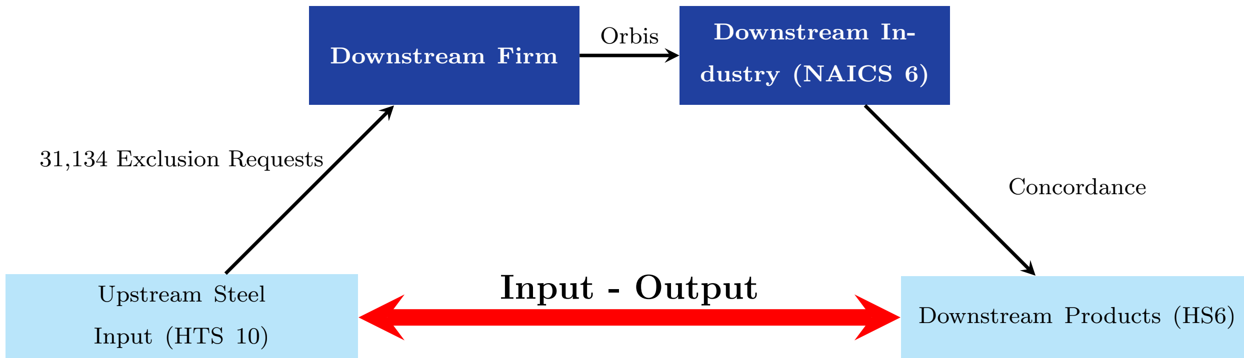
To map specific steel inputs, and their associated tariff rates, to specific downstream industries, I create a steel-specific input-output table using exclusion requests that were filed in response to the steel tariffs that were announced by the Trump Administration in March 2018. After the 2018 tariffs were announced, companies were given the opportunity to submit requests to exclude certain products from the tariffs.[15] These publicly available "exclusion requests" contain information on the company requesting the exclusion, the specific 10-digit subheading of the Harmonized Tariff Schedule of the United States (HTSUS) of the product the company wanted excluded, and other information describing the company's use of the product and why it felt an exclusion was justified. I collect over 70,000 of these requests from the website Regulations.gov and parse several variables of interest from each, creating a database of exclusion requests for detailed steel products that were subject to the Trump steel tariffs. The steel products covered by the Bush steel tariffs were a subset of those under the Trump tariffs, which is why the database is relevant for the empirical exercise in this paper.

I take advantage of the fact that, by definition, an exclusion requesting firm is a *downstream user* of a very specific (10-digit) upstream steel product. By merging the exclusion requesting firm names with both Orbis and the Dunn & Bradstreet (D&B) database,[16] I connect each firm to a downstream NAICS industry. This merge provides a mapping between upstream steel inputs and downstream NAICS industries. To facilitate analysis of downstream global trade flows, I then map the downstream NAICS industries back to HS codes using the concordance developed by Pierce and Schott (2012). As shown in the schematic in Figure 3, this process leaves me with a concordance between a highly detailed set of steel inputs and the downstream industries that use them. While the concordance theoretically allows for an input-output mapping at the 10-digit level, for the purposes of this analysis I link upstream steel products at the HS8 level—the level at which tariffs are implemented—to

[15] Specifically, OMB Form 064-1039.

[16] For details on these databases and the merge, see Appendix A.1.1.

Figure 3: Input-Ouput Schematic



downstream industries at the HS6 level—the most detailed level for which global trade flows data are available.[17]

To illustrate more concretely how the mapping procedure works, consider an example. The steel-specific input-output table identifies HS 210320 —*tomato ketchup and tomato sauces*—as a downstream user of two upstream steel products that were protected by the Bush tariffs: 72101100 and 72102000 —*flat-rolled products of iron or nonalloy steel, of a width of 600 mm or more, clad, plated or coated with tin* of a thickness of 0.5 mm or more, or less than 0.5 mm, respectively.[18] According to the Wiley Encyclopedia of Packaging Technology, modern "tin" cans that typically hold foods like tomato sauce are made of a thin piece of iron or steel that is coated with a thin layer of tin. In this case, the steel-specific IO table does what it is supposed to do—matches a specific steel input to a downstream industry that uses it.

Of the roughly 70,000 exclusion requests submitted for the Trump steel tariffs, 31,134 requests were for products that were also covered by the Bush steel tariffs and were submitted by companies that could be merged with Orbis or D&B. These 31,134 requests cover 170 of the 171 steel products that were covered by the Bush tariffs. The steel-specific input-output table links those 170 steel inputs to over 1200 downstream products (HS6). To put into perspective the scope of the downstream impact that steel tariffs can have, the downstream industries identified as steel users represented $176 billion in exports in the year 2001—roughly a quarter of U.S. exports in that year.

There are a few advantages to using the exclusion requests as a source of highly disaggregated input-output relationships, relative to potential alternatives such as the confidential firm-level data collected by the U.S. Census Bureau. Because the exclusion requests are pub-

[17] And similar to the NAICS 6 level of aggregation at which I get downstream industry classifications.

[18] One exclusion request for these steel products was made by Seneca Foods Corporation—an American food processor and distributor headquartered in Marion, New York.

licly available, they provide a public source of detailed input-output data. In Appendix A.1.2 I show that this methodology can be used for inputs other than steel, specifically aluminum. In addition, the exclusion requests provide information that is not likely to be found in other data sets. For example, on the exclusion request, firms are required to report the percent of the product they are requesting an exclusion for that *cannot* be produced in the U.S. One might imagine this information would be important for understanding the extent to which a firm or industry will be affected by tariffs, but it is not the type of information that is likely to be found elsewhere. Finally, the exclusion requests may be better suited to identify final users of steel imports than the Census data, where firm-level imports do not always reflect firm use in cases where firms import a product and re-sell it to another industry.

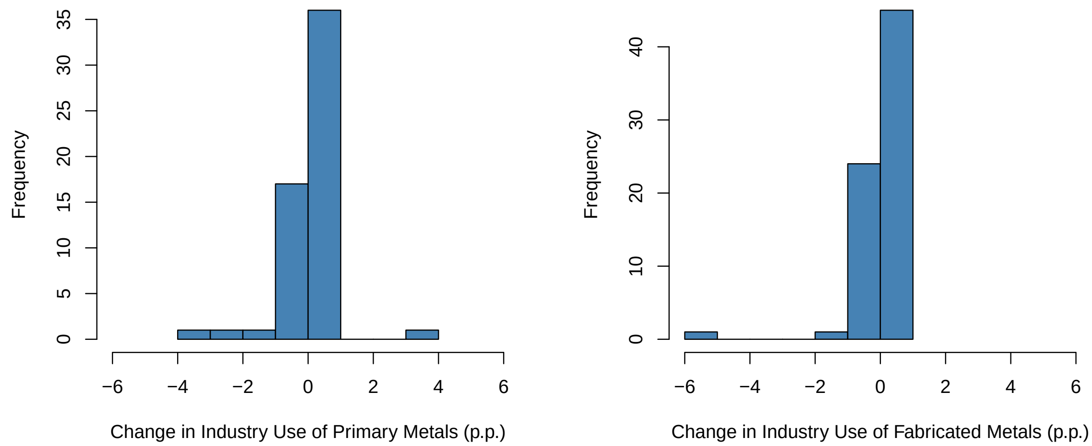
3.2 Performance of the Steel-Specific IO Table

Before turning to my empirical analysis of the Bush steel tariffs, I will present some evidence that the steel-specific input-output table that I have created is an effective way to match detailed steel inputs with relevant downstream industries. Note that the exercises I present throughout the rest of this section are intended to address the ability of the IO table to map inputs to industries in a general sense (i.e., they have nothing to do with the steel tariffs levied by either Bush or Trump). First, I will address the key assumption that is required in order to use the steel-specific IO table for causal inference. Namely, because the exclusion requests were filed in response to tariffs put in place starting in 2018, I must assume that steel inputs to different industries in 2018 are a good representation of steel inputs in 2002. Next, I will show some evidence that I am able to link downstream industries to relevant steel inputs—inputs that those industries actually use. Finally, I will compare my steel-specific input-output table to other published input-output tables to underscore its importance for the empirical question that I am studying in this paper.

3.2.1 Input-Output Relationships Over Time

Because the exclusion requests that underlie the steel-specific input-output table were filed in 2018, I assume that steel input-output relationships in 2018 are a reasonable representation of steel input-output relationships in 2002. A comparison of the input-output tables published by the Bureau of Economic Analysis (BEA) over time illustrates that steel inputs were allocated similarly across industries in 2018 as they were in 2002. The BEA publishes a "Use Table," which reports the use of different commodities by different industries. The most detailed version of this table that is available on an annual basis covers 73 different sectors. Steel is not separately defined among these 73 sectors, but is encompassed in "Primary

Figure 4: Distribution of Change in Industry Use of Metal, 2001-2017



(a) Primary Metals

(b) Fabricated Metal Products

Metals" and "Fabricated Metal Products." A simple comparison of the shares of each of the two metal commodities allocated to each industry in 2001 and 2017 shows little change in industry use over the period. Figure 4 shows that absolute changes in the share of metals used by different industries between 2001 and 2017 were less than one percentage point for most industries.

3.2.2 Efficacy of Downstream Industry Selection

Next, I show that changes in steel import unit values predict changes in material costs in downstream manufacturing industries that are linked using the steel-specific IO table. For this exercise, I use data from the NBER-CES Manufacturing Industry Database (Bartelsman and Gray (1996)) on the cost of materials for 473 manufacturing industries, classified at the NAICS 6 level. Of these 473 industries, I am able to map 81 to one or more steel products using the steel-specific IO table. Using trade data, I calculate the weighted average unit value[19] of the relevant steel imports for each downstream industry.

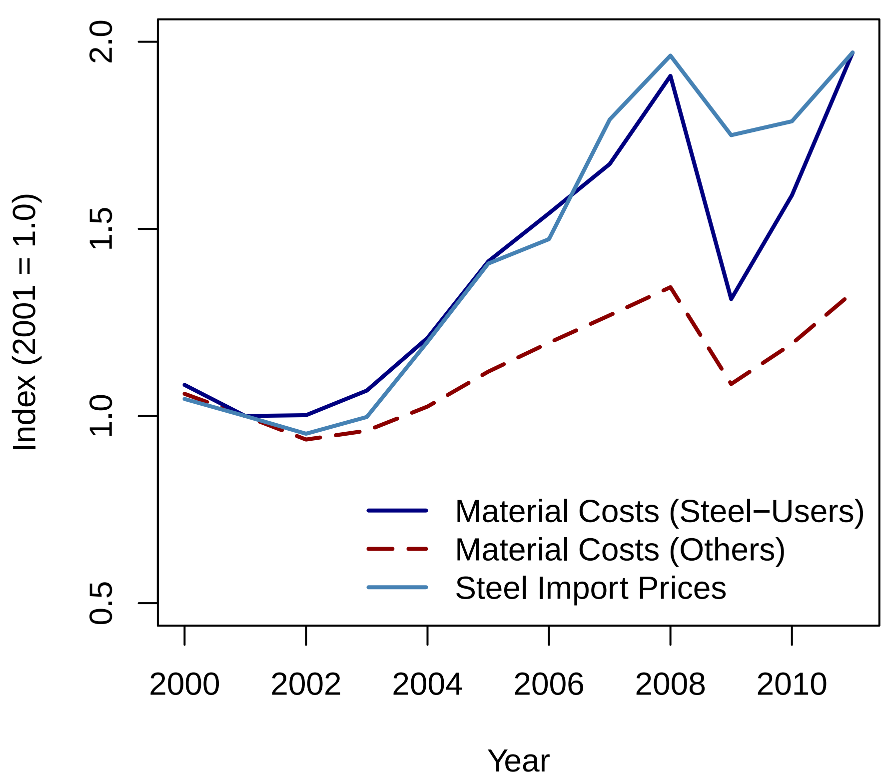
In Figure 5, I show a time-series of the average unit value of steel inputs and a time-series of average material costs in downstream manufacturing industries. I split the downstream manufacturing industries in the NBER-CES Manufacturing Industry Database into two groups: those that I identify as steel-using industries with my IO table, and those that I don't. The red dashed line shows average material costs in manufacturing industries from the database that are *not* identified as steel users, the dark blue line shows average material

[19]Details of how I calculate this weighted average are provided in Section 4.1.

costs in manufacturing industries that *are* identified as steel users, and the light blue line shows the average cost (unit value) of the relevant steel inputs. Costs are indexed to equal 1.0 in 2001 for ease of comparison. Steel prices and material costs for identified steel-using industries relative to non steel-using industries appear highly correlated.

I then use the steel-specific input-output table to estimate the impact that specific imported steel product prices have on downstream material costs, industry by industry. Table 1 shows regressions at the downstream industry level of the effect of changes in the unit value of linked upstream steel imports to the change in material costs of corresponding downstream industries. Column (1) shows that an increase in the unit value of linked steel inputs leads to a statistically significant increase in material costs of the corresponding downstream industry. Column (2) shows that this statistically significant relationship holds even when we control for changes in a Producer Price Index for Iron and Steel.[20] In other words, the import prices of the upstream products linked to downstream industries by the steel-specific input-output table impact the material costs of those downstream industries, above and beyond average changes in the price of steel.

Figure 5: Manufacturing Industry Material Costs and Steel Import Prices



[20]I include six-digit NAICS fixed effects in both regressions, however I can only include year fixed effects in column (1) because steel producer prices are identical across sectors.

Table 1: Steel-Import Prices Predict Downstream Material Costs: Industry-Level

	(1) Δ Material Costs	(2) Δ Material Costs
Δ Steel Unit Value	0.079	0.078
	(0.029)	(0.029)
Δ PPI Steel		0.574
		(0.033)
Constant	-0.058	-0.023
	(0.038)	(0.040)
Year Fixed Effects	Yes	No
Sector Fixed Effects	Yes	Yes
Observations	888	884

Standard errors in parentheses
Sample years: 2001-2011.

3.2.3 Intensity of Use

Input-output tables typically provide more than just binary indicators of use—they provide a measure of the intensity of which a downstream industry uses an upstream input. The exclusion requests I use to formulate the steel-specific IO table provide two key pieces of information that can be used to proxy for the intensity of an industry's use of a given product. First, on each exclusion request, the requesting party must provide the average annual volume of the 10-digit steel product being requested for exemption consumed between 2015 and 2017. This volume, provided in kilograms, can be converted to dollars using unit values (dollars per kilogram) of imports of the 10-digit steel import in question. The second measure of intensity comes from a simple count of the number of downstream industries that filed an exclusion request for a particular upstream input. This is a coarser measure of intensity of use, but is useful under the assumption that if a steel input is more important to or more intensely used by a downstream industry, more parties may file requests to exclude that input from the tariffs.

To test the strength of these measures of intensity, I compare them to a measure of steel inputs as a share of a downstream industry's total input requirements, calculated using the BEA's input-output table. Both the quantity measure and the count measure are highly correlated with the BEA steel-cost share, with correlation coefficients (standard errors) of 0.912 (0.001) and 0.711 (0.02), respectively.

3.2.4 Comparison with Other Published IO Tables

Finally, comparing my steel-specific input-output table to other published input-output tables—such as the BEA's "Use Table" and the input-output mapping constructed by Berlingieri et al. (2018)[21]—helps underscore the importance of the high-level of detail that my steel-specific input-output table provides. The published versions of the two aforementioned external tables provide data on industry use of one or two broad categories of steel.[22] In principle, what my steel-specific IO table does is expand these one or two broad categories into several hundred specific products. Collapsing my table down, I can calculate a measure of industry use of one broad category of steel that is comparable to what is available in the public IO tables.

According to the steel-specific IO table, the top downstream industry consumers of steel products protected by the Bush steel tariffs were: *other metal container manufacturing*, *metal coating, engraving, and allied services*, and *fruit and vegetable canning.* According to the BEA table, the top users of steel (in general) are *motor vehicle metal stamping*, *fabricated structural products*, and *metal tank (heavy gauge) manufacturing.* The implication of this difference is that using the BEA table to calculate a measure of exposure to the Bush steel tariffs would not do a good job of indicating the industries likely to be most affected. Just because those industries are heavy users of steel, in general, does not mean that they are heavy users of the specific steel products that were protected by tariffs. The same is true of the Berlingieri et al. (2018) concordance, which reflects use of steel imports by French firms, but again, not necessarily imports of products protected by the Bush steel tariffs.[23]

To underscore this point, the left panel of Table 2 shows the top users of steel products covered under the Bush tariffs according to the steel-specific IO table, while the right panel of the table shows the top users of steel products covered under the Trump steel tariffs according to the steel-specific IO table. Again, the lists are different, illustrating the level of detail that the steel-specific IO table is designed to capture.

One final example can help to illustrate the richness of the steel-specific IO table. Consider three downstream industries—HS 854330 *machines and apparatus for electroplating, electrolysis, or electrophoresis*, HS 820740 *tools for tapping or threading with parts of base metal*, and HS 820750 *other tools for drilling, other than rock drills.* According to the BEA

[21] Berlingieri et al. (2018) use transaction-level import data from French Customs and administrative information for private sector French enterprises to create a detailed input-output table for French imports. They have published an aggregated version of the table (4-digit SIC codes), which is used here for comparison.

[22] *Iron and Steel Mills Ferroalloy Manufacturing* and *Steel Product Manufacturing from Purchased Steel* in the case of the BEA and *Manufacture of Basic Iron and Steel* in the case of Berlingieri et al. (2018).

[23] Table 12 in Appendix A.1.3 shows a comparison of the top 10 steel-using industries according to all three input-output tables.

Table 2: Sensitivity of Steel-Specific IO Table

Steel-Specific IO: Bush Tariffs	Steel-Specific IO: Trump Tariffs
Other Metal Container Mfg	Iron & Steel Pipe and Tube Mfg
Metal Coating, Engraving, Allied Services	New Single-Family Housing Construction
Fruit & Vegetable Canning	Other Metal Container Mfg
Other Motor Vehicle Parts Mfg	Steel Wire Drawing
Other Transportation Equip. Mfg	Other Motor Vehicle Parts Mfg
Support Activities: Oil & Gas	Metal Coating, Engraving, Allied Services
Fabricated Structural Metal Mfg	Fabricated Pipe and Pipe Fitting Mfg
All Other Plastics Prod. Mfg	Fruit and Vegetable Canning
Crane, Hoist, Monorail Sys. Mfg	Other Machinery Mfg
Metal Can Mfg	Other Transportation Equipment Mfg
Hardware Mfg	Other Fabricated Wire Product Mfg

input-output table, these two downstream industries use similar amounts of steel, with steel representing between 4 and 5 percent of total costs in each of the three industries.[24] According to my steel-specific IO table, however, these two industries use very different types of steel, and as a result, faced different tariff rates on their inputs. In Table 3, I show that HS 854330 is associated with five upstream steel inputs and faced an average increase in steel tariff rate of 15.5 percent as a result of the Bush steel tariffs. HS 820740 and HS 820750, on the other hand, are associated with two and one upstream steel inputs, respectively. These industries faced much larger changes in their average steel tariff rates, at 27.9 and 29.2 percent, respectively.[25] It is this variation that I will leverage in my empirical analysis, that I would not be able to do using a more aggregated input-output table.

Table 3: Example Demonstrating Richness of Steel-Specific IO Table

	HS 854330	HS 820740	HS 820750
Steel-Specific IO Inputs	72139900 72210000 72230090 72279060 72287030	72286010 72288000	72286010
BEA Steel Cost Share	4.6 %	4.8 %	4.8%
Δ Average Tariff	15.5 %	27.9 %	29.2 %

[24]The BEA Cost-Share Proxy is constructed using the Industry by Industry Total Requirements table. Specifically, I calculate an industry's total steel requirements as use of the two BEA steel industries: "iron and steel mills and ferroalloy manufacturing" and "steel product manufacturing from purchased steel." I then divide total steel requirements by total industry output requirements.

[25]Construction of this variable is described in Section 4.1.

4 Estimation Strategy and Threats to Identification

In this section, I discuss the empirical strategy that I use to estimate the effect of tariffs on upstream steel inputs on the downstream industries that use them. Using the new steel-specific input-output table described in Section 3, I leverage variation in steel tariff rates faced by downstream users in 2002-2003 to causally estimate the impact of changes in those rates on downstream industries. Estimation of these effects is carried out dynamically, providing new evidence about the long-term effects of tariffs on upstream inputs on downstream industries.

4.1 Construction of Downstream Variables

Using the steel-specific input-output table, I construct the key dependent variable of interest: $\tau_{d,y}$—the average statutory tariff rate on steel inputs faced by downstream industry d in year y. To see how this variable is constructed, consider a downstream industry d that has N associated upstream steel inputs, which faced tariffs ($\tau_{1,y}$,..., $\tau_{N,y}$), respectively, in year y. The average tariff rate faced by downstream industry d is given by:

$$\tau_{d,y} = \sum_{u=1}^{N} \omega_u \tau_{u,y}$$

where ω_u is the share of consumption of upstream input u:

$$\omega_u = \frac{p_u \bar{Q}_{u,d}}{\sum_{u=1}^{N} p_u \bar{Q}_{u,d}}.$$

The share of consumption of the upstream inputs is calculated using the average consumption in kilograms of an upstream product u by a firm in downstream industry d, $\bar{Q}_{u,d}$. This quantity is provided on the exclusion request for each individual firm requesting an exclusion for product u, and I take the average for all firms in downstream industry d. I convert this volume to a dollar value using the average (across all countries) unit value of product u from trade flows data in 2001.[26] I use the same weights to construct several control variables, including a measure of downstream industry's pre-tariff (2001) exposure to the tariffs,[27] and a measure of the percent of an industry's steel inputs that cannot be produced in the United States.[28]

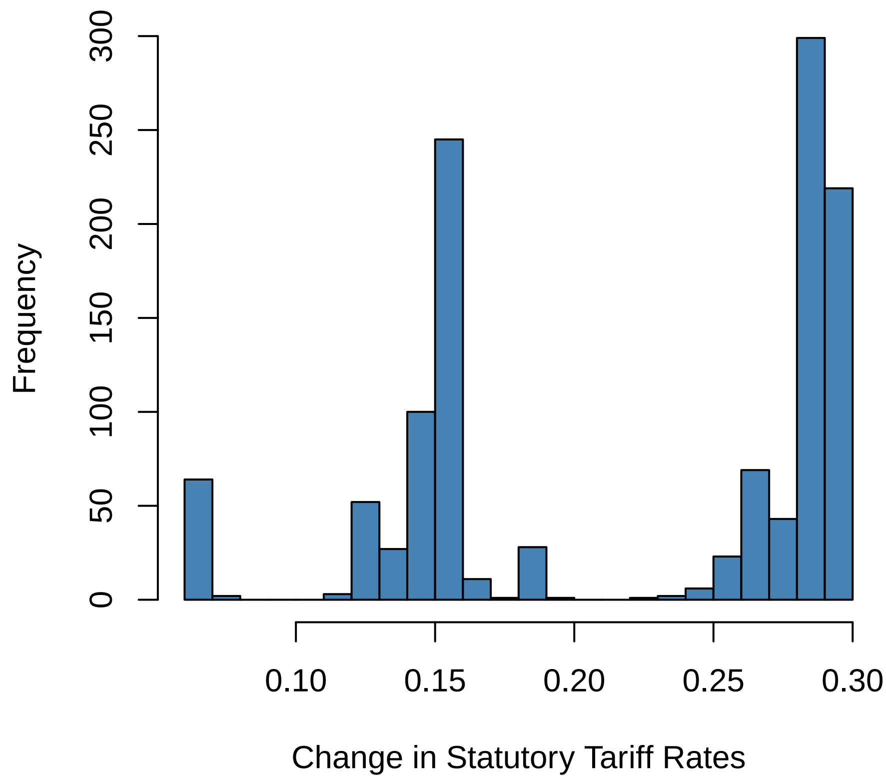
[26] Trade flows data are simply Customs data, downloaded from the U.S. ITC.

[27] This variable is calculated as the average share of the downstream industry's imported steel inputs that come from countries that were not exempt from the Bush tariffs. For example, suppose downstream industry d uses two upstream steel inputs, i and j, in equal proportions. Of total U.S. imports of industry i, 50 percent came from non-exempt countries in 2001. For input j, 25 percent came from non-exempt countries in 2001. For this industry, I calculate pre-tariff exposure to be: $\eta_d = \frac{1}{2}(0.5 + 0.25) = 0.375$.

[28] A variable I take from the exclusion requests.

Due to the different inputs used by different downstream industries, there is substantial variation in the steel tariff rates those industries faced. This variation, shown in Figure 6, is the basis for the empirical estimation of the impact that tariffs on upstream inputs have on downstream industries.

Figure 6: Distribution of Changes in Statutory Tariff Rates from 2001 to 2003



4.2 Estimation Specification

My primary estimating equation is given by:

$$x_{d,t} - x_{d,2001} = \alpha_t + \beta_t(\tau_{d,2003} - \tau_{d,2001}) + \Xi_t' X_d + \Sigma_{t,d} \quad (2)$$

The left hand side, $x_{d,t} - x_{d,2001}$, is the change in an outcome variable x in downstream industry d between year t and 2001. The coefficient of interest is β_t, which governs the change in the average statutory steel tariff rate on steel inputs faced by downstream industry d between 2001 (pre-Bush tariffs) and 2003. Note that the coefficients of interest have time subscripts because this regression is estimated separately in each year $t > 2001$ in order to assess how the effects play out over time. This approach is similar to the ones used in Jordà (2005) and Flaaen and Pierce (2019).

4.3 Threats to Identification

While focusing on the downstream impacts of upstream tariffs eliminates many potential threats to identification,[29] Gawande et al. (2012) and Bown et al. (2020) point out several sources of endogeneity that can thwart identification of the negative impacts of tariffs along supply chains. First, because tariffs on upstream products have the potential to hurt downstream industries, there may be counter-lobbying by downstream firms, especially those that stand to lose the most. To the extent that counter-lobbying efforts are successful, some of the negative impacts of the tariffs will fail to materialize in the data. In the case of the Bush steel tariffs, there is some evidence to suggest that these concerns can be at least partially alleviated. A document published by USTR following the announcement of then tariffs indicates that the level of tariffs that were levied on all but one category of steel product (stainless steel bar) were equal to or higher than the level recommended by the majority of ITC commissioners.[30] In other words, if there was lobbying by downstream industries to reduce tariff rates relative to ITC recommendations, it appears to have been unsuccessful.

There is anecdotal evidence to support this story as well. According to an article published by the Wall Street Journal[31] on March 6, 2002 (days after the tariffs were announced):

> For months, trade analysts and even some administration officials had thought the president would impose only very limited tariffs. In the months-long lobbying war that preceded Tuesday's decision, those who opposed high tariffs appeared to have the upper hand. Steel-using manufacturers and port owners gained the administration's ear, arguing that tariffs would cost far more jobs than they saved... But in the final days, Bush advisers say, the White House came under intense pressure from the steel unions, the big steel companies, and perhaps most important, lawmakers from steel states. The unions held a mass rally outside the White House last Thursday, while steel-state legislators made their case in the Oval Office. Officials say Mr. Bush and his advisers most feared a possible backlash among voters in the "rust belt," as well as erosion of support for Mr. Bush's other trade objectives in Congress... Sharply limited tariffs would have let the weakest coke-and-iron-ore steelmakers die and helped the strongest to grow and become more efficient competitors of mini-mills. Instead, Mr. Bush extended help to the steel industry across the board.

[29] When looking at the own-industry impact of protection, an industry's need for protection is likely correlated with its performance. Downstream industries, however, are more likely to be collateral damage—they are not specifically targeted.

[30] http://lobby.la.psu.edu/_107th/097_Steel_Safeguard/Agency_Activities/USTR/USTR_Bush_decides_on_safeguards.pdf

[31] https://www.wsj.com/articles/SB101533904883100680

In other words, the will of the downstream lobby appears to have been overridden by other political concerns.

A second potential source of endogeneity is that there is an omitted variable that is correlated with both the tariff on upstream inputs faced by a downstream industry, and the downstream industry outcome. For example, suppose foreign input suppliers experience a positive productivity shock that leads to an influx of imported inputs. On one hand, the influx of imported inputs might induce a higher tariff rate on those inputs as domestic input suppliers demand a greater level of protection. On the other hand, the influx could also boost domestic downstream production, leading to a positive correlation between downstream outcomes and input tariffs. Similarly, a productivity shock in the domestic downstream industry could lead to an influx of imported inputs that leads to a higher tariff rate. I test for endogeneity of this form by regressing changes in downstream industry outcomes leading up to the tariffs on the tariff rates those industries faced. Specifically, I run the following:

$$\Delta y_{d,1998-2001} = \alpha + \beta(\tau_{d,2003} - \tau_{d,2001}) + \varepsilon_d \tag{3}$$

Where y is the change in the downstream variable of interest between 1998 and 2001.

The results are reported in Table 4. There is not a statistically significant relationship for any of the outcome variables of interest, suggesting downstream industries that faced higher upstream tariffs were not on differential trajectories prior to those tariffs being implemented. The dynamic regression specification that I employ throughout Section 5 similarly shows that there are no apparent pre-trends.[32] Together, this evidence assuages concerns about the presence of endogeneity in the form of an omitted variable.

Table 4: Testing for Pre-Trends

	(1) Δ Export Share (98-01)	(2) Δ Log Exports (98-01)	(3) Δ Log Export Price (98-01)
Δ statutory_tariff	0.023	0.382	0.223
	(0.024)	(0.245)	(0.655)

Standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Finally, it is worth noting that any of the sources of endogeneity discussed will likely bias my results upward, making it *harder* to identify negative impacts of tariffs on downstream industries.

[32] Lake and Liu (2021) similarly highlight the absence of pre-trends between 1998 and 2000 in their difference-in-differences specification to show that the parallel trends assumption holds.

5 The Downstream Impact of Steel Tariffs

In this section, I describe my empirical findings on the impact of steel tariffs on downstream industries. Unless otherwise noted, results are estimated using the dynamic specification in equation 2, and results are shown for two samples: all downstream industries (dark blue line), and steel-intensive industries (red line, defined as industries for which steel constitutes an above-median share of costs).[33]

5.1 Downstream Export Market

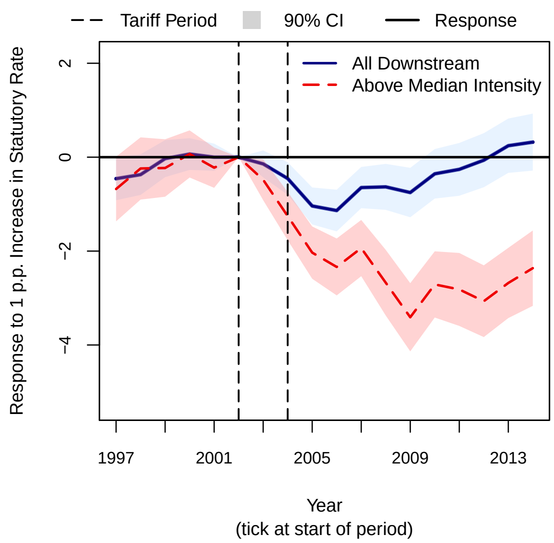
I first consider the impact of the tariffs on the export performance of downstream industries. I consider both the log level of exports (values and quantities), log export prices, and then the U.S. share of global exports—a measure of U.S. market share. Figure 7a shows that downstream industries that faced relatively high steel tariffs saw relatively large declines in export values (prices times quantities). Specifically, a one percentage point increase in an industry's steel tariff rate is associated with a peak decline of one percent in exports relative to pre-tariff levels (2 percent for steel-intensive industries).[34] Exports remain dampened for 6 years after the tariffs are removed for all industries, and for even longer for steel-intensive industries.

Figures 7c and 7d show that relative declines in export values were due to both lower export quantities and prices. The price (unit-value) and quantity data available from U.S. Customs is notoriously noisy, so I show results that are smoothed using two-year rolling regressions. For transparency, the raw results are in the Appendix. Exported quantities decline upon impact of the tariffs and remain dampened, while export prices remain flat on impact before eventually declining. That sectors that faced higher input tariffs saw lower export prices and quantities suggests that foreign consumers reallocate away from U.S. production, lowering prices in those sectors. (See Section 5.4 for further discussion). Fajgelbaum et al. (2020) also find that sector-level export prices fell with retaliatory tariffs during the Trump trade wars, as retaliatory tariffs induced a similar reallocation of foreign demand away from the U.S. In all four panels of Figure 7, note the absence of apparent pre-trends.

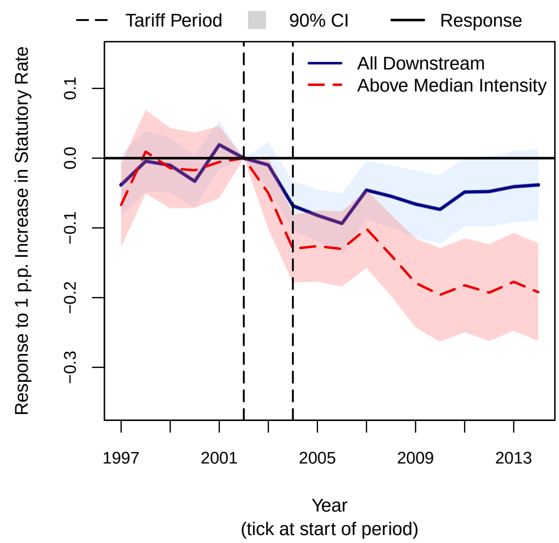
[33] I categorize industries using cost-shares calculated from the BEA total requirements table, but I get similar results using measures of intensity discussed in Section 3.2.3.

[34] Handley et al. (2020) study the impact of the Trump tariffs on downstream industry export values. While the magnitude I estimate cannot be compared directly with the theirs due to the use of a different independent variable (they use a measure of industry exposure to the tariffs), the direction is consistent with their findings.

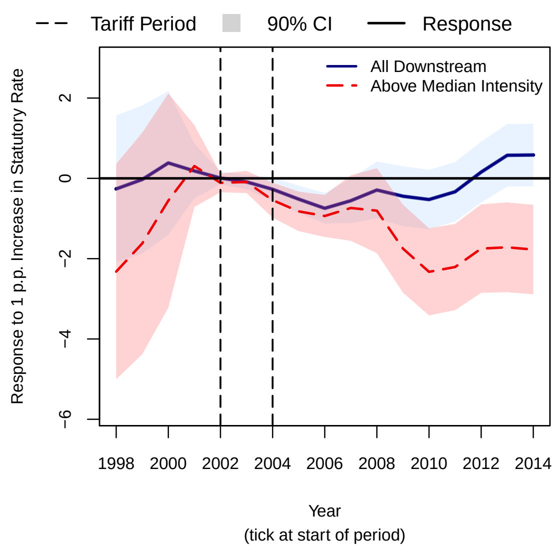
Figure 7: Effect of Higher Statutory Rates on Downstream Exports



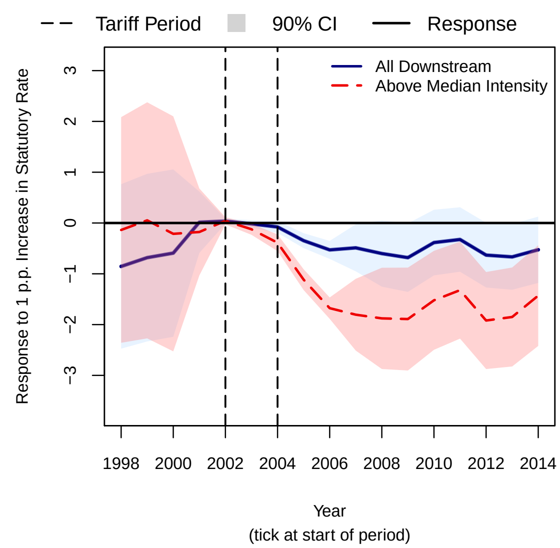
(a) Export Values



(b) Export Share



(c) Export Quantities



(d) Export Prices

Figure 7b shows the response of the U.S. share of global exports in downstream industries to the tariffs—a measure of the industry's global competitiveness or global market share. For downstream industries that faced relatively high steel tariffs, export shares exhibited a sharp decline during the period in which the tariffs are in place and remain depressed relative to pre-tariff levels for at least 8 years after the tariffs are removed. To put the magnitude of the estimated impact into perspective, shifting an industry from the 25th to the 75th percentile in terms of the change in upstream tariff it faces between 2001 and 2003 (a swing of 13.5 percentage points) results in a relative decline in global market share of 0.9 percentage points per year (on average) overall, and 1.9 percentage points per year for steel-intensive industries.

5.2 Reconfiguration of Global Trade Flows

The notion that temporary tariffs can have persistent downstream effects on the competitiveness of U.S. exports implies that there is a reconfiguration of downstream global trade flows in response to the tariffs that does not revert back once the tariffs are lifted. To test this, I use data on exports of the top 25 non-U.S. exporters of the relevant downstream products. I run the analogous specification to equation 2, but replace the dependent variable with the change in export share in downstream industry d in country j between year t and 2001.

$$x_{dj,t} - x_{dj,2001} = \alpha_t + \beta_t(\tau_{d,2003} - \tau_{d,2001}) + \Xi_t' X_d + \Sigma_{t,d} \tag{4}$$

Of the top 25 exporters I find that higher tariffs in a U.S downstream industry lead to a significant *increase* in global market share in those industries for Germany, Japan, and France. Regression results for these three countries are shown in Figure 8. Upon implementation of the tariffs in the United States, foreign market shares in industries that faced relatively high tariffs in the U.S. saw relative increases, especially for steel-intensive industries. German market shares exhibited the strongest response, followed by Japan and France. Notably, prior to the tariffs being enacted in the U.S., Germany, Japan and France were the second, third, and fourth largest exporters (in that order) of products in these downstream industries (behind the United States). As was the case in the U.S. export market, foreign market share responses to the steel tariffs are highly persistent.[35][36]

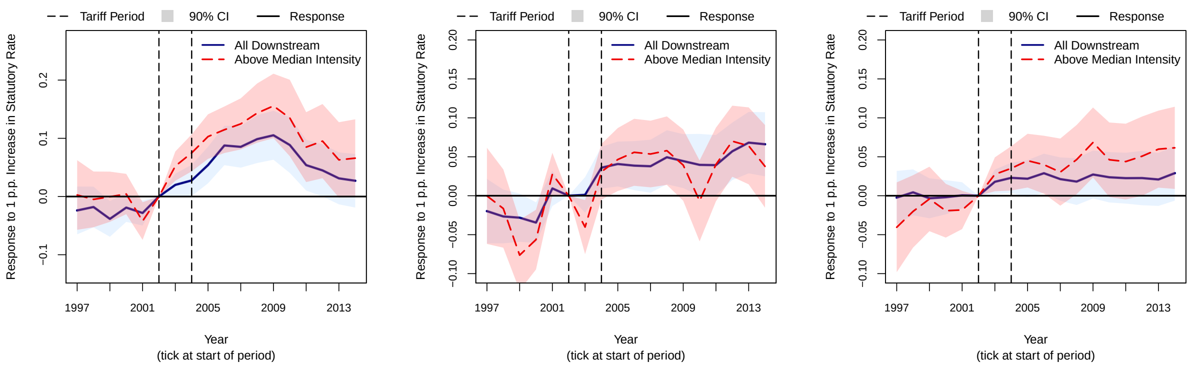
5.3 Downstream Domestic Outcomes

Lastly, I consider the impact of upstream tariffs on domestic downstream production and employment. Data on domestic production for domestic consumption (i.e., excluding exports) are not readily available, so instead I estimate the response of U.S. imports of downstream

[35]Note that because I am comparing the relative outcomes of U.S. industries that faced different upstream tariff rates *and* because I am estimating the results separately in each year (i.e., my regressions have time fixed effects), exchange rates will not be a factor in these results.

[36]Because of the proximity of the Bush tariffs to the "China Shock" that has been the subject of many papers in the literature, it is natural to question what role China had in these findings. In Appendix A.4, I show the response of the Chinese share of world downstream exports to the U.S. steel tariffs. Chinese downstream exports exhibit a slight increase relative to pre-tariff levels while the tariffs were in place, but between 2003 and 2009 are not measurably different from their pre-tariff levels. In other words, China does not appear to be a recipient of downstream market share that was lost in the U.S. *due to the steel tariffs*.

Figure 8: Global Market Share Shifts to Other Top Producers



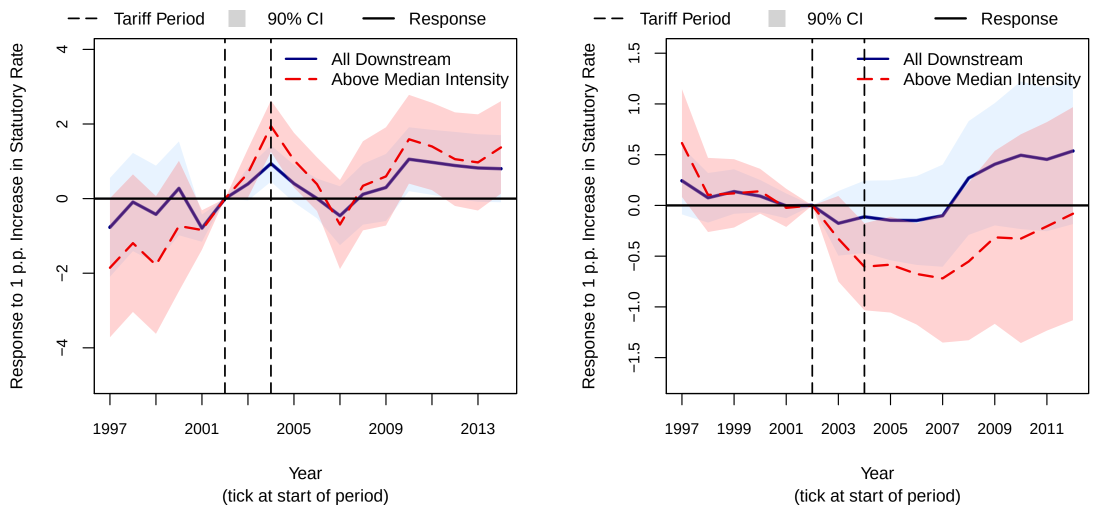
(a) Germany (b) Japan (c) France

industry products.[37] Intuitively a relative increase in imports for products that faced higher tariffs upstream would indicate that domestic consumers substituted toward presumably lower-priced foreign downstream products in response to the tariffs. Indeed, I show in Figure 9a that this is the exact response found in the data. Upon impact, imports of downstream products that faced a one percentage point higher input tariff in the U.S. rose by about 1 percent for all industries, and 2 percent for steel-intensive industries (commensurate in absolute value with the declines seen on the export side). Unlike exports, however, the increase in imports is transitory—returning to pre-tariff levels soon after the tariffs were lifted. This suggests that while downstream domestic production suffered in response to the tariffs, producers were able to regain domestic market share much more quickly than they were able to regain global market share.

Figure 9b shows the response of U.S. downstream industry employment to higher upstream steel tariffs. Particularly in steel-intensive industries, I find relative declines in employment for industries that faced relatively high steel tariffs. Employment declines are somewhat persistent—remaining (statistically significantly) depressed in steel-intensive industries for 4 years after the tariffs are removed. These findings are in line with those of Lake and Liu (2021), who find that employment in local labor markets more exposed to the Bush steel tariffs remains relatively depressed until their sample ends in 2008.

[37] In the Appendix I show results using a variable created using data on the value of shipments from the NBER CES Manufacturing Database, less industry exports, but this is a relatively noisy measure since the two data sources are measured using different industry classifications. The results are consistent, but are not measured with precision.

Figure 9: Effect of Tariffs on Imports and Employment



(a) U.S. Import Quantities

(b) Employment

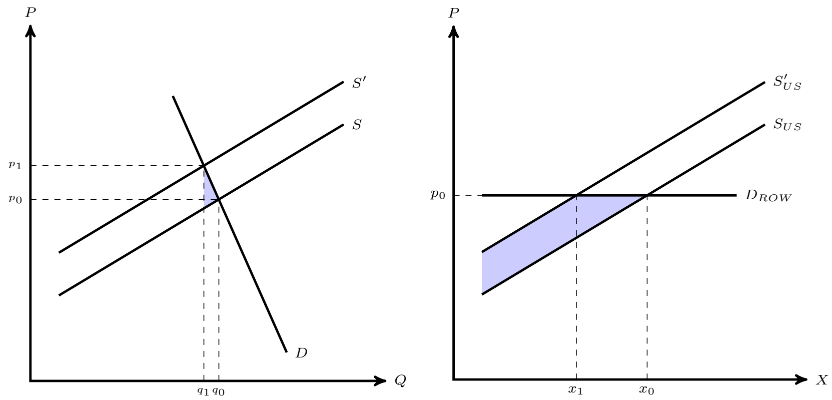
5.4 Discussion of Empirical Results

The results presented in Sections 5.1 through 5.3 can be summarized by three main findings: (1) higher tariffs on steel inputs have a persistent negative impact on exports in downstream industries; (2) global market share in downstream industries that faced higher steel tariffs shifted to other top exporting countries; and (3) higher input tariffs have a negative impact on downstream domestic production, but this impact is more transitory. In Figures 10 and 11, I depict a simple conceptual framework to interpret the short- and long-run effects, respectively. The intuitions from these graphs guide my reduced-form welfare calculations in Section 6 and the full structural model in Section 7. A unified conceptual framework can help explain these findings.

In the short run, on the export side, the data showed sharp relative declines in downstream exported quantities accompanied by little to no change in export prices. This suggests that U.S. downstream exporters are facing a relatively elastic foreign demand curve, as depicted in Figure 10b. My findings on the domestic side are the opposite: tariffs induce little change in quantities and only a small (albeit imprecisely measured) increase in prices. This suggests that domestic demand is fairly inelastic, as shown in Figure 10a in contrast to its foreign counterpart.

Once the tariffs are lifted, I find that domestic prices and outcomes bounce back relatively quickly; in other words, the U.S. supply curve appears to revert to its pre-tariff location. In the export market, however, persistent declines in both export prices and quantities imply an

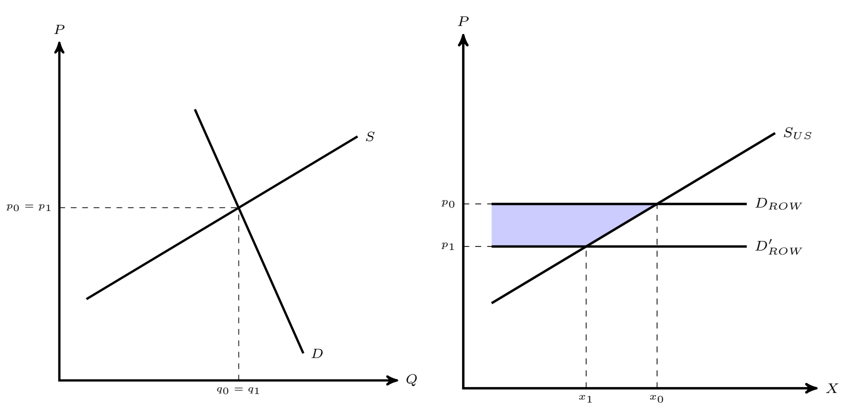
Figure 10: Contemporaneous Effect of Steel Tariffs on Downstream Industries



(a) Domestic Market (b) Export Market

inward shift of the foreign demand curve (see Figure 11b). Consistent with this explanation, Section 5.2 showed that other top exporters of downstream products—Germany, Japan, and France—took over the forfeited U.S. market share, explaining the ensuing reduction in demand for U.S. products. The persistent nature of this dampened foreign demand can be explained by the presence of relationship-specific sunk costs. Intuitively, if foreign buyers that were purchasing from the U.S. switch to a cheaper source (e.g. Germany) when the tariffs are implemented, it may not be worth it for all buyers to return to the U.S. once the tariffs are removed if there are high enough sunk costs associated with doing so. This graphical analysis will guide my reduced form estimation of the welfare impacts of the Bush steel tariffs, presented in the next section, and the intuition will carry through the structural model presented in Section 7.

Figure 11: Persistent Effects of Steel Tariffs on Downstream Industries



(a) Domestic Market (b) Export Market

6 Reduced Form Estimates of Welfare Impacts

The welfare impacts of steel tariffs will materialize both in the market for imported steel—through changes in consumer surplus, terms of trade, and tariff revenue—and in the market for downstream products. I focus on downstream welfare impacts in the form of producer surplus in the market for exports. It is here that I find the strongest impact in my empirical results, and also where I find that persistence is most likely to be a factor (as per the discussion in Section 5.4). In this section, I estimate the aggregate welfare impacts of the steel tariffs, both in the steel sector (contemporaneously) and in downstream industries (dynamically). I do this by assuming fairly general forms for the downstream industry export supply curve and the steel import demand curve, empirically estimating the U.S. elasticities of downstream export supply and steel import demand, respectively, and then using reduced form evidence to calculate changes in aggregate surplus due to the tariffs between 2002 and 2009.

6.1 Downstream Industries

In the downstream export market, changes in welfare will be represented by changes in aggregate producer surplus, or aggregate profit.[38] In general terms, consider a policy change that lowers prices in a sector, d, from $p_{d,t}$ to $p_{d,t+k}$. If we assume that production is allocated optimally across firms,[39] the ensuing change in producer surplus will be given by:

$$\Delta PS_{d,t+k} = \Pi_d(p_t) - \Pi_d(p_{t+k}) = -\int_{p_{t+k}}^{p_t} q_{d,t+k}(s)ds$$

Making one further assumption, that downstream industry supply curves are upward sloping and take the (inverse) form:

$$p_t = aq_t^{\sigma}, \tag{5}$$

where a is a marginal cost shifter and σ is the elasticity of supply, I rewrite the formula for producer surplus as:

[38] The conventional method for measuring policy-induced changes in welfare in a partial equilibrium model is to estimate changes in aggregate surplus—the net of producer surplus, consumer surplus, and tax revenue. In this case, consumer surplus accrues in the foreign market, and there is no tax revenue downstream.

[39] That is, marginal costs of production are equated across firms in an industry.

$$\Delta PS_{d,t+k} = \int_{p_{t+k}}^{p_t} (ap)^{\frac{1}{\sigma}} = q_t p_t^{\sigma+1} \frac{\sigma}{\sigma+1} \left[1 - (\Delta \ln p_{t+k} + 1)^{\frac{\sigma+1}{\sigma}}\right] \tag{6}$$

For the scenario in question, I estimate σ, the elasticity of supply for downstream U.S. exporters. I observe $p_{d,t}$ and $q_{d,t}$, pre-tariff export prices and quantities; and using the estimate of σ and dynamic estimates of changes in quantities due to the tariffs, we can calculate the change in downstream producer surplus in each year due to the steel tariffs.

Estimating the Elasticity of Supply, σ

Starting with the production function (5) and taking log-differences yields:

$$\Delta \ln p_{t+k} = \sigma \Delta \ln q_{t+k}. \tag{7}$$

In this case, $\Delta \ln p_{t+k}$ is the change in U.S. export prices between periods t and $t+k$, and $\Delta \ln q_{t+k}$ is the change in export quantities during the same period. Of course, the endogeneity of prices and quantities precludes us from credibly running a regression of the form above. We can, however, instrument for $\Delta \ln q_{t+k}$ with an appropriate exogenous foreign demand shock to get an unbiased estimate of σ.

I construct a foreign demand shock as follows. First, I consider the top 10 sources of U.S. exports of downstream products.[40] Let $\tilde{m}_{id,t}$ be imports of downstream product d by country i in year t from all sources *excluding* the United States and define $\tilde{M}_{d,t} = \sum_i \tilde{m}_{id,t}$. Following Mayer et al. (2016), in each year, t, I calculate a first difference as:

$$\Delta \tilde{M}_{d,t} = (\tilde{M}_{d,t} - \tilde{M}_{d,t-1})/(0.5\tilde{M}_{d,t} + 0.5\tilde{M}_{d,t-1})$$

This measure is useful because it preserves observations when $\tilde{M}_{d,t}$ switches from 0 to a positive number and is bounded between -2 and 2. $\Delta \tilde{M}_{d,t}$, then, represents increases in "world" demand (as represented by the top 10 U.S. buyers), and can be used to instrument for $\Delta \ln q_{t+k}$ in equation 7 to estimate σ.

Results are shown in Table 5. I estimate an inverse elasticity of export supply of $\sigma = 0.29$, suggesting export supply is fairly elastic. This estimate is in line with similar estimates from the literature, for example Romalis (2007) who estimates a value between 0.24 and 0.52. I use the estimate from column (1), which covers sample years 1995-2001 (pre-tariff), but the estimate is robust to sample selection.

[40]Canada, Mexico, Japan, Germany, United Kingdom, France, Brazil, China, South Korea, Netherlands

Table 5: U.S. Export Supply Elasticity

	(1) Δ Price	(2) Δ Price	(3) Δ Price
Δ Quantity	0.285***	0.244**	0.298***
	(0.082)	(0.085)	(0.046)
F-Statistic	213.544	180.100	651.058

Standard errors in parentheses
Sample years:1995-2001, 2001-2010, 1998-2010
Regressions include commodity and year fixed effects.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Calculating the Percent Change in Prices

To estimate $\Delta \ln p_{t+k}$, I use estimates of the change in export quantities due to input tariffs in each year relative to pre-tariff levels. These estimates are calculated using the dynamic specification shown in equation 8, the results of which are presented in Section 5, Figure 7c.

$$q_{d,t} - q_{d,2001} = \alpha_t \beta_t^q \ln((1 + \tau_{d,2003})/(1 + \tau_{d,2001})) + \Xi_t' X_d + \Sigma_{d,t} \tag{8}$$

The coefficients, β_t^q, recovered from this estimation in each year t, can be used to calculate $\Delta q_{d,t+k}$ as:

$$\beta_t^q \Delta \tau_d \approx \frac{q_{d,t+k} - q_{d,t}}{q_{d,t}} = \Delta \ln q_{d,t+k}$$

Using equation 7 and the estimate of σ, we can then estimate $\Delta \ln p_{d,t+k}$ in each year, t. Plugging this as well as observed values of initial prices and quantities ($p_{d,2001}$ and $q_{d,2001}$) into equation 6 yields estimates in the change in downstream industry producer surplus in each year, t, due to the steel tariffs. The results, displayed in Table 6, show losses to downstream producers of 2 to 6 percent of exports between 2002 and 2009. Although in many years I cannot reject the null hypothesis that the change in producer surplus due to the tariffs was 0,[41] the results strongly suggest economically significant and persistent losses to downstream producers from the steel tariffs.

6.2 Upstream (Steel) Industry

I use a similar process to estimate changes in welfare in the steel industry. First, I assume that U.S import demand for steel is given by:

[41] This is due to imprecision in the estimates of the change in quantity due to the tariffs.

Table 6: Downstream Loss in Producer Surplus

Year	ΔPS ($B)	$90\% CI$	% of Exports
2002	-1.99	[-5.93,2.13]	1.09
2003	-5.98	[-11.9,0.36]	3.19
2004	-11.06	[-17.56,-4.01]	5.16
2005	-15.51	[-22.4,-7.94]	6.36
2006	-11.83	[-22.19,0]	4.22
2007	-6.38	[-20.19,9.95]	1.97
2008	-9.59	[-23.52,7.05]	2.59
2009	-11.25	[-24.81,4.93]	4.13
2010	-7.28	[-21.48,9.61]	2.12
2011	3.59	[-12.74,23.02]	-0.86

$$m_{ig,t} = \kappa p_{ig,t}^{-\gamma}$$

Where $p_{ig,t}$ the duty-inclusive price, i.e., $p_{ig,t} = (1 + \tau_{ig,t})p^*_{ig,t}$, and κ is the U.S. import demand elasticity. Taking log-differences, we can estimate the desired elasticity, γ, from a regression of the form:

$$\Delta \ln m_{ig,t} = -\gamma \Delta \ln p_{ig,t}$$

Where i are steel industries, g are source countries, and $\Delta \ln p_{ig,t}$ is instrumented with an exogenous supply shifter. In this case, we can use the steel-tariffs themselves to instrument for $\Delta \ln p_{ig,t}$. The results of the first and second stages are displayed in columns (1) and (2) of Table 7, respectively. Though the tariffs are a weak instrument for the change in prices according to the F-statistic, the resulting estimate of $\gamma = -2.389$ is exactly in line with the U.S. import demand elasticity of -2.53 that Fajgelbaum et al. (2020) estimate using the Trump tariffs.

Following the same process that I did for the downstream industries, I use the estimated coefficient, β^s, from a regression of the change in imported steel quantities on the change in the statutory tariff rate faced by that steel industry (shown in column (3) of Table 7), to calculate:

$$\Delta \ln q_{ig,t} = \beta^s(1 + \tau_{ig,t})$$

in years 2002 and 2003. The estimate of $\Delta \ln q_{ig,t}$ combined with the (assumed) formula for the demand curve yields an estimate for $\Delta \ln p = -\frac{1}{\gamma}\Delta \ln q$ for each year.

From here, following the same logic as for the downstream sector, I calculate the change in consumer surplus in the steel sector due to the tariffs as:

Table 7: U.S. Import Demand Elasticity

	(1) Δ Log Duty-Inclusive Price	(2) Δ Log Quantity	(3) Δ Log Quantity
Δ Log (1+τ)	0.737*		-4.598**
	(0.295)		(1.443)
Δ Log Duty-Inclusive Price		-2.389*	
		(1.090)	
Constant	0.047		0.420
	(0.053)		(0.223)
F-Statistic		5.835	

Standard errors in parentheses
Sample years: 2002-2003
Regressions include country-year fixed effects.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

$$\Delta CS_{d,t+k} = q_t p_t \left(\frac{1}{1-\gamma} \right) \left[1 - (1 + \Delta p_{t+k})^{1-\gamma} \right]$$

The resulting estimates, shown in the third column of Table 8, also include changes tariff revenue earned due to the tariffs in the two years in which the tariffs were in place.

6.3 Overall Change in Welfare

Combining estimates of changes in welfare in the downstream sectors with changes in the steel sector, I calculate the overall change in welfare due to the steel tariffs, relative to pre-tariff levels, in each year. The results are shown in Table 8. I find that welfare losses amount to between 1 and 6 percent of exports in each year. Losses are primarily concentrated in the downstream sector, though persistent declines in the downstream sector may have had a continuing negative impact upstream as well (in most years, I cannot reject the null hypothesis of 0 change in welfare in the upstream sector). More important than the magnitudes estimated in each year is the fact that welfare losses accrue for years after the tariffs were removed, something that conventional methods for evaluating the impacts of such a policy traditionally miss. A comprehensive estimate of the welfare impacts of an input tariff will be substantially underestimated if the downstream dynamic impacts are not taken into account. In the next section, I show that welfare losses estimated using a full structural model are in line with these partial equilibrium calculations.

Table 8: Overall Welfare Loss from 2002-2003 Steel Tariffs

Year	Downstream ($B)	Upstream ($B)	Total ($B)	Total % of Exports
2002	-1.99*	-0.51	-2.49*	1.37*
2003	-5.98*	-0.88	-6.86*	3.66*
2004	-11.06*	-0.37*	-11.42*	5.33*
2005	-15.51*	-0.18	-15.69*	6.43*
2006	-11.83*	-0.52	-12.35*	4.41*
2007	-6.38	-0.38	-6.76	2.09
2008	-9.59	0.13	-9.46	2.55
2009	-11.25	-0.52	-11.77	4.32

A * indicates that result is statistically significant with a 90 percent confidence interval.

7 A Structural Dynamic Model

In this section, I present a dynamic model of trade that features relationship-specific sunk costs of exporting. I use the model first to show that the presence of sunk costs can generate a persistent response of downstream exports to a temporary input tariff that is consistent with the patterns that I find in the data. I then use the model to evaluate the aggregate welfare implications of a temporary input tariff shock.

7.1 Overview

The model features two asymmetric countries (Home and Foreign), each with three sectors: an (Armington) steel sector, which uses labor to create tradable steel products; a downstream manufacturing sector, which uses labor and a composite of home and foreign steel to produce a (differentiated) tradable consumption good; and an outside sector that produces a homogeneous consumption good that is freely traded. Governments can place tariffs on steel imports to support the domestic steel industry and generate tariff revenue. Households provide labor and earn wages in all three producing sectors, and derive utility from the consumption of a Cobb-Douglas aggregate of downstream manufactured goods and the outside sector good.

The downstream manufacturing industry is modeled in the spirit of Melitz (2003). The industry features a large number of monopolistically competitive establishments. As in Melitz (2003), establishments in the downstream sector must pay a fixed cost in order to export goods. As a result, not all establishments will find it profitable to sell in the foreign market. In each period, a mass of existing establishments are distributed over productivity and export status. Idiosyncratic shocks to productivity and fixed export costs generate movements of establishments into and out of the domestic and export markets. There is free entry, and new establishments are created by incurring a fixed entry cost. The key feature of the model is that there is a sunk cost associated with entering the export market: specifically, the fixed cost of *starting* to export differs from the cost of *continuing* to export. Seminal work by Baldwin (1988), Baldwin and Krugman (1989), and Dixit (1989) showed that the presence of such a sunk cost generates hysteresis in export dynamics in response to temporary shocks.

Steel tariffs levied by the home country force some downstream manufacturing firms to exit the export market, as higher input costs render exporting unprofitable. The opposite occurs in the foreign country, where producers find it more profitable to enter. As soon as the tariffs are lifted, domestic steel input prices return to pre-tariff levels, but due to the sunk cost that firms face in their initial exporting period, home country exporters cannot immediately re-join the export market and extra entrants in the foreign country do not immediately exit. As a result, the economy is slow to converge back to its initial steady state.

7.2 Set-Up

In this subsection I will describe the model's basic features. Further details are relegated to Appendix A.5.

Steel Sector.
Steel production occurs both at home (s) and abroad (ω) using the production technologies:

$$s_t = A\ell_t$$
$$\omega_t = A^*\ell_t^*,$$

where A is a country-specific productivity parameter. Steel is tradeable, and downstream goods in each country are produced using a composite of home and foreign steel inputs:

$$S_t = \left[s_t^{\frac{\varepsilon-1}{\varepsilon}} + \omega_t^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}},$$

where s is consumption of domestically produced steel, ω is imported steel, and ε is the elasticity of substitution between home and foreign steel. Steel consumption in the foreign country is analogous (unless otherwise noted, assume that this is the case going forward). Foreign variables will be demarcated with an asterisk going forward. Prices of home and foreign steel are given by $p_{s,t}$ and $p_{\omega,t}$, respectively. The home government can place a tariff, τ_s, on imported steel, so that the price of foreign steel in the home country is given by $(1+\tau_s)p_{\omega,t}$. The price of the composite steel product is standard:

$$P_t^S = \left[(p_{s,t})^{1-\varepsilon} + ((1+\tau_s)p_{\omega,t})^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

Outside Good Sector.

The outside consumption good is produced (linearly) with labor. The outside good, D_O, is sold in a competitive market and is freely traded across countries. I treat the outside good as the numeraire and normalize the wage in each country to 1: $W_t = W_t^* = 1$.[42]

Households.

Households choose consumption and investment to maximize utility:

$$V_{C,0} = \max \sum_{t=0}^{\infty} \beta^t U(C_t)$$

subject to the sequence of budget constraints:

$$P_t C_t + Q_t B_t \leq P_t W_t L_t + B_{t-1} + P_t \Pi_t + P_t T_t,$$

where $\beta \in (0,1)$ is the time discount factor, C_t is consumption of final goods, Q_t and B_t are the price of and quantity of bond holdings, W_t is the real wage rate, Π_t are profits from domestic producers, and T_t is a real lump-sum transfer from the home government to the households that includes tariff revenue collected in the steel sector. Households have log utility over consumption of the final good, whose composition is described next.

Final Good Producers.

There is a final good production sector that assembles the consumption good—a Cobb-Douglas composite of the outside good, D_O and the manufactured good, D_T:

$$D_t = D_{T,t}^{\gamma} D_{O,t}^{1-\gamma}$$

where $D_{T,t}$ is a CES composite of domestic and foreign tradeable manufactured goods, $y_{H,t}(z,v,x)$ and $y_{F,t}(z,v,x)$:

[42]While Demidova and Rodriguez-Clare (2013) argues that the addition of an outside sector to the Melitz (2003) model can affect the welfare implications of changes in iceberg tariffs, as argued in Bagwell and Lee (2020), changes in sector-specific ad valorem tariffs, as I study here, are less likely to generate aggregate wage effects. Therefore, an outside sector seems reasonable in this case.

$$D_T = \left[\sum_{x=0}^{1} \iint y_{H,t}(z,v,x)^{\frac{\theta-1}{\theta}} \psi_{T,t}(z,v,x) dz + y_{F,t}(z,v,x)^{\frac{\theta-1}{\theta}} \psi^*_{T,t}(z,v,1) dz dv \right]^{\frac{\theta}{\theta-1}}$$

Here, (z, v, x) is a technology triplet that defines downstream firms and will be defined in the next section, $\psi_T(z, v, x)$ and $\psi^*_T(z, v, 1)$ are the distributions of downstream producers in the Home country and downstream exporters in the Foreign country, and θ is the elasticity of substitution among downstream manufactured goods.

Downstream Manufacturing Sector

Downstream good producers are heterogeneous with respect productivity, and therefore, export status. The set-up of the downstream sector is adapted from Alessandria and Choi (2014). Incumbent firms have idiosyncratic productivity, z, which follows a first-order Markov process where a firm's probability of having productivity z' in period $t + 1$ given it has productivity z in period t is given by $\Phi(z'|z)$. Next-period productivity, z' is bounded by $z' \in (\underline{z}, \bar{z})$. Establishments face an exogenous probability of "death" (or exogenous exit) given by $0 \leq n_d(z) \leq 1$. The survival rate of a firm with productivity z is given by $n_s(z) = 1 - n_d(z)$.

There is a fixed cost associated with exporting, that depends on the firm's current export status. An incumbent exporter in period t must pay the cost f_1 in each period to continue exporting in period $t + 1$. A firm that is not exporting in period t must pay f_0 to start exporting in period $t + 1$, where $f_0 > f_1$. Thus, it is more costly to start exporting than to continue exporting. These fixed costs are subject to idiosyncratic shocks, v, drawn in each period from $\phi_v(v)$.

In each period, producers draw their exporting fixed cost shocks, productivity shocks, and make a decision about whether to export in the next period. Lastly, entrants pay a fixed entry cost f_E to draw a productivity parameter, z, for the next period from the distribution $\phi_E(z')$. Firms in the downstream manufacturing sector are defined by the triplet: technology (z), fixed cost shock (v), and export status (x). Let $j = (z, v, x)$. In each period, firms choose current prices, $P_{H,t}(j)$ and $P^*_{H,t}(j)$; inputs of labor, $\ell_{T,t}(j)$, and the composite steel product, $s_{T,t}(j)$; and the next period's export status. Producers have a Cobb-Douglas production technology:

$$y_{T,t} = \exp(z) \left[s_{T,t}(j)^{\alpha} \ell_{T,t}(j)^{1-\alpha} \right]$$

And producers solve the following Bellman equation:

$$V_{T,t}(j) = \Pi_{T,t}(j) - x \exp(v) f_x + n_s(z) \iint V_{T,t+1}(j') \phi(z'|z) \phi_v(v') dz' dv',$$

where x is an indicator for the firm's current export status, and $f_x \in (f_0, f_1)$ is the relevant export fixed cost. Firm profits in each period, $\Pi_{T,t}$, are given by:

$$\Pi_t(j) = P_{H,t}(j)y_{H,t}(j) + mP^*_{H,t}(j)y^*_{H,t}(j) - W_t\ell_t(j) - P_{S,t}s_t(j) - f_x.$$

Total production at Home must satisfy the demands of both home and foreign demand (subject to an iceberg trade cost, ι):

$$y_{T,t}(j) = y_{H,t}(j) + (1+\iota)y^*_{H,t}(j).$$

Let the value of a producer j that decides to export in period $t+1$ be:

$$V^1_{T,t}(j) = \max \Pi_{T,t}(j) - \exp(v)f_x + n_s Q_t \iint V_{T,t+1}(z', v', 1)\phi(z'|z)\phi_v(v')dz'dv',$$

and let the value of a producer j that does not export in period $t+t$ be:

$$V^0_{T,t}(j) = \max \Pi_{T,t}(j) + n_s Q_t \iint V_{T,t+1}(z', v', 0)\phi(z'|z)\phi_v(v')dz'dv'.$$

Then, the actual value of a producer will be equal to $V_{T,t}(j) = \max\{V^1_{T,t}, V^0_{T,t}\}$. As is standard, there will exist a productivity threshold, $z_{m,t}(v)$ such that an establishment is indifferent between exporting and not exporting. This export threshold will depend on the establishment's current export status, m, productivity, z, and fixed cost shock v.

Lastly, new establishments are created by incurring a fixed entry cost, f_E, in the period prior to production. Entrants draw a productivity z from the distribution $\phi_E(z')$ and entrants *cannot* export in their first period of production. Free entry requires that:

$$V^E_{T,t} = f_E + Q_t \iint V_{T,t+1}(z', v', 0)\phi_E(z')\phi(v')dz'dv' \leq 0$$

7.3 Equilibrium

In equilibrium, the markets for steel, downstream manufactured goods, outside sector goods, and labor clear in both the home and foreign countries. Profits and tariff revenue are distributed to consumers. Allocations are such that firms in all sectors solve their profit maximization problems, consumers solve their utility maximization problems, market clearing conditions are met, and free-entry conditions hold in the downstream sector in both countries. The full set of equilibrium conditions are reported in Appendix A.5.

7.4 Calibration

Where possible, I calibrate the model in accordance with the baseline calibration of Alessandria and Choi (2014), which is set to target a number of moments that characterized U.S. manufacturing establishments in 1987. Details of the calibration are described in Appendix A.5.3. The model by Alessandria and Choi (2014) has no steel sector, so parameters governing the steel sector are calibrated in accordance with the data used for my empirical analysis. These parameters are: A and A^*—productivity parameters for the home and foreign steel sectors, ε—the elasticity of substitution between home and foreign steel, and α—the Cobb-Douglas share of costs in the downstream manufacturing sector.

In the baseline "all industries" case, I set $\alpha = 0.15$—the average steel-cost share for all downstream industries in my data. For "steel-intensive industries", α is set to 0.30—also in accordance with my data. Relative steel-sector productivity, $\frac{A^*}{A}$, is important because it determines how much of an impact the tariffs on foreign steel have for downstream domestic producers. If $A = A^*$, in response to the tariffs, downstream domestic producers can reallocate steel consumption toward the domestic steel industry at no additional cost. If $A < A^*$, domestic steel prices are higher than foreign, so the tariffs have a more inescapable impact. I set $\frac{A^*}{A}$ such that domestic steel prices are 10 percent higher than foreign steel prices. The assumption seems plausible: were it not the case that domestic steel was less productive than foreign, there would have been little need for the steel tariffs in the first place. Lastly, I set $\varepsilon = 2$. This is at the upper end of the range of estimates for the "macro" Armington elasticity (the elasticity between home and foreign goods) found by Feenstra et al. (2018). Further details on the calibration procedure are described in Appendix A.5.3.

7.5 Simulation and Results

7.5.1 Baseline Simulation

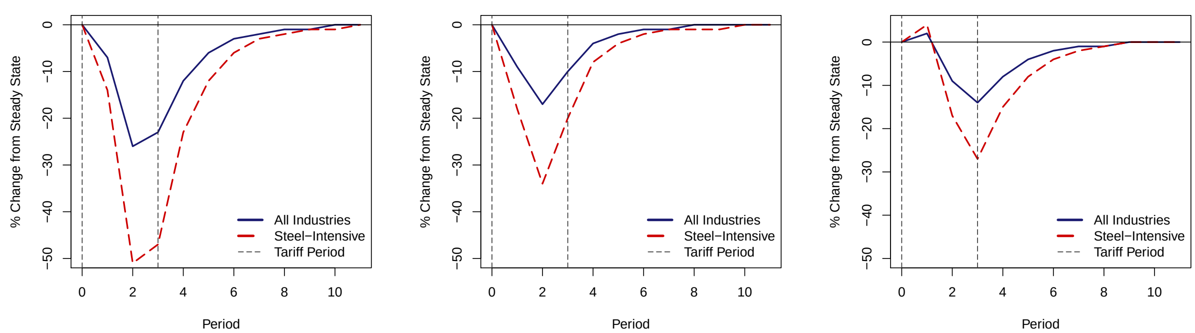
In the baseline simulation, the two countries start off in an (asymmetric) steady-state. The only asymmetry in the initial steady state is that the price of domestically produced steel in the home country is slightly higher than it is in the foreign country. In Period 1, the home country imposes a 25 percent tariff on steel imports. The tariff is in place for two model periods before returning to 0 in period 3. In this model, agents have perfect foresight for all periods except period 0. In other words, they are surprised by the shock but know exactly how long it will last.

Figures 12a through 12c show the impulse responses for export values, export quantities, and export prices, respectively. The magnitude of the responses are consistent with the reduced form results, generating a roughly 0.7 percent decline in exported quantities, a 0.6

percent decline in export prices, and a 1 percent decline in export values for every 1 percent increase in the input tariff. As in the reduced form results, though the tariffs are in place for only 2 periods, it takes export quantities five to six periods to return to their steady-state levels and export prices and values 7 to 8 periods. Responses are both larger in magnitude and more persistent for steel-intensive industries (the red dashed lines), also in line with the reduced form evidence.

Intuitively, imposition of steel tariffs in the Home country lead to higher marginal costs for Home downstream manufacturers. Higher marginal costs force Home country exporters to raise their prices, which reduces Foreign demand. The reduction in Foreign demand renders it unprofitable for many Home exporters to continue paying the continuation cost, f_1, of exporting, and the lowest productivity exporters drop out of the export market. At the same time, there is increased entry in the Foreign country—it becomes worth it for Foreign firms to pay the entry cost to begin producing. When the tariffs are removed, the increased mass of Foreign producers relative to the initial steady state makes it less profitable for Home country exporters to pay the high fixed exporting cost, f_0, to rejoin the export market, so exported quantities do not immediately rebound to steady-state levels. Export prices also remain lower than steady-state levels, because the Home exporters who do remain in the export market are those with the highest productivities and, therefore, lowest prices.

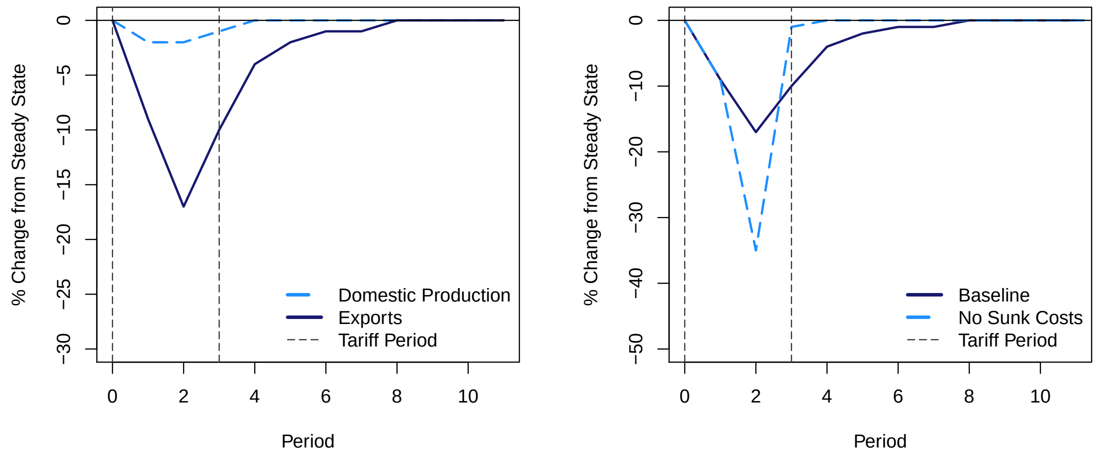
Figure 12: IRFs for Exports, Baseline Simulation



(a) Export Values (b) Export Quantities (c) Export Prices

In Figure 13a, I show that the model is able to match another feature of the data. The response of domestic production—the dashed light blue line in the figure—to the temporary shock to steel tariffs is smaller and much less persistent than the response of exports (the solid, dark blue line). In Figure 13b, I show that the sunk costs of exporting are the key feature driving persistence in the export response. In this figure, the dashed light blue line shows the response of exports (quantities) to a simulation of the model in which I remove the sunk cost of exporting. That is, I set the cost to start exporting, f_0, equal to the continuation cost, f_1. Removing the sunk cost completely removes any persistence in the response of exports to the temporary tariff shock. The baseline response is plotted again in navy blue for comparison.

Figure 13: Domestic Production and No Sunk Cost

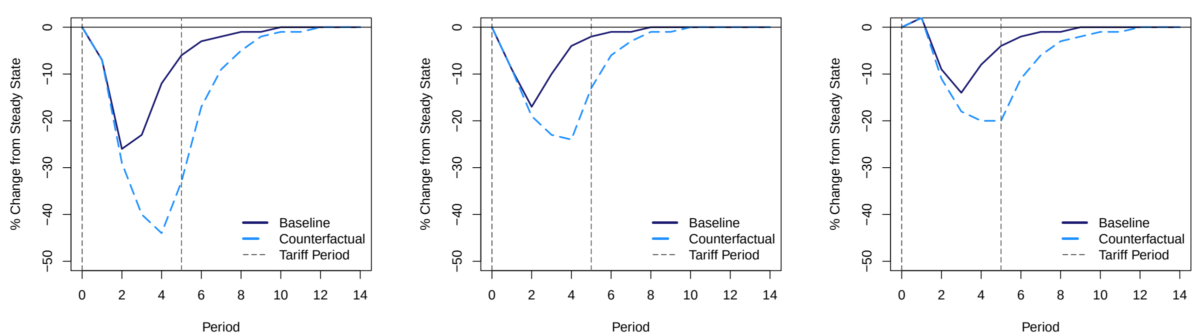


(a) Domestic Production (b) Export Quantities, No Sunk Cost

7.5.2 Counterfactual Simulation

Next, I simulate a counterfactual in which the steel tariffs are in place for twice as long as in the baseline simulation—4 periods instead of 2. All other model parameters are unchanged. The impulse responses for export values, quantities, and prices in the counterfactual are displayed in Figure 14 (the dashed light-blue lines). Tariffs in place for a longer duration lead to both a larger peak decline in exports and a longer recovery period relative to the baseline case. In the baseline case, export values took 7 periods after the tariffs were removed to recover to their initial steady-state levels. In the counterfactual, recovery takes 9 periods.

Figure 14: Counterfactual IRFs



(a) Export Values (b) Export Quantities (c) Export Prices

7.5.3 Welfare

I use the model to estimate the change in real income, as a result of the temporary tariff shock in the baseline simulation. In Table 9, I report the annual tariff-induced change in real income as a percent of GDP and as a percent of exports. In the right-most column, for comparison, I report the analogous results from the reduced form estimation discussed in Section 6. While the shape of the model-simulated responses is different from that of the reduced form estimates, average welfare losses as a percent of exports over 10 periods are virtually identical between the model and the reduced form estimation at 2.80 percent and 2.79 percent, respectively.

Table 9: Model Estimated Change Welfare

Period	% of GDP	% of Exports	Reduced Form (% of Exports)
0	0	0	0
1	-0.25	-9.74	-1.37*
2	-0.35	-14.98	-3.66*
3	-0.08	-3.16	-5.16*
4	-0.04	-1.32	-6.36*
5	-0.02	-0.68	-4.22*
6	-0.01	-0.39	-1.97
7	-0.01	-0.22	-2.59
8	0	-0.17	-4.13
9	0	-0.11	-2.12
10	0	-0.11	0.86
Average	0.07	-2.80	-2.79

Next, I calculate the aggregate change in welfare due to the steel tariffs as the sum of the discounted change in utility relative to steady-state. Table 10 shows the results for the baseline simulation (two-period tariff) and the counterfactual (four-period tariff). The first row of the table shows the percent change in welfare for each simulation. In the baseline simulation, the temporary shock leads to welfare losses of 0.08 percent. Losses roughly double when we double the duration of the tariffs in the counterfactual simulation. To put these magnitudes into perspective, Alessandria and Choi (2014) show using a similar model that permanently eliminating an 8 percent tariff on traded goods leads to welfare gains of just over 1 percent.

The second row of the table shows the share of welfare losses that accrue during the temporary shock vs the share that accrues after the tariffs are removed. A sizable portion—20 to 25 percent—of the losses are incurred after the tariffs are lifted. Similar to my reduced form results, this suggests that ignoring the long-term impacts of temporary tariff shocks can substantially alter welfare estimates.

Table 10: Model Estimated Change Welfare

	Baseline	Counterfactual
Pct Change in WF	-0.08	-0.15
Share Accrued During Shock	81.82	76.31

8 Conclusion

Using a case study of the steel tariffs levied by George W. Bush in 2002-2003 and a newly devised method for mapping detailed steel inputs to downstream users, I provide the first comprehensive estimates of the long-term effects that temporary upstream tariffs have on downstream industries. I find that temporary upstream tariffs have negative impacts on downstream industries, both in terms of their competitiveness in the export market and in terms of domestic outcomes like employment and production. Crucially, I find that these declines are highly persistent, particularly on the export margin and especially for steel-intensive industries. The global market share of U.S. downstream industries remained depressed long after the tariffs were removed as foreign buyers permanently shifted sourcing patterns toward other top producers. Using a dynamic model of trade, I show that the presence of relationship-specific sunk costs of exporting can generate a persistent response of downstream exports to a temporary input tariff that is consistent with the patterns I find in the data. Intuitively, because it is costly for countries to change sources of imports, if an input tariff induces a change in sourcing patterns, those patterns will not immediately revert when the tariffs are lifted.

Overall, my results highlight the complex nature of tariff policy in a world with globally integrated production networks. Even temporary tariffs on a small subset of imports can have persistent effects on a broad swath of the economy. Failing to take this persistence into account can lead to a substantial underestimate of the welfare implications of tariff policy.

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A Appendices

A.1 Steel-Specific IO Table

A.1.1 Data and Merge

I use three data sources to create the steel-specific input output table: exclusion requests from Regulations.gov, firm-level data from Orbis, and firm-level data from the Dunn & Bradstreet Database. Data from Regulations.gov are publicly available, and I had access to the firm-level databases through Harvard's library.

From Regulations.gov, using their API, I pulled all exclusion requests that were filed under OMB Form 064-1039 — the form that related to Trump's Section 232 steel and aluminum tariffs.

I merge firm names from the exclusion requests with Orbis to match those firms with NAICS industry classifications. For the merge, I use the fuzzy matching algorithm described in Appendix 3 of Schoenle (2017). In brief, I standardize all firm names in both databases by removing capitalization and punctuation, and transforming generic terms (like "Inc." and "Co.") into standard forms. I then merge the databases on firm name and location (U.S. state). Using this methodology I am able to match about 50 percent of exclusion requesting firms.

After the merge with Orbis I was left with 12 steel products that were covered by the Bush tariffs, were covered by the exclusion requests, but that I did not have a merge match for. I manually searched for exclusion-requesting firms for these products in the Dunn & Bradstreet database. I was able to match 11 of the 12.

A.1.2 Extending the Steel-Specific IO Methodology to Other Inputs

In this Appendix, I show that the methodology I use to create the steel-specific input-output table also works for aluminum. In principle, the same methodology should work for any input that was protected by the Trump tariffs (for which a substantial number of exclusion requests were filed). In Table 11 shows regressions of changes in material costs in downstream industries to changes in the unit value of aluminum imports. I link aluminum imports to industries using the same exclusion-request methodology that I used for the steel sector. The results show that changes in linked aluminum import unit values are significant predictors of changes in downstream material costs, even after controlling for the average price of aluminum.

Table 11: Aluminum-Import Prices Predict Downstream Material Costs: Industry-Level

	(1) Δ Material Costs	(2) Δ Material Costs
Δ Aluminum Unit Value	0.094	0.153
	(0.049)	(0.049)
Δ PPI Aluminum (Non-Ferrous Metals)		0.530
		(0.049)
Constant	-0.048	-0.009
	(0.034)	(0.033)
Year Fixed Effects	Yes	No
Sector Fixed Effects	Yes	Yes
Observations	650	650

Standard errors in parentheses
Sample years: 2001-2011.

A.1.3 Comparison with Other IO Tables

In Table 12, I list the top 10 downstream using industries of steel according to my steel-specific IO table, the publicly available IO table from the BEA, and the IO table from Berlingieri et al. (2018). The differences in these lists highlight the level of detail that my IO table is able to capture. Instead of representing industry use of *all* steel products, my IO table represents industry use of a very specific set of steel products—those that were covered by the Bush steel tariffs.

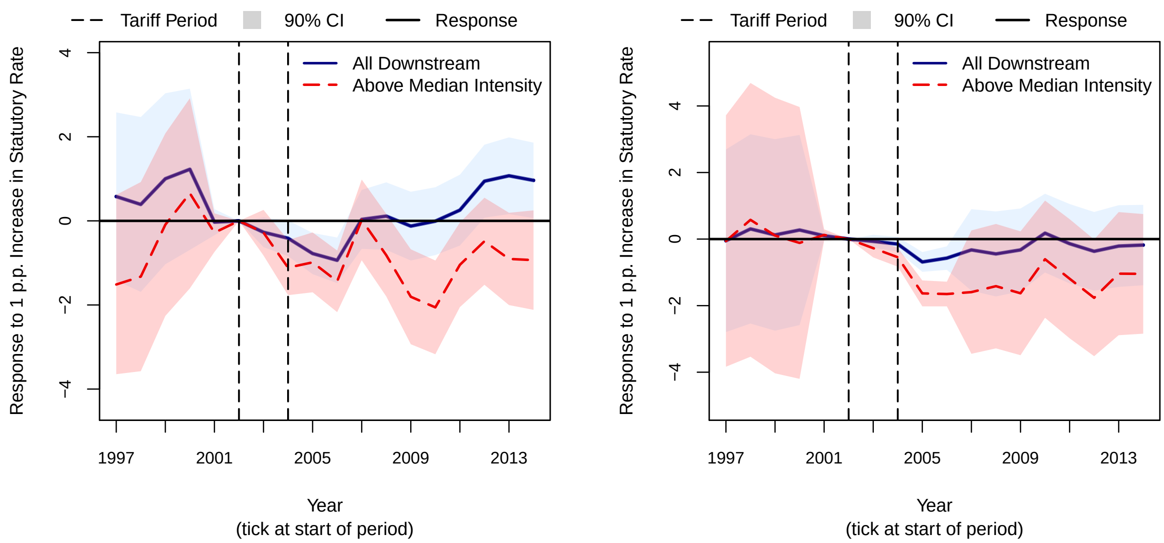
A.2 Raw Regression Results

Due to the inherently noisy quality of export price (unit value) and quantity data available from Customs, in the main body of the paper I smooth price and quantity regressions over a rolling two-year window. The raw results are presented here for transparency—the impulse responses take the same shape as the smoothed results, but are estimated with less precision.

Table 12: Intensity of Steel Use: Comparison with BEA IO Table

Steel-Specific IO	BEA IO	Berlingieri et al. (2018)
Other Metal Container Mfg	Motor Vehicle Metal Stamping	Forging, Pressing, Stamping & Roll-Forming
Metal Coating, Engraving, Allied Services	Fabricated Structural Product	Fabricated Metal Products, n.e.c.
Fruit & Vegetable Canning	Metal Tank (Heavy Gauge) Mfg	Other Transport Equipment n.e.c.
Other Motor Vehicle Parts Mfg	Spring and Wire Product Mfg	Casting of Iron and Steel
Other Transportation Equip. Mfg	Metal Crown, Closure, Metal Stamping	Bearings, Gears, Driving Elements Mfg.
Support Activities: Oil & Gas	Ornamental & Architectural Metal Prod.	Tanks, Reservoirs, Metal Container Mfg.
Fabricated Structural Metal Mfg	Other Fabricated Metal	Pumps, Compressors, Taps & Valves Mfg.
All Other Plastics Prod. Mfg	Turned Product, Screw, Nut & Bolt Mfg	Structural Metal Products Mfg.
Crane, Hoist, Monorail Sys. Mfg	Cutlery & Handtool Mfg	Treatment and Coating of Metals
Metal Can Mfg	Motor Vehicle Steering, Susp., Brakes	Domestic Appliances n.e.c. Mfg
Hardware Mfg	Other Motor Vehicle Parts Mfg	Electric Motors, Generators, Transformers Mfg.

Figure 15: Effect of Higher Statutory Rates on Downstream Exports



(a) Export Quantities

(b) Export Prices

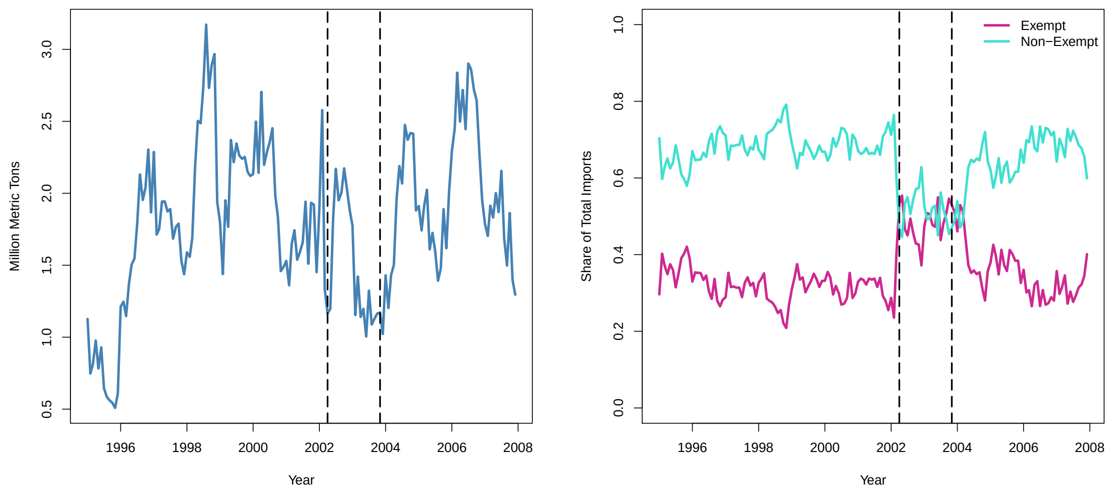
A.3 Underlying Dynamics

A.3.1 Shifting to Exempt Countries

While results presented above show that upstream tariffs have negative consequences for downstream industries, the impacts are not always direct. Safeguard remedies like the steel tariffs are put in place to reduce import competition. In theory, if buyers face a higher foreign price, they will be more likely to buy from a domestic producer. In practice, however, the choice is more complicated. The buyer of a previously imported product has two choices when faced with a new import tariff: (1) continue buying the imported product and pay the added cost of the tariff, or (2) switch suppliers and purchase from a country that is exempt from the tariff (note, this would include purchasing from a domestic source). Trade data can shed light on the choices that domestic buyers made when the Bush tariffs were enacted. The left panel of Figure 16 shows that there was not a meaningful difference in the quantity of protected steel products imported into the United States during the 2002-2003 period. What does change, however, during the tariff period is the source of those imports. The right panel of Figure 16 shows that there is a sharp increase in the share of protected imports coming from countries that were exempt from the tariffs. This change in the sourcing pattern of protected steel products lasts until the tariffs are lifted; soon after, import shares return to roughly pre-tariff levels.

To test whether industries that use inputs for which a larger share were shifted to exempt

Figure 16: Imports of Protected Steel Products



(a) Total Imports, All Countries

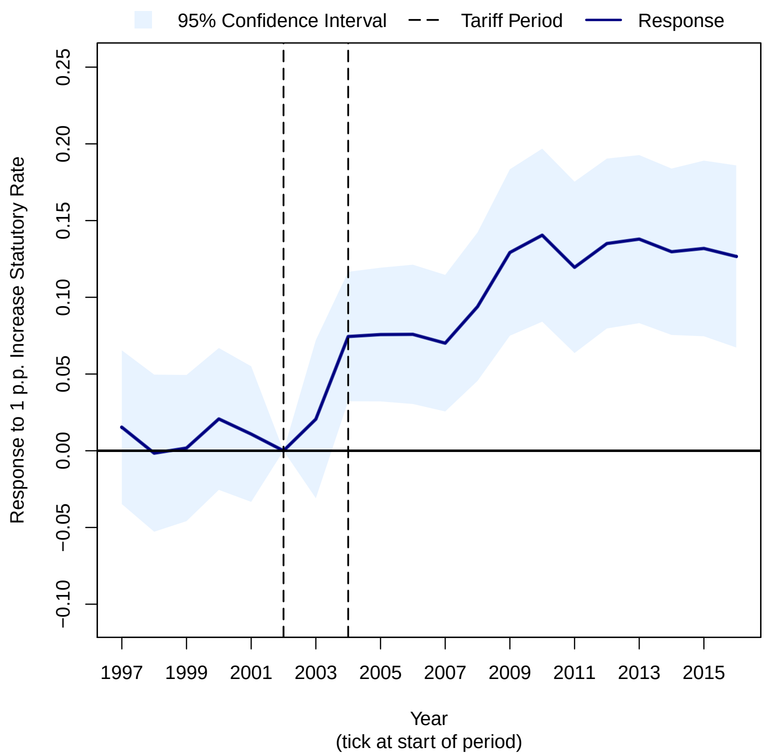
(b) Exempt vs. Non-Exempt Share

countries fared better than industries that did not shift sources, I run the same regression from equation 2, but also include the change in share of inputs coming from exempt countries between 2001 and 2003—Δ*exempt share*— on the right hand side. I plot the response of the change in the U.S. export share since 2001 to changes in Δ*exempt share* in Figure 17. The results show that industries that use inputs for which a larger share was shifted to come from exempt countries suffered a smaller relative decline in global market share.

To assuage potential concerns that the ability to shift sources is systematically related to long-term industry performance, I compare industry performance prior to the tariffs in terms of growth (or decline) in global market share to the change in exempt source share once the tariffs are in place. Specifically, the correlation between the change in an industry's export share between 1995 and 2000 (pre-tariff) and the amount that the industry shifts sources to exempt countries is 0.031 with a standard error of 0.033. In other words, industries for which inputs shifted sources in response to the tariffs were doing no better in terms of export shares prior to the tariff. (This lack of pre-trend can also be seen for 2001-2002 in Figure 17.)

There are two factors that do appear to drive the shift toward exempt sources for upstream products in response to the tariffs: the level of the tariff, and the share of the product that was being sourced from exempt countries in 2001, prior to the tariffs. The first column in Table 13 shows that upstream products that faced a higher statutory tariff rate were more likely to shift toward an exempt source—intuitively, if we assume there is a fixed cost to shifting sources, a higher tariff makes it more likely that the benefit of shifting would outweigh the cost. The second column divides upstream products into four groups: those

Figure 17: Effect of Shifting Sources on U.S. Export Share



that faced a low tariff (below median), those that faced a high tariff (above median), those that had a low share (below median) of imports from exempt sources in 2001 (high exposure) and those that had a high share (above median) of imports from exempt sources in 2001 (low exposure). The largest shift in sourcing happened for steel products that faced a high tariff, and were highly exposed to the tariff, followed by inputs that had a low tariff and were highly exposed, and those that had a high tariff and low exposure. The third column shows that having some share of imports coming from exempt countries in 2001 increases the likelihood of shifting toward exempt sources in response to the tariff—presumably, existing market share in an exempt country means a lower fixed cost of shifting—but only to a certain extent. As ex-ante exempt share increases, exposure to the tariff decreases, so there is less incentive to shift further resources.

Table 13: Drivers of Shift to Exempt Sources

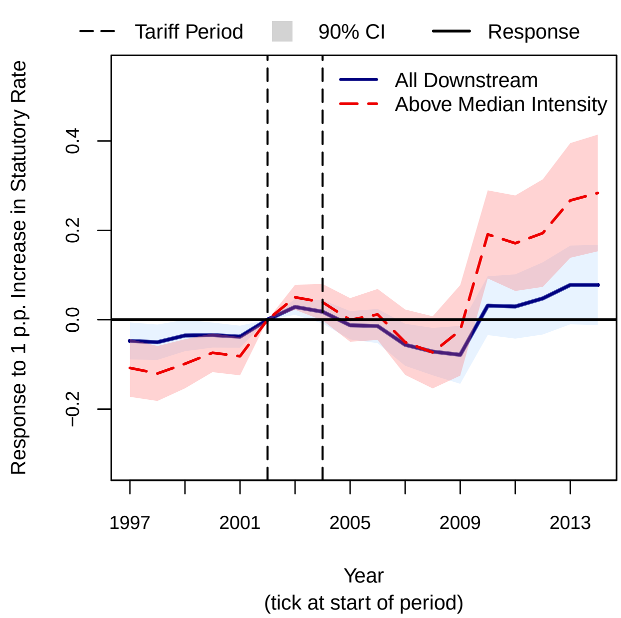
	(1) Δ Exempt Share	(2) Δ Exempt Share	(3) Δ Exempt Share
Tariff Rate	0.569		0.603
	(0.262)		(0.240)
Low Tariff × Low Exposure		0.000	
		(.)	
Low Tariff × High Exposure		0.174	
		(0.071)	
High Tariff × Low Exposure		0.136	
		(0.059)	
High Tariff × High Exposure		0.228	
		(0.059)	
Exempt Share 2001			0.658
			(0.203)
Squared Exempt Share 2001			-0.951
			(0.214)
Observations	169	169	169

Standard errors in parentheses

A.4 Global Reconfiguration: China

Figure 18 shows that, unlike Germany, Japan and France (shown Section 5.2), U.S. export shares do not appear to have shifted persistently toward China in the wake of the steel tariffs.

Figure 18: Chinese Export Shares



A.5 Model

In this appendix I provide further detail on the model presented in Section 7, its equilibrium conditions, and the solution method.

A.5.1 Equations for the Model Solution

Steel Production occurs both at home (s) and abroad (ω) using the production technologies:

$$s_t = A\ell_t \tag{9}$$

$$\omega_t = A^* \ell_t^*, \tag{10}$$

where A is a country-specific productivity parameter. Steel is tradable, and downstream goods in each country are produced using a CES composite of home and foreign steel inputs.

$$S_t = \left[s_t^{\frac{\varepsilon-1}{\varepsilon}} + \omega_t^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{11}$$

where ε is the elasticity of substitution between home and foreign steel. Steel consumption in the foreign country is analogous (unless otherwise noted, assume this is teh case going forward). Foreign variables will be demarcated with an asterisk going forward. Prices of home and foreign steel are given by $p_{s,t}$ and $p_{\omega,t}$, respectively. The home government can place a tariff, τ_s on imported steel, so that the price of foreign steel in the home country is given by $(1+\tau_s)p_{\omega,t}$. The price of the composite steel product is standard:

$$P_t^S = \left[(p_{s,t})^{1-\varepsilon} + ((1+\tau_s)p_{\omega,t})^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{12}$$

Demand for home and foreign steel in the home country will be given, respectively, by:

$$s_t^d = \left(\frac{p_{s,t}}{P_t^S} \right)^{-\varepsilon} S_t \quad \text{and} \quad \omega_t^d = \left(\frac{(1+\tau_s)p_{\omega,t}}{P_t^S} \right)^{-\varepsilon} S_t \tag{13}$$

Outside Good Sector. The outside consumption good, D_O, is produced (linearly) with labor and is sold in a competitive market. D_O is produced in both countries and is freely traded, thus I treat the outside good as the numeraire and normalize wages in both countries,

W and W^* to 1.

Households choose consumption and investment to maximize utility:

$$V_{C,0} = \max \sum_{t=0}^{\infty} \beta^t U(C_t) \tag{14}$$

subject to the sequence of budget constraints:

$$P_t C_t + Q_t B_t \leq P_t W_t L_t + B_{t-1} + P_t \Pi_t + P_t T_t \tag{15}$$

Where $\beta \in (0,1)$ is the time discount factor, C_t is consumption of final goods, Q_t and B_t are the price of and quantity of bond holdings, W_t is the real wage rate, Π_t are profits from domestic producers, and T_t is a real lump-sum transfer from the home government to the households that includes tariff revenue collected in the steel sector. Households have log utility over consumption of the final good, whose composition is described next.

Final Good Producers.
There is a final good production sector that assembles the consumption good—a Cobb-Douglas composite of the outside good, D_O and the manufactured good, D_T:

$$D_t = D_{T,t}^{\gamma} D_{O,t}^{1-\gamma} \tag{16}$$

where $D_{T,t}$ is a CES composite of domestic and foreign tradeable manufactured goods, $y_{H,t}(z,v,x)$ and $y_{F,t}(z,v,x)$:

$$D_T = \left[\sum_{m=0}^{1} \iint y_{H,t}(z,v,x)^{\frac{\rho-1}{\rho}} \psi_{T,t}(z,v,x) dz + y_{F,t}(z,v,x)^{\frac{\rho-1}{\rho}} \psi_{T,t}^*(z,v,1) dz dv \right]^{\frac{\rho}{\rho-1}} \tag{17}$$

Here, (z,v,x) is a technology triplet that defines downstream firms and will be defined in the next section, $\psi_T(z,v,x)$ and $\psi_T^*(z,v,1)$ are the distributions of downstream producers in the Home country and downstream exporters in the Foreign country, and θ is the elasticity of substitution among downstream manufactured goods.

Demand for each of the downstream goods will be given by:

$$y^d_{H,t} = \left(\frac{p_{H,t}}{P_{T,t}}\right)^{-\theta} D_T = p^{-\theta}_{H,t} P^{\theta-1}_T P_t D_t \tag{18}$$

$$y^d_{F,t} = \left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\theta} D_T = p^{-\theta}_{F,t} P^{\theta-1}_T P_t D_t \tag{19}$$

Where $P_{T,t}$ is the price index of the downstream manufactured composite good, D_T is total demand for the composite good, and P_t is the price index of the aggregate consumption good, D_t.

Downstream Manufacturing Sector

Downstream good producers are heterogeneous with respect productivity, and therefore, export status. The set-up of the downstream sector is adapted from Alessandria and Choi (2014). Incumbent firms have idiosyncratic productivity, z, which follows a first-order Markov process where a firm's probability of having productivity z' in period $t+1$ given it has productivity z in period t is given by $\Phi(z'|z)$. Next-period productivity, z' is bounded by $z' \in (\underline{z}, \bar{z})$. Establishments face an exogenous probability of "death" (or exogenous exit) given by $0 \leq n_d(z) \leq 1$. The survival rate of a firm with productivity z is given by $n_s(z) = 1 - n_d(z)$.

There is a fixed cost, f_x, associated with exporting, that depends on the firm's current export status. An incumbent exporter in period t must pay the cost f_1 in each period to continue exporting in period $t+1$. A firm that is not exporting in period t must pay f_0 to start exporting in period $t+1$, where $f_0 > f_1$. Thus, it is more costly to start exporting than to continue exporting. These fixed costs are subject to idiosyncratic shocks, v, drawn in each period from $\phi_v(v)$.

In each period, producers draw their exporting fixed cost shocks, productivity shocks, and make a decision about whether to export in the next period. Lastly, entrants pay a fixed entry cost f_E to draw a productivity parameter, z, for the next period from the distribution $\phi_E(z')$. Firms in the downstream manufacturing sector are defined by the triplet: technology (z), fixed cost shock (v), and export status (m). Let $j = (z, v, x)$. In each period, firms choose current prices, $P_{H,t}(j)$ and $P^*_{H,t}(j)$; inputs of labor, $\ell_{T,t}(j)$, and the composite steel product, $s_{T,t}(j)$; and the next period's export status. Producers have a Cobb-Douglas production technology:

$$y_{T,t} = \exp(z)\left[s_{T,t}(j)^{\alpha} \ell_{T,t}(j)^{1-\alpha}\right] \tag{20}$$

And producers solve the following Bellman equation:

$$V_{T,t}(j) = \Pi_{T,t}(j) - m\exp(v)f_x + n_s(z)\iint V_{T,t+1}(j')\phi(z'|z)\phi_v(v')dz'dv' \tag{21}$$

where m is an indicator for the firm's current export status, and f_x is the relevant export cost. Firm profits in each period, $\Pi_{T,t}$, are given by:

$$\Pi_t(j) = P_{H,t}(j)y_{H,t}(j) + mP^*_{H,t}(j)y^*_{H,t}(j) - W_t\ell_t(j) - P_{S,t}s_t(j) - f_x \tag{22}$$

Total production at Home must satisfy the demands of both home and foreign demand (subject to an iceberg trade cost, ι):

$$y_{T,t}(j) = y_{H,t}(j) + (1+\iota)y^*_{H,t}(j) \tag{23}$$

Profit-maximization will lead to optimal production of:

$$\begin{aligned} y_{H,t} &= \frac{1}{2\gamma}\left[\alpha - \eta Q - MC_{T,t}\exp(-z)\right] \\ y^*_{H,t} &= \frac{1}{2\gamma}\left[\alpha - \eta Q^* - MC_{T,t}\exp(-z)(1+\iota)^{-1}\right] \end{aligned} \tag{24}$$

Where $Q = \int_\Omega y(z)dz$ and Ω is the set of available varieties.
where $MC_{T,t}$ is the marginal cost of production for a tradeable good producer with $z = 0$.

$$MC_{T,t} = \left[\left(\frac{PS_t}{\alpha}\right)^{\alpha}\left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}\right] \tag{25}$$

and $D_{T,t}$ is total demand for the composite tradeable good and $P_{T,t}$ is the price index of the composite tradeable good at time t:

$$P_T = \left(\sum_{m=0}^{1}\int_{z\times v} P_{H,t}(z,v,x)^{1-\theta}\psi_{T,t}(z,v,x)dzdv + \int_{z\times v} P_{F,t}(z,v,1)^{1-\theta}\psi^*_{T,t}(z,v,1)dzdv\right)^{\frac{1}{1-\theta}} \tag{26}$$

$\psi_{T,t}(z,v,x)$, above, is the distribution of downstream producers in the home country and $\psi^*_{T,t}$ is the distribution of exporters in the foreign country. Total production for a firm will be given by:

$$y_{T,t} = \left[\frac{\theta}{\theta-1} MC_{T,t}\right]^{-\theta} \exp(\theta z) \left(P^{\theta}_{T,t} D_{T,t} + (1+\iota)^{1-\theta} P^{*\theta}_{T,t} D^*_{T,t}\right) \tag{27}$$

Let the value of a producer j that decides to export in period $t+1$ be:

$$V^1_{T,t}(j) = \max \Pi_{T,t}(j) - \exp(v) f_x + n_s Q_t \iint V_{T,t+1}(z', v', 1)\phi(z'|z)\phi_v(v')dz'dv' \tag{28}$$

And let the value of a producer j that does not export in period $t+t$ be:

$$V^0_{T,t}(j) = \max \Pi_{T,t}(j) + n_s Q_t \iint V_{T,t+1}(z', v', 0)\phi(z'|z)\phi_v(v')dz'dv' \tag{29}$$

Then, the actual value of a producer will be equal to $V_{T,t}(j) = \max\{V^1_{T,t}, V^0_{T,t}\}$. As is standard, there will exist a productivity threshold, $z_{m,t}(v)$ such that an establishment is indifferent between exporting and not exporting. This export threshold will depend on the establishment's current export status, m, productivity, z, and fixed cost shock v.

Lastly, new establishments are created by incurring a fixed entry cost, f_E, in the period prior to production. Entrants draw a productivity z from the distribution $\phi_E(z')$ and entrants *cannot* export in their first period of production. Free entry requires that:

$$V^E_{T,t} = f_E + Q_t \iint V_{T,t+1}(z', v', 0)\phi_E(z')\phi(v')dz'dv' \leq 0 \tag{30}$$

Aggregation. Integrating over producers, aggregate production in the home country downstream industries will be given by:

$$H_{T,t} = \left[\frac{\theta}{\theta-1} MC_{T,t}\right]^{-\theta} P^{\theta}_{T,t} D_{T,t} \left[\Psi_{T,t} + u(1+\iota)^{1-\theta}\Psi_{X,t}\right] \tag{31}$$

where $u = P^{*\theta}_{T,t} D^*_{T,t} / P^{\theta}_{T,t} D_{T,t}$ and

$$\Psi_{T,t} = \iint \exp((\theta-1)z)\psi_{T,t}(z,v,x)dzdv \tag{32}$$
$$\Psi_{X,t} = \iint \exp((\theta-1)z)\psi_{X,t}(z,v,1)dzdv \tag{33}$$

Aggregate steel and labor used for production will be given by:

$$S_{T,t} = \alpha\left(\frac{MC_{T,t}}{P_t^S}\right)H_{T,t} \tag{34}$$
$$L_{T,t} = \frac{1-\alpha}{\alpha}P_t^S S_{T,t} \tag{35}$$

A.5.2 Equilibrium

In an equilibrium, variables satisfy a number of resource constraints. The final goods market clearing conditions are met in both countries:

$$D_t = C_t$$

The steel market clears in both countries:

$$s_t + \omega_t = s_t^d + \omega_t^d$$

And:

$$S_t = S_{T,t}$$

Labor market clearing condition are met:

$$L = L_S + L_O + L_T + L_F$$

Where $L_F = f_E * N_E + f_0 \iint_{z_{0,t}(v)}^{\bar{z}} \exp(v)\psi_{T,t}(z,v,0)dzdv + f_1 \iint_{z_{1,t(v)}}^{\bar{z}} \exp(v)\psi_{T,t}(z,v,1)dzdv$ is labor used to cover the fixed costs of entry and exporting. Feasibility conditions are met in the market for downstream manufactured goods in both countries:

$$Y_{H,t} = y_{H,t} + (1+\iota)y^*_{H,t}$$

And tariff revenue and profits are distributed to households. An equilibrium is a collection of consumption allocations for home and foreign consumers, C, B_t, C_t^* and B_t^*; allocations, prices, and export decisions for home and foreign manufacturing producers; prices and allocations for outside sector producers; labor used for exporting and entry costs at home and in foreign, and transfers by home and foreign governments, bond prices, Q_t. The allocations are such that:

- Households maximize utility (14)
- Final good producers maximize profits. (25)
- Downstream producers choose steel inputs, labor inputs, and prices to maximize profits. (18)
- Free entry conditions are met in the downstream sector. (30)
- Market clearing conditions hold.

A.5.3 Calibration

Here I will describe the calibration. When available, I start with the parameters set at the levels used by Alessandria and Choi (2014) which are set to target empirical moments describing the distribution of U.S. manufacturing establishments in 1987. I make adjustments to those parameters to fit my empirical results. In ongoing work, I am adjusting the parameterization to ensure consistency with relevant empirical moments describing the distribution of manufacturing establishments in 2001—relevant to my case study.

The discount factor, β is standard at 0.96. As in Alessandria and Choi (2014), the structure of shocks determines the distribution of establishments in the downstream manufacturing sector. Productivity is modeled as an AR(1), so that $z' = \rho z + \epsilon$ where $\epsilon \sim N(0, \sigma_\epsilon^2)$. This renders a log-normal distribution of U.S. manufacturing establishments consistent with Alessandria and Choi (2014) and others in the literature. I set $\rho = 0.65$ and $\sigma = 0.2$.
The elasticity of substitution, θ is set to 5, consistent with Alessandria and Choi (2014), and γ—the share of downstream manufactured goods in final good consumption—is set to 0.4. This is higher than what is in Alessandria and Choi (2014) (0.21), which is needed in order to ensure downstream exports occur at a high enough level. Fixed costs for new and continuing exporters are set at $f_0 = 5.0$ and $f_1 = 1.5$ — for now I set these to match my empirical results. Steel's share of costs in the downstream sector, α, are calibrated to match the steel cost shares in my data—0.15 for all producers and 0.3 for steel intensive producers. Other relevant parameters are listed in Table 14.

Table 14: Model Parameters

Parameter	Description	Calibration
β	Discount Rate	0.96
ρ	Productivity AR(1) Persistence	0.65
σ_ϵ	Std dev. of productivity distribution	0.2
γ	Cobb-Douglas share of manufactured goods in final consumption	0.4
θ	Elasticity of substitution, downstream	5.0
f_0	Fixed cost for new exporter	5.0
f_1	Fixed cost for continuing exporter	1.5
f_E	Entry cost	0.5
n_d	Exogenous death probability	0.005
α	Steel's Cobb-Douglas share of downstream costs	0.3 or 0.15
ε	Steel sector, Armington Elasticity	2.0

A.5.4 Solution Method

I solve the model following the procedure detailed in the Technical Appendix of Alessandria and Choi (2014). In brief, I solve for the steady-state and then use a shooting algorithm to solve for the transition path.

A.5.5 Who Pays the Sunk Cost?

Here, I show that regardless of which party pays the relationship-specific sunk cost, the foreign importer or the home exporter, the sunk cost will result in the same condition for the exporting threshold for home country firms.

Consider a static model in which a foreign country deciding to buy imports from the home country must pay a fixed cost, f_S, so that the per-unit price of the home good is given by: $p^*_{a,t}(z) + \frac{f_S}{a^*_t(z)}$. The foreign country will have demand for home good, $a^*_t(z)$, equal to:

$$\frac{a^*_t(z)}{Y^*_t} = \left(\frac{p^*_{a,t}(z) + \frac{f_S}{a^*_t(z)}}{P^*_t}\right)^{-\rho}$$

Home country profits will be given by:

$$\Pi_t(z) = p_{a,t}(z)a_t(z) + x_t(z)p^*_{a,t}(z)a^*_t(z) - \ell_t(z) - x_t(z)f_X$$

Solving for $p^*_{a,t}$:

$$p^*_{a,t} = \left(\frac{a^*_t(z)}{Y^*_t}\right)^{\frac{-1}{\rho}} P^*_t - \frac{f_S}{a^*_t(z)}$$

Plugging this into the profit function:

$$\begin{aligned}\Pi_t(z) &= p_{a,t}(z)a_t(z) + x_t(z)\left[{Y_t^*}^{\frac{1}{\rho}} P_t^* a_t^*(z)^{\frac{\rho-1}{\rho}}\right] - x_t(z)a_t^*(z)\frac{f_S}{a_t^*(z)} - \ell_t(z) - x_t(z)f_X \\ &= p_{a,t}(z)a_t(z) + x_t(z)\left[{Y_t^*}^{\frac{1}{\rho}} P_t^* a_t^*(z)^{\frac{\rho-1}{\rho}}\right] - \ell_t(z) - x_t(z)(f_S + f_X)\end{aligned}$$

Instead, suppose that it is the home country exporter that is required to pay the fixed cost to export to the foreign country. Now, foreign demand will be given by:

$$\frac{a_t^*(z)}{Y_t^*} = \left(\frac{p_{a,t}^*(z)}{P_t^*}\right)^{-\rho}$$

Home country profits will be given by:

$$\Pi_t(z) = p_{a,t}(z)a_t(z) + x_t(z)p_{a,t}^*(z)a_t^*(z) - \ell_t(z) - x_t(z)(f_S + f_X)$$

Once again, solving for $p_{a,t}^*$ and plugging back into the profit function yields:

$$p_{a,t}(z)a_t(z) + x_t(z)\left[{Y_t^*}^{\frac{1}{\rho}} P_t^* a_t^*(z)^{\frac{\rho-1}{\rho}}\right] - \ell_t(z) - x_t(z)(f_S + f_X)$$

Carrying through with profit-maximization yields the static solution for firms in the home country:

$$\Pi_t(z) = \Pi_D \exp(z) + \max(\Pi_D^* \tau^{1-\rho} \exp(z) - (f_X + f_S), 0)$$

Where $\Pi_{D,t}(z)$ is given by:

$$\Pi_{D,t} = \frac{P_t^\rho Y_t}{\rho^\rho(\rho-1)^{1-\rho}}$$

(First-time) home-country exporters will sell to foreign countries if:

$$\Pi_D^* \tau^{1-\rho} \exp(z) > (f_X + f_S)$$

Thus, regardless of which country is responsible for paying the sunk cost to start exporting/importing, the resulting condition on home-country exporters will be the same.