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Abstract

We find evidence that US manufacturing sectors experience US import tariffs either as supply-side or demand-side shocks, depending on the location of the sector and the affected products in the US production network. Using local projections in a panel of US manufacturing sectors, we find that US import tariffs – in particular including the 2018-19 tariff hikes – led to sectoral output contractions via two different channels: (1) Tariff increases act as negative supply shocks for sectors that use the affected goods as input in production and thus face rising input costs. (2) Tariff increases act as negative demand shocks for sectors whose customers experience the tariff increase as a negative supply shock and reduce their production. Though the aim of tariffs often is to protect local industries, we find only limited evidence of such a protective effect. Overall, our finding suggests that tariffs markedly reduce US manufacturing production and that the role of input-output linkages is key for understanding the transmission of import tariff shocks.

Keywords: Import tariffs, sectoral production and prices, input-output-tables, production networks, United States.
JEL-Classification: E23, E32, F13.

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1 Introduction

The macroeconomic literature has highlighted the importance of sectoral input-output linkages in the transmission of sectoral and aggregate shocks (cf. Carvalho and Tahbaz-Salehi 2019). More recently, it turned to the question on the transmission of trade shocks.[1] This comes as import tariffs have become a corner stone of US trade policy in recent years.[2] Yet, the empirical evidence on the transmission of trade shocks through the domestic input-output network has been scarce. This raises the question, how and through which channels import tariffs affect price and output dynamics of US industries.

Ex ante, higher import tariffs on a given good may be a supply shock for some US sectors and a demand shock for others, depending on the location of the good and the sector in the domestic production network. Import tariffs typically aim at protecting the local industry from foreign competition, potentially raising the demand for goods produced in the protected sectors. In the domestic production network, suppliers to customers in protected industries may also benefit from that rise in demand of that customers. At the same time, tariffs imposed on imported intermediate goods raise input costs in sectors that use these goods as input in their production. Importantly, such supply-type repercussions may amplify output losses via the domestic production network. If, for instance, car engines face increased import tariffs, cars will likely become more expensive as well, because car production requires engines as intermediate inputs. This dampens the demand for cars. Moreover, other US sectors that supply inputs to US car production – such as, e.g., electronics – will face a lower demand for their products as their customers in the car industry reduce their production due to the tariff increase. We aim to assess the relevance of these intertwined channels empirically.

To disentangle the effects of import tariffs on US industries, we use US input-output data and construct measures of the industries' potential tariff exposures via linkages in the production network. Specifically, we utilize a panel of 71 US manufacturing industries with data spanning from 2005 to 2020 to compute measures of backward and forward exposure in the domestic production network.

To identify sector-specific tariff shocks, we use tariff information on US imports at the HS-10 product level that we aggregate at the sectoral level. The interaction of the identified tariff shocks with backward and forward linkages of a specific industry to other industries allows us to trace the transmission of sector-specific tariff shocks within a production network. In addition, we can separate the direct (i.e. horizontal) effect of import tariffs within an industry. Furthermore, we

[1] See, e.g., Caliendo and Parro (2015); Caliendo et al. (2021); Bachmann et al. (2022); Baqaee and Farhi (2024).

[2] The first Trump administration increased import tariffs markedly in 2018 and 2019. Over the course of these years, average import tariffs jumped by close to 2pp. In his second term, president Trump enacted additional and far more dramatic imports tariff hikes.

can differentiate between the effects of shocks to tariffs on intermediate goods and final goods. Notably our approach is designed to study short-run dynamic responses to import tariff hikes.

We find that via the backward exposure of industries to imported inputs, tariff increases are transmitted as negative supply-type shocks. Raising an industry's input costs, tariffs on intermediate goods imports also raise its producer prices and reduce its output. In addition, our results suggest that the direct effect of a sector-specific tariff shock, which is the estimated effect of an import tariff that hits the own' sectors products, also acts like a supply-type shock. This owes to the fact that at the level of sectoral aggregation in which we conduct our analysis, input-output tables reveal strong intra-industry linkages with most sectors being their own key supplier. Finally, our analysis provides evidence that tariff hikes act as negative demand shocks for sectors whose customers experience the tariff increase as a negative supply shock and reduce their demand for the industries goods. Consequently the industry's output declines and its producer prices as well.

Overall, we find that US import tariffs markedly reduce production of US manufacturing sectors. We show that this effect is largely owing to the transmission of import tariffs on intermediate goods. Tariffs on imported intermediate goods that increase production cost in one sector are significantly amplified by the transmission via backward and forward input-output linkages in the production network.

Our results speak to theoretical contributions emphasizing the role of complementarities in the input-output network. In particular, Guerrieri et al. (2022) show in a New Keynesian model that within production networks, a macroeconomic shock that affects one sector negatively on the supply-side can lower demand in other sectors. Our finding of the effect of the forward tariff exposure channel presents novel evidence confirming their theoretical insights. Moreover, we provide evidence for the amplification of supply-type trade shocks in input-output networks (see, e.g., Baqaee and Farhi 2024).

Though the aim of tariffs often is to protect local industries, we find only limited evidence of such a protective effect. Only in the case of positive tariff shocks on final goods we find that suppliers to the industries that produce the affected final goods experience an increase in demand. However, this increase is short-lived. Further we do not find any direct protective effect of final goods tariff shocks on the affected industry itself via the horizontal channel. Overall, our findings suggest that, at least in the short run, the negative effects on manufacturing production by US import tariffs on intermediate goods – that are amplified in the input-output network – outweigh any positive effects of potentially protective tariffs on final goods.

Notably, while we find overall negative effects on production, the sign of the sectoral producer price response depends on the channels, via which the sector is exposed to tariff shocks. The finding thus highlights that the effect of import tariff shocks on the aggregate price level (such as the US aggregate produce price) crucially depends on the relative importance of upward and downward affected sectors in the domestic production network.

Related literature

We are not the first to analyze the effects of US import tariffs on manufacturing output and prices of US industries. Closest to our investigation is the analysis by Flaaen and Pierce (2025). Using a difference-in-difference approach they investigate the effects of the 2018-2019 tariffs via the backward exposure (rising input cost) channel, a protection channel and retaliatory tariffs. In line with these findings, we confirm that US import tariffs markedly raise producer prices of industries via the backward exposure channel. In contrast to our finding, they do not find any significant output effects. Importantly, we add to their study by highlighting the role of forward exposure in the US production network for the transmission of tariff shocks. Barattieri and Cacciatore (2023) study the dynamic employment effects of temporary trade barriers through vertical production linkages and find evidence for marked employment declines in downstream industries that correspond to large input price hikes. We add to this paper by focusing on import tariff shocks as well as taking forward linkages into account. Moreover, our evidence concerns the role of output responses instead of employment, which allows us to characterize supply- and demand-type patterns arising from tariff shocks.

In the theoretical macroeconomic literature, the role of input-output linkages for the transmission of trade shocks has gained much attention in recent years. Caliendo and Parro (2015); Caliendo et al. (2021); Baqaee and Farhi (2019) employ multi-sector models and highlight the importance of input-output linkages and sectoral heterogeneity for the correct assessment of trade shocks on trade, output and welfare. Our empirical results corroborate insight that the effect of tariff rate shocks on industries differ, depending on the goods that are subject to tariffs and the location of the industry in the production network. Our analysis thereby focuses on the transmission of the domestic production network, while we abstract from possible connections of domestic sectors due to linkages in the foreign production networks.

The limited evidence we find for protective tariff effects, we find in the case of tariffs on final goods, while tariffs on intermediate goods lower industries' output regardless of the considered channel. This is in line with Deutsche Bundesbank (2020), who show in a simple New Keynesian model with global value chains, that final good tariffs may mildly stimulate domestic production in the short run, whereas intermediate goods tariff weigh on production. Antonova et al. (2025) cast this argument into a multi-sector model, highlighting that whether a tariff shock is recessionary or expansionary depends on whether it mainly hits upstream or downstream industries. Simulating their model they find that the effect of the "Liberation Day" tariffs enacted briefly by the United States in early April 2025 was highly stagflationary.

Finally, we contribute to the literature studying the implications of (US) trade policy shocks for the domestic economy (see, inter alia, Amiti et al. 2019; Furceri et al. 2019; Lindé and Pescatori 2019; Jacquinot et al. 2022 and Khalil and Strobel 2024). We add to these papers by focusing on role of the domestic production network in the transmission of trade policy shocks.

We proceed as follows: Section 2 presents the data and the data treatment. Section 3 discusses the construction of the tariff exposure measures. Section 4 lays out our econometric approach. Our main results are discussed in section 5. In section 6, we differentiate between intermediate goods tariff shocks and final goods tariff shocks. We also decompose the effect of tariff shocks into the transmission via inter-industrial and inter-industrial linkages. Section 7 concludes.

2 Data and concordance

We use data from January 2005 to January 2020 on US goods imports and import duties, sectoral industrial production and producer prices, as well as sectoral input-output tables. We retrieve monthly data on the dollar value of imports and calculated duties of US imports at the disaggregated HS-10 level from the US Census District-level reports.[3] Sectoral data on monthly industrial production and producer prices of industries according to the North American Industry Classification System (NAICS) are sourced from the Federal Reserve and from the Bureau of Labor Statistics, respectively. In addition, we use yearly input-output tables by the Bureau of Economic Analysis (BEA) at the 71 industries – 73 commodities level. Details on the data sources are outlined in Appendix A.

To facilitate the investigation of the tariff exposure of US industries, we map the HS-10 product codes covered by tariffs to NAICS industries at the 6-digit industry level employing the concordance tables provided by Pierce and Schott (2012). In calculating industry-specific tariff rates we divide the sum of the calculated duties on products associated with an industry by the sum of the import values of these HS-10 products. As NAICS codes are revised every five years, we concord NAICS6 industry codes from the full observation period (2005-2019) into the 2012-NAICS6 classification. To allow for the construction of tariff exposure measures, which capture industries' exposure via their input and output linkages, we match the 2012-NAICS6 codes to the 412 industries of the 2012-vintage BEA input-output tables. As industrial production series are not available at this disaggregated level, we need to go up the aggregation classification tiers for our purposes. Thus, we utilize the input-output tables at the 71industry/73commodity BEA classification, which are available on a yearly frequency. Details on the concordance are outlined in Appendix B.

Producer prices and industrial production series are available at different NAICS levels. In our

[3] See `https://usatrade.census.gov/`.

analysis, we restrict the universe of industries to those for which we have industrial production series. Further, not all of the commodities in the input-output-tables have import data and tariff rates. This restricts the construction of BEA commodity level tariff rates to 21 non-service commodities.

3 Identifying tariff rate shocks and input-output linkages

In the following we outline how we identify tariff rate shocks as well as how we measure backward and forward linkages in the US product network. More details are reported in Appendix C.

3.1 Tariff rate shocks

The US administration sets the tariff rates at the disaggregated HS-10 product level. To calculate the tariff rate τ_j that is specific to the BEA commodity j at a higher aggregation level, we sum the import duties on all HS-10 products associated with the BEA commodity j and divide it by the sum of import values. That is, in our analysis we use an average effective tariff rate, that not only reflects changes in the tariff rate set by the administration, but also composition effects. Such composition effects arise, for instance, if domestic importers reroute imports to other destinations in the light of higher bilateral tariffs.

3.2 Input channel - backward exposure measure

Industries are exposed to tariff changes through their input costs. Consider an unexpected rise in the import tariff rate on commodity j. Then, US industries that use product j in their production process face a cost shock, the extent of which is determined by the relative importance of the product in their production process (measured by its cost share from total inputs) and the import share in total supply. An industry is thus exposed through all the commodities involved as inputs in its production process. We refer to this as backward exposure to tariffs. More formally, for each commodity j that industry i uses, consider

$$BW_{i,j,y} \equiv \frac{use_{i,j,y}}{M_{i,y} + CE_{i,y}} \times \frac{imp_{j,y}}{supply_{j,y}} = USE_{i,j,y} \times IM_{j,y}, \quad (1)$$

where $use_{i,j,y}$ is the volume of commodity j used by industry i as an intermediate input in year y. $M_{i,y}$ is the total intermediate use of inputs by industry i in year y and $CE_{i,y}$ is the total compensation of employees paid within industry i in year y. $imp_{j,y}$ is the volume of imports of commodity j in year y.and $supply_{j,y}$ denotes the total supply of commodity j (i.e., domestic supply plus imports) in year y.

More compactly written, $USE_{i,j,y}$ represents industry i's use share of commodity j in its production process in year y. This term approximates the direct vertical linkage between commodity j and industry i. $IM_{j,y}$ is the import share of commodity j in its total supply. Since the BEA use tables do not allow the use of commodity j by industries to be differentiated between use of *domestically* produced and imported j, we multiply $USE_{i,j,t}$ by the economy-wide import share of j (namely $IM_{j,y}$) to obtain a proxy for the backward exposure of industry i to tariffs on commodity j, $BW_{i,j,y}$.

The backward exposure measure was introduced in Flaaen and Pierce (2025) and used in Khalil and Weber (2022) and Amiti et al. (2019) and Benguria and Saffie (2019). Different from their analysis, we here account for the yearly time variation in the input-output linkages. This allows us to captures changes in the exposure to the technology changes (cf. Bown et al., 2020).[4]

3.3 Output channel - forward exposure measure

In addition to the backward exposure measure, we introduce a second exposure measure that attempts to measure exposure to tariffs through industries' output linkages in the domestic production network.

The forward exposure measure captures how an industry is exposed to a tariff that affects its customers in other industries. We define the forward exposure measure $FW_{i,j,x,y}$ for an industry i, which domestically produces a commodity x and another industry j using this commodity as an input, in year y.

Let the government raise the import tariff on the product(s) that industry j produces. This sector now ought to be "protected" by tariffs and if demand were to be redirected from foreign producers toward j, we could expect its demand for inputs to increase, including for x. If such a protective channel were active, industry i would benefit from the introduction of tariffs on goods produced by industry j through its product x's output linkage. On the other hand, a tariff hike on the products that industry j produces can also lead to output contractions in sector j. As input-output tables reveal strong intra-industry linkages with most sectors being their own key supplier, a tariff shock on j products can act a negative supply-type shock for j produced goods.

The BEA *make* and *use* tables do not contain information on what share of an industry *i's* production of x is used by industry j. We thus proxy the forward linkage of i to j through x by using the dollar value of industry i's total supply of commodity x and the total demand of

[4]In the regressions, we use a predetermined moving-average to capture structural exposure.

each industry for the good x. The forward linkage between industry i and industry j through commodity x thus reads

$$FW_{i,j,x,y} \equiv \underbrace{\frac{supply_{i,x,y}}{supply_{x,y}}}_{\substack{\text{commodity } x\text{' } \\ \text{supply share} \\ \text{from industry } i}} \times \underbrace{USE_{j,x,y} \times (1 - IM_{x,y})}_{\substack{\text{industry } j\text{'s domestic} \\ \text{demand of commodity } x}}. \tag{2}$$

$USE_{x,j,y} \times (1 - IM_{j,y})$ approximates the share of commodity x that industry j sources domestically. Multiplying it with the domestic supply share of industry i in the production of commodity x, we obtain a proxy for the domestic sourcing of commodity x by j that is supplied by industry i. Taking a weighted average of such commodity-specific linkages over all commodities, we obtain a total linkage between the two industries

$$FW_{i,j,y} \equiv \sum_x w_{i,x,y} \times FW_{i,j,x,y}, \tag{3}$$

where $w_{i,x,y}$ is given by commodity x's relative importance in industry i's total output, $\frac{supply_{i,x,y}}{supply_{i,y}}$.

3.4 Input-output linkages in 2017

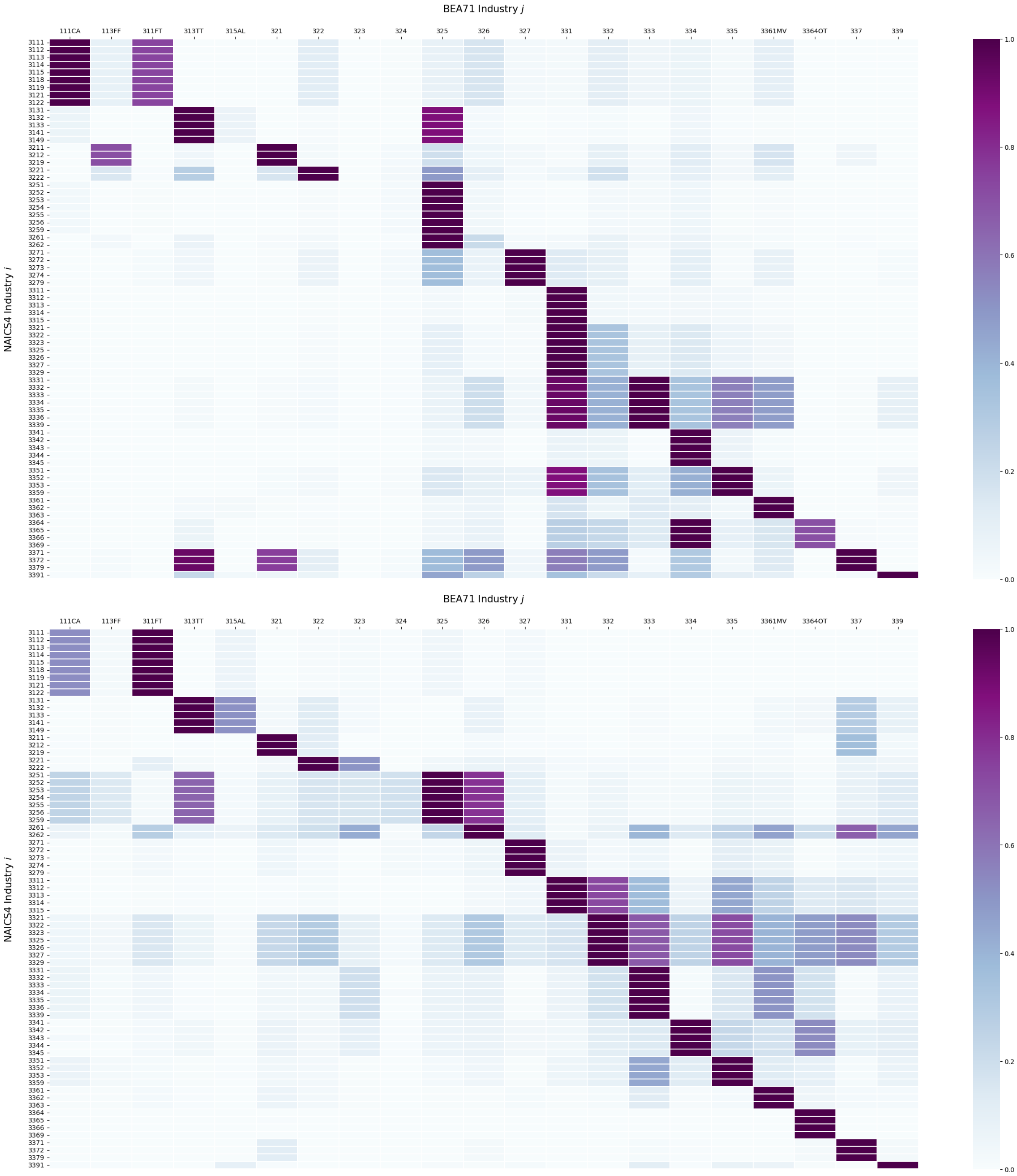
Figure 1 shows the distribution of backward linkages and forward linkages in the US production network. The heatmaps depict backward and forward exposure normalized by row as $(\frac{BW_{i,j}}{\max_j BW_{i,j}})$ and $(\frac{FW_{i,j}}{\max_j FW_{i,j}})$. The darker the cells, the higher are the exposure of industries to tariffs via input or output linkages. Importantly, most industry's overall exposures are concentrated in a few linkages.

As it turns out, at the level of disaggregation in which we conduct our analysis (71 sectors; mostly NAICS-4 industries), firms in a given industry tend to be important suppliers and customers to other firms in the same industry. Our baseline backward and forward exposure measures contain both intra-industrial and inter-industrial linkages. In Section 6.2, we show that our main results hold, when we analyze the tariff exposure only focusing on inter-industry links.

4 Empirical strategy

We employ the local panel projections approach by Jorda (2005) to estimate the effect of import tariff changes on industry-specific production and output prices in the US manufacturing sector,

Figure 1: Tariff exposure linkages in the US input-output table



Upper panel: Normalized backward exposure linkages of NAICS industries (y-axes) to BEA commodities (x-axis) in 2017. Lower panel: Normalized forward exposure linkages of NAICS industries (y-axes) to BEA commodities (x-axis) in 2017. Darker cells indicate a higher exposure of industries via production network linkages.

taking input-output linkages into account.[5] Let $\mathcal{Y}_{i,t}$ denote either the log of the producer prices PPI or the log of the industrial production IP of NAICS industry i in month t. The estimation sample spans $t =$ January 2005 to January 2020. Consider the following *panel* local projection specification independently estimated for each $h = 0, 1, \ldots, 17$

$$\Delta_c \mathcal{Y}_{i,t+h} = \alpha^{(h)} + \underbrace{\mu^{(h)} \Delta T_{i,t}}_{\substack{\text{Horizontal}\\ \text{channel}}} + \underbrace{\beta^{(h)} \mathbf{BW}_{i,t} \times \Delta \mathcal{T}^{Input}_{i,t}}_{\text{Input channel}} + \underbrace{\gamma^{(h)} \mathbf{FW}_{i,t} \times \Delta \mathcal{T}^{Output}_{i,t}}_{\text{Output channel}} + f_i + \delta^{(h)} C_{i,t-l} + \varepsilon^{(h)}_{i,t+h}, \tag{4}$$

where $\Delta_c \mathcal{Y}_{i,t+h}$ is the cumulative change between t and $t + h$ for either the producer price or industrial production index, both in log. $\Delta T_{i,t}$ is the monthly change in the tariff rate applied to NAICS4 industry i. $\Delta \mathcal{T}^{Input}_{i,t}$ and $\Delta \mathcal{T}^{Output}_{i,t}$ are monthly changes in the weighted average tariffs faced by sectors to which industry i is linked backward and forward. $BW_{i,t}$ and $FW_{i,t}$ are the aggregate backward and forward exposures defined as $BW_{i,y} \equiv \sum_j BW_{i,j,y-1}$ and $FW_{i,y} \equiv \sum_j FW_{i,j,y-1}$ where $y-1$ denotes a one-year lag of the exposure measures. This ensures that the exposure measures are pre-determined at date t and not affected by changes in tariff rates. We control for industry fixed effects f_i, and for a vector of control variables, $C_{i,t}$, which contain $\mathbf{BW}_{i,t}$, $\mathbf{FW}_{i,t}$ as wells as twelve lags of $\Delta \mathcal{Y}_{i,t}$, $\Delta T_{i,t}$, $\mathcal{T}^{Input}_{i,t}$, $\mathcal{T}^{Output}_{i,t}$ $\mathbf{BW}_{i,t} \times \Delta \mathcal{T}^{Input}_{i,t}$, and $\mathbf{FW}_{i,t} \times \Delta \mathcal{T}^{Output}_{i,t}$.[6] In addition, control vector $C_{i,t}$ contains a wide range of variables characterizing the economic conditions, namely current values and 12 lags of the log changes of US real GDP, the S&P Goldman Sachs Brent Crude Index, the US City Average Price for Electricity, the Natural gas future price, the effective Federal Fund Rate, and the US dollar effective exchange rate. The coefficients $\mu^{(h)}$,$\beta^{(h)}$, and $\gamma^{(h)}$, capture the effects of tariffs on sector i's production and producer prices via the horizontal channel, the backward exposure and the forward exposure of an industry.

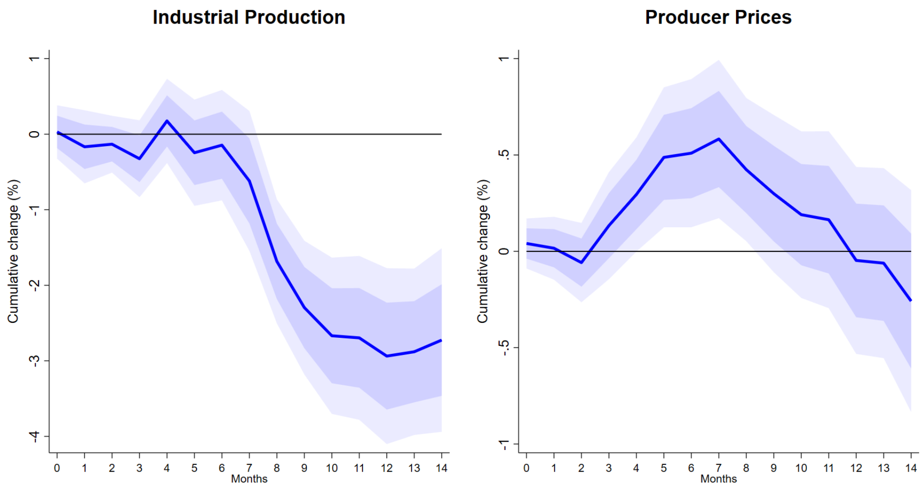
5 Consequences of US import tariff hikes for US production

This section discusses our empirical results on the transmission of sector-specific tariff shocks through the industries' backward tariff exposure, the horizontal channel and the forward tariff exposure.

[5]More details on the empirical specification are described in Appendix D

[6]Montiel Olea and Plagborg-Møller (2021) show that the inclusion of an additional lag of the dependent variable in the LP accounts for the serial correlation in the residuals, validating inference based solely on heteroskedasticity-robust standard errors.

Figure 2: The role of exposure to imported intermediates in the transmission of tariff shocks



Cumulative response in % to a 1pp increase of the weighted average input tariff faced by an average industry. In scaling the effect, we set the average backward exposure across all industries to its 2022 mean (14%). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

5.1 The effect of a tariff via the industry's backward linkages

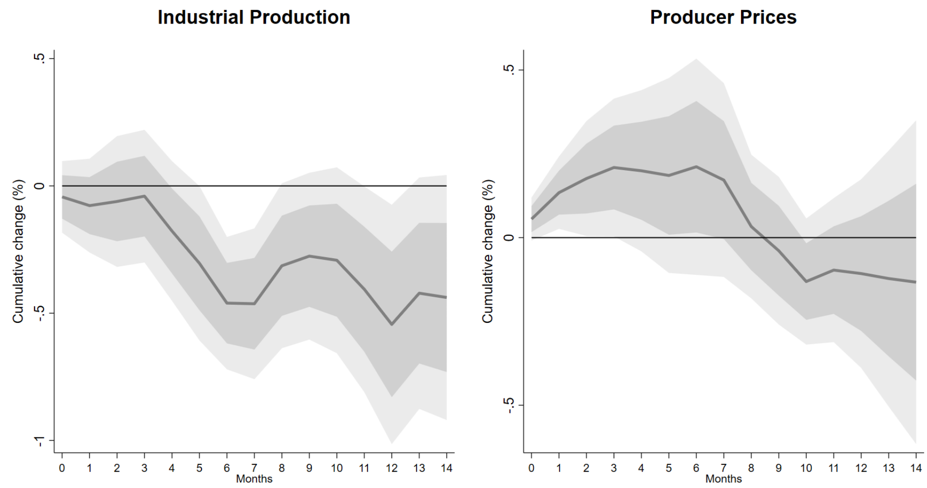
We find that, via the channel of the backward exposure of industries to imported inputs, tariff shocks affecting suppliers are transmitted as supply-type disturbances (Figure 2). Previous studies show that US pre-tariff import prices did not change after the 2018-19 tariff hikes (cf. Amiti et al. 2019; Fajgelbaum et al. 2020), leading to a near complete pass-through to importers. Thus, tariff hikes affecting industries via their input suppliers directly increase production costs. Our results indicate that these shocks raise average producer prices and lower production. Prices increase after a quarter, pointing at nominal rigidities, and peak at 0.5% seven months after an one percentage point increase of a weighted average input tariff faced by an industry via its backward exposure. Production starts to contract after half a year, eventually decreasing by up to 3%. The sluggish output response may be due to firms depleting their input stocks before adjusting production.

5.2 The effect of a tariff directly on the industry's goods

Figure 3 shows the effects of tariff hikes on goods produced in a specific sector on output and producer prices of that sector. We call this the direct or horizontal effect of tariffs. Interestingly, we find that direct tariff shocks also act as negative supply shocks.

A possible explanation is that US input-output tables reveal strong intra-industry linkages, with

Figure 3: The effects of direct tariff shocks



Cumulative response in % to 1pp increase of weighted average tariff faced by average industry. Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

most sectors being their own key suppliers and customers. Thus, tariffs on imports intended to protect the production of some firms in this industry, also raise input costs for other firms within that industry. While protective effects may exist on a more disaggregated level, at the level of sectoral aggregation in which we conduct the analysis, the contractionary effects from higher input costs within a sector appear to be dominant.[7] This explains why the response via the horizontal channel is at least in the short-term similar to that via the backward channel, with negative effects on output and positive effects on prices.

We find no evidence that tariffs on imported goods protect the domestic industry producing the same goods. This aligns with other findings in the literature on the dynamic implications of protectionist measures for the domestic economy (cf. Flaaen and Pierce 2025 and Barattieri and Cacciatore 2023). While protectionary effects may exist, the contractionary effects from higher input costs within a sector appear to be dominant. [8]

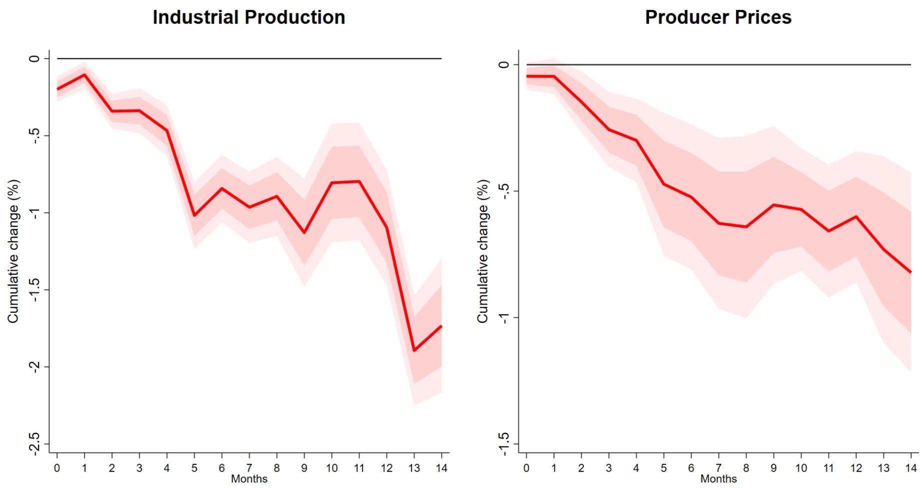
5.3 The effect of a tariff via the industry's forward linkages

Figure 4 assesses how output and producer price in industries that supply their goods to sectors that experience a tariff shock are affected. In this exercise, we keep in mind that industries

[7]There are other possible adverse amplification forces of supply shocks arising from higher input prices that are not related to the production network. One such mechanism arises from entry and exit (see Bilbiie and Melitz 2022 and Khalil and Lewis 2024).

[8]In Section 6.1, we differentiate between intermediate goods tariff shocks and final goods tariff shocks and find that the contraction is mainly stemming from intermediate goods tariff shocks.

Figure 4: The role of forward exposure to sectors that face higher tariffs



Cumulative response in % to a 1pp increase of the weighted average output tariff faced by an average industry. In scaling the effect, we set the average forward exposure across all industries to its 2022 mean (15 %). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

facing a tariff shocks directly experience, on average, a supply-type disruption (see 3). Thus, the question arises how sectors are hit that have forward linkages to the sector facing a supply-type disruption.

Figure 4 indicate marked negative demand effects as a consequence of tariff shocks in downstream absorbers of an industries output. Our findings indicate that a one-percentage point increase in the average tariff rate on goods produced or used by its customer sectors leads to a 1.5% contraction in the industry's own output, while producer prices drop by up to roughly 0.75%. That is, industries, that see the production of their customers drop, face contracting demand for their own goods.

The contraction via the forward channel amplifies the overall production contraction in the economy beyond the contraction in the initially affected sectors. Our empirical result thus aligns with recent theoretical contributions. Among others, Guerrieri et al. (2022) stress that a negative supply shock in one sector can reduce output in other sectors, thereby amplifying the initial output contraction.

Notably, US manufacturing sectors that experience US import tariffs as demand-side shocks because of their forward linkages face negative price pressures. This counteracts the typically positive price pressures of import tariff hikes on producer and consumer prices. The findings highlight that the aggregate effect of import tariff shocks on the aggregate producer prices crucially depends on where the import tariff hits the domestic production network and, consequently, the relative weight of the transmission channels in shaping its impact.

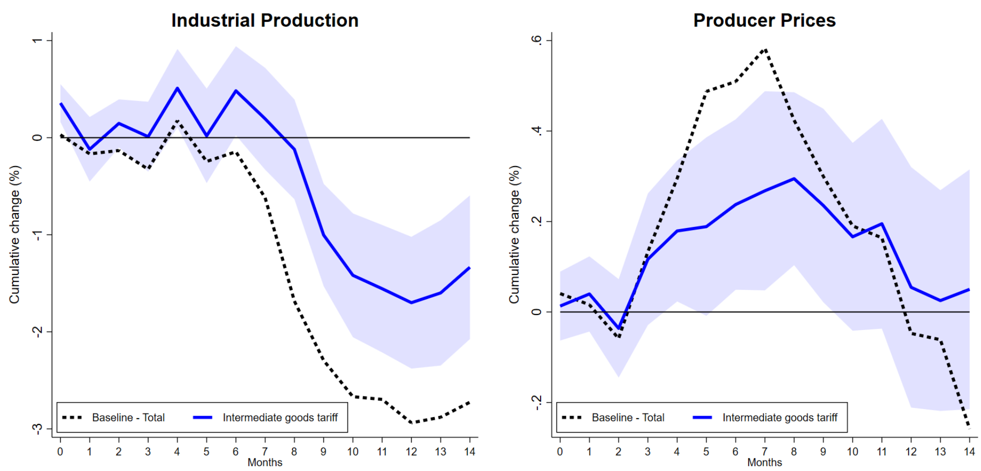
6 Inspecting the shocks and the channels

In this section, we show that the effects of tariff shocks on final goods differ from those on intermediate goods. Secondly, we isolate the shock transmission that runs via inter-industry linkages from effects that run via within-industry linkages.

6.1 Intermediate goods tariff shocks versus final goods tariff shocks

Our data allows us to separate intermediate goods tariff from final goods tariff. This enables us to zero in on to heterogeneities in the transmission of intermediate and final goods tariff shocks. To do so, we repeat regression 4 with the difference that for each channel we separately estimate the effects of intermediate goods tariff shocks and final goods tariff shocks.

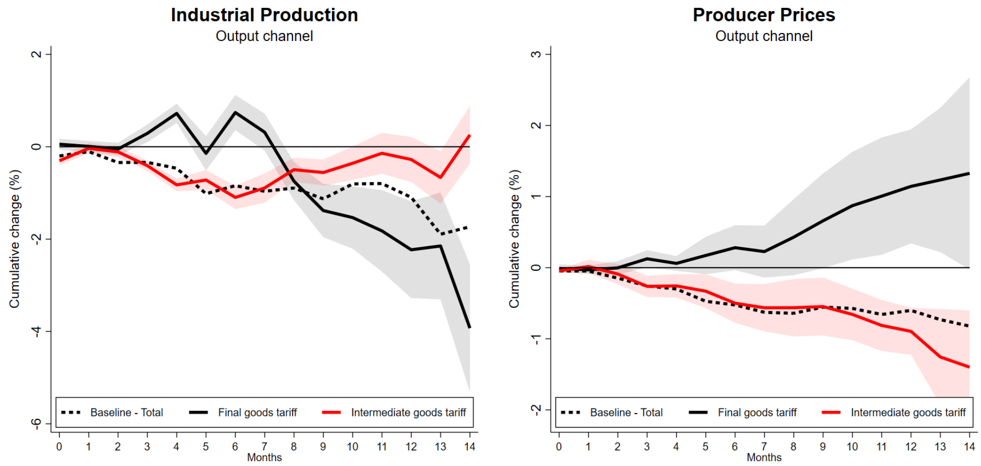
Figure 5: The role of exposure to imported intermediates in the transmission of **tariff shocks on intermediate goods**



Cumulative response in % to a 1pp increase of the weighted average input tariff faced by an average industry. In scaling the effect, we set the average backward exposure across all industries to its 2022 mean (14%). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

As a first result, Figure 5 (solid blue line) and Figure 6 (solid red line) show that intermediate goods tariff shocks rationalize the effects of import tariffs estimated in Section 5. This likely owes to the fact that the large tariff hikes in the US observed in 2018-19 were mainly driven by tariffs on intermediate goods imports (cf. Khalil and Strobel forthcoming).

Figure 6: The role of forward exposure to sectors that face **tariff shocks on intermediate goods** or **tariff shocks on final goods**



Cumulative response in % to a 1pp increase of the weighted average output tariff faced by an average industry. In scaling the effect, we set the average forward exposure across all industries to its 2022 mean (15%). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

Intermediate import tariffs shocks are exogenous price shifters and are thus, when interacted with a sector's backward exposure, clearly identified production cost shocks for a particular industry. Hence – reinforcing the findings in Section 5 – two results emerge that help in understanding how production cost shocks that affect one sector transmit within a production network: (i) For sectors with a non-zero intermediate import content in production, producer prices respond markedly positively while production responds markedly negative to an increase production cost induced by higher intermediate import goods tariff. Both, output and price responses, are sluggish, hinting at nominal and real inertia. (ii) Sectors that are integrated forward in a production network, i.e. they are supplying inputs to other industries, experience demand-type contractions as their customers face higher intermediate imports tariffs and thus supply-type constraints.[9]

In this exercise we are also able to distill the transmission of final goods tariffs. A priori, such tariffs do not affect production cost and thus have the potential to protect the affected industries.[10] In the context of a production network, it is particularly interesting to see how

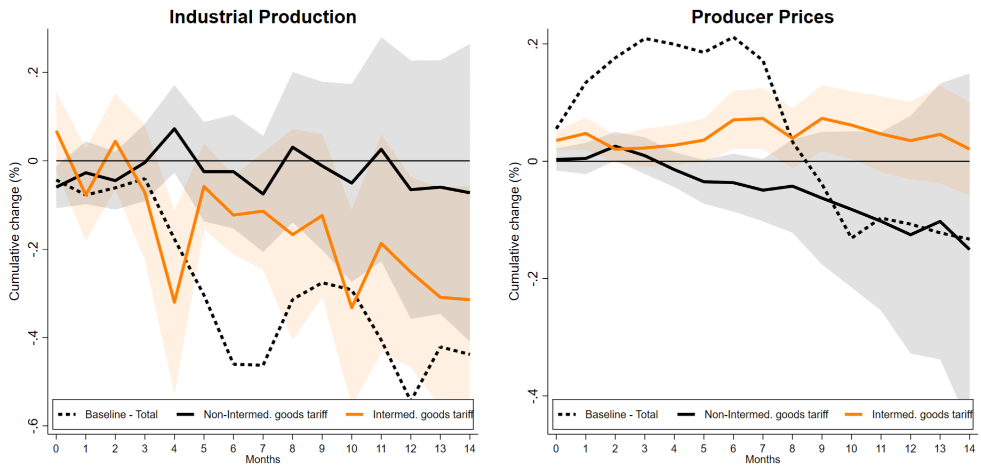
[9]For this result, we have interacted an industry i's forward measure with the intermediate goods tariff shocks of its customers. The results remain robust if we weight the intermediate goods tariff shocks of its customers by the customer's backward exposure.

[10]In our exercise based on input-output tables it is conceptually difficult to characterize capital goods as intermediate good and/or final good. We choose to bundle consumption goods together with capital good as final goods. This has the advantage that intermediate goods tariff shocks are clearly identified as production cost shocks.

upstream suppliers are affected by final goods tariffs that aim to protect the supplier's customers in the downstream industries. Intuitively, protective tariff have the potential to induce demand-type effects for suppliers of the protected industries.

Figure 6 (grey dashed lined) shows that at least in the short run this is indeed the case. With higher final goods import tariffs in a customer industry, the forward channel leads to an output expansion in the supplier's industry for the first 7 months after the tariff increase. At the same time producer price rise. However, after around 8-9 months, output starts to contract while prices tend to increase further. Thus, we find only short-lived protecting effects that arise from this channel.

Figure 7: The effects of **direct tariff shocks on intermediate goods** and **direct tariff shocks on final goods**



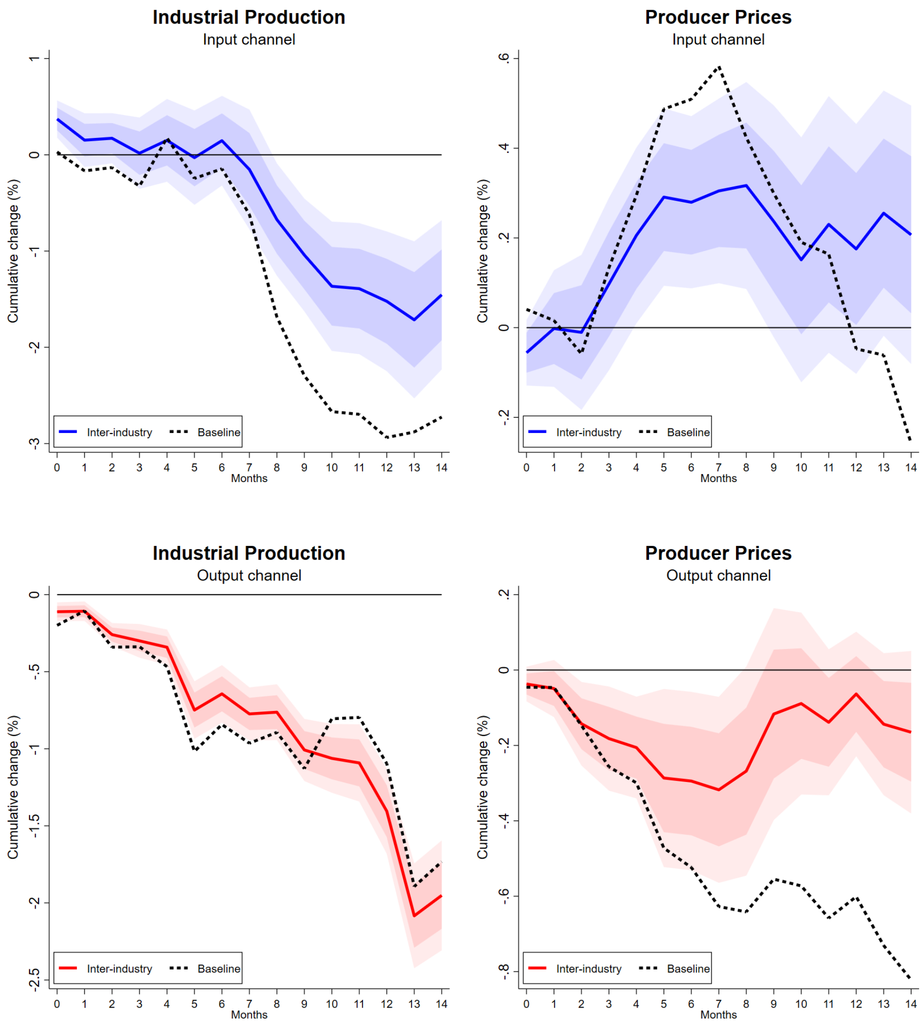
Cumulative response in %, weighted average tariff faced by an industry increases by 1pp. Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

Interestingly, Figure 7 shows that final goods import tariffs also do not appear to protect the directly affected industry. In this exercise, we separate the direct channel from the backward and forward channels while differentiating between intermediate goods and final goods tariff shocks. Intermediate goods tariffs have similar implications compared to the baseline exercise in Figure 3.[11] Final goods tariffs have more positive effects compared to intermediate goods tariffs. Still, for final goods, the effects are close to zero.

Overall, protective effects from final goods tariffs are limited. Moreover, historically, these were clearly outweighed by negative repercussions from higher production costs induced by intermediate import tariff hikes.

[11]The effects are, however, less pronounced the different channels are more precisely identified by distinguishing between intermediate and final goods tariff shocks.

Figure 8: Transmission of tariff increases through inter-industry linkages



Cumulative response in %, weighted average tariff faced by an industry increases by 1pp. Average effect of inter-industry exposure measures across all industries (taken at 2022 mean). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

6.2 Disentangling inter-industry and intra-industry linkages

Our results hold, when we focus on inter-industry linkages and omit intra-industry linkages. To determine if strong intra-industry linkages drive our results, we adjust our local projection setting and decompose backward and forward channels into intra- and inter-industry contributions.

We estimate the following h panel local projections to disentangle inter- and intra-industry contributions to the different transmission channels:

$$\Delta_c \mathcal{Y}_{i,t+h} = \alpha^{(h)} + \mu^{(h)} \Delta T_{i,t} + \underbrace{\beta^{(h)}_{intra} BW_{i,\mathbf{i},y-1} \times \Delta\tau_{\mathbf{i},t} \; + \; \gamma^{(h)}_{intra} FW_{i,\mathbf{i},y-1} \times \Delta\tau_{\mathbf{i},t}}_{\text{Intra-industry}}$$

$$+ \underbrace{\beta^{(h)}_{inter} \widetilde{\mathbf{BW}}_{i,t} \times \Delta\widetilde{\mathcal{T}}^{Input}_{i,t} \; + \; \gamma^{(h)}_{inter} \widetilde{\mathbf{FW}}_{i,t} \times \Delta\widetilde{\mathcal{T}}^{Output}_{i,t}}_{\text{Inter-industry}} + \delta^{(h)} controls + \varepsilon^{(h)}_{i,t+h}$$

where $\widetilde{\mathbf{BW}}_{i,t}$, $\widetilde{\mathbf{FW}}_{i,t}$, $\widetilde{\mathcal{T}}^{Input}_{i,t}$, and $\widetilde{\mathcal{T}}^{Output}_{i,t}$ are the backward and forward tariff exposure measures excluding the link of the industry i to itself, and the corresponding tariff rate measures.[12]

$$\widetilde{\mathbf{BW}}_{i,t} = \sum_{j \neq \mathbf{i}} BW_{i,j,y-1} \quad \text{and} \quad \Delta\widetilde{\mathcal{T}}^{Input}_{i,t} = \sum_{j \neq \mathbf{i}} \frac{BW_{i,j,y-1}}{\widetilde{\mathbf{BW}}_{i,t}} \times \Delta\tau_{j,t},$$

$$\widetilde{\mathbf{FW}}_{i,t} = \sum_{j \neq \mathbf{i}} FW_{i,j,y-1} \quad \text{and} \quad \Delta\widetilde{\mathcal{T}}^{Output}_{i,t} = \sum_{j \neq \mathbf{i}} \frac{FW_{i,j,y-1}}{\widetilde{\mathbf{FW}}_{i,t}} \times \Delta\tau_{j,t}.$$

Figure 8 shows that the effects of tariff shocks via the backward and forward linkages are not solely driven by the strong intra-industry linkages. Inter-industry linkages appear to be of prime importance for the transmission of tariff increases within the US manufacturing sector. This evidence corroborates that the role of input-output linkages is key for understanding the transmission of import tariff shocks.[13]

7 Conclusion

Input-output linkages are crucial for understanding the transmission of import tariff shocks. We find that tariff rate increases reduce industry-specific production through backward and forward channels arising in a domestic production network. However, the response of an industry's producer price depends on which channel dominates the transmission of the tariff increase.

For aggregate output and prices, our results suggest that intra-industry linkages amplify the contraction of production due to tariff increases. At the same time, the negative demand-type repercussion of tariff shocks for some sector in the domestic production network ought to dampen aggregate price increases. The findings align with recent theoretical literature on shock transmission in production networks. Thus, our results are likely relevant for other supply-type shocks such as supply chain disruptions or energy price shocks.

[12] For more details, see Appendix B.

[13] In Appendix D.2, we repeat this exercise by separating intermediate and final goods tariffs. Also in this exercise, we find a strong role for inter-industry linkages.

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Appendix

A Data sources

We start by further describing the data sources and associated measures in Section 2. All data come from publicly available resources.

Import data at the product level – HS classification: The Harmonized System (HS) classification is an international commodity classification system developed independently by the World Customs Organization (WCO) specifically used to classify international trade. Simply put, the HS classification starts by assigning products into 99 broad 2-digit classes and then further breaks down each class into more precise product groups (identified by adding digits after the first two). The process of assigning products to a group is solely based on the product physical characteristics. The baseline WCO classification goes down to six digits and this 6-digit dimension, referred to as HS6, is common to all countries and only changed when revised by the WCO. Revisions happen every five years and lead to different HS versions (HS 2002, HS 2007 . . . HS 2022). Countries are also free to further break down the HS6 product groups into more details subgroups at their own discretion. To that end, the US International Trade Commission (ITC) maintains the 10-digit disaggregated HS classification HS10. In addition to revisions every five years of the HS6 basis, the digits 7 to 10 can also be revised, this time annually, by the ITC.

We source data from the US Census Harmonized System District-level reports[14] and focus on imports. Specifically, we obtain at the monthly frequency and at the most disaggregated level (HS10) the following series: Customs Value in US$ ("The value of goods imported as appraised by U.S. Customs and Border Protection. Excludes freight and duties"), CIF Value in US$ ("The value of goods imported – cost, insurance, and freight; excludes duties"), Calculated duty in US$ and Quantity ("The physical volume of imports based on the second quantity measurement"). The yearly files between 2002 and 2021 then consist of the four aforementioned series for all imported products, identified by their HS10 code. It is noteworthy to mention that the yearly files are unbalanced panels in the sense that for each HS10 product it will only show months where there actually was imports of this product.

For our purposes we also rely on the international product classification by Broad Economic Categories[15] (BEC) maintained by the United Nations Statistics Division (UNSD) to further classify imported products by their end use dimension. The BEC classification starts by assigning

[14] `https://usatrade.census.gov/`.
[15] `https://unstats.un.org/unsd/classifications/Econ`.

products to one of eight *Broad Economic Categories*, then the product dimension is determined (Goods or Services). And the third level is what we are interested in: *SNA and end use dimension.* The end use categories are: Intermediate consumption, Gross fixed capital formation, Final consumption. In theory all products have a mixed end use purpose, but specifically when the use is not disproportionately in one category some product will then be labeled as Dual-Use and the UNSD provides proportions of dual use. Examples of dual use goods provided by the UNSD are the following: a personal vehicle as capital good and as final consumption good, or gasoline as intermediate and final consumption. This is specifically the latter case that we do not wish to miss imports from. The UNSD still mentions that the proportions should be determined at the national level but we nonetheless use the provided values.

Industrial production: The Federal Reserve System produces Industrial Production (IP) series which aim at measuring the real output of different industries located within the US. These series are identified by their IP codes but *related NAICS industries* codes are also provided. The North American Industry Classification System (NAICS) is a classification system of business activities that uses up to six digits to attribute an establishment to a national industry. The first two digits represent the Sector, digit three the Subsector, digit four the Industry group, digit five the NAICS industry and lastly digit six the National industry. The related NAICS industry associated which each IP code have peculiar features that should be mentioned.

First, depending on the aggregation level of the industry considered by the Industrial Production index, the IP code will be related to a NAICS code between NAICS3 (aggregated) to NAICS6 (disaggregated). For instance, for the industry "Oil and gas extraction" (G211) the related NAICS3 is 211 while for "Crude Oil alone" (G21112) the related NAICS6 is 21112. Second, IP codes can also only be linked to *part of* NAICS industries. For instance, "Natural gas" (N21113G) and "Natural gas liquid extraction" (G21113PQ) both have the same *related NAICS* that is "211130pt.", where pt. stands for *part of.* We directly discard these IP codes as the sole indication *part of* but no proportion/weight makes it impossible to divide any data with this NAICS between the IP-labeled industries. Lastly, some IP codes are also related to an aggregation of multiple NAICS level codes. For instance, the industry "Hydroelectric, renewables, and other" with IP code G221111A4T8 is related to "NAICS 221111,4-8" (where 4-8 stands for digits 4 to 8). This IP series thus represents the aggregate industrial production of NAICS6 industries 221111, 221114, 221115, 221116, 221117 and 221118. We also do not make use of these series as we might not have data for all underlying subcodes and prefer basing the analysis on simple industry levels rather than mixing industries and aggregates.

Producer price index: The Producer Price Index (PPI) is a set of indices constructed by the Bureau of Labor Statistics (BLS) measuring the average change over time in prices received by producers for domestically produced products: goods, services and output of construction. The PPIs include a wide range of industries from the following sectors: mining, manufacturing, agriculture, utilities, construction, retail, transportation, and other services sectors. In addition to the industry level PPIs, more disaggregated series at the industry-produced-product level are also available. For instance complementary to the (global) NAICS industry "Petroleum refineries" (NAICS 324110) PPI series, 17 more disaggregated PPI series for this NAICS industry are also available and include: "Petroleum refineries-Primary products", "Petroleum refineries-Regular gasoline", "Petroleum refineries-Premium gasoline" ... The baseline approach that we take is to make use of the simple industry level PPI and not focus on a specific industry-product series.

Input-output tables – BEA classification: The Input-Output (IO) Accounts are a series of detailed tables released by The Bureau of Economic Analysis (BEA). They illustrate economic activity by detailing how industries interact with one another. On the one hand, Supply tables show the domestic production of commodities (groups of goods and services) by different industries but also import volumes of these commodities. The Use tables on the other hand, show for each industry its use of different commodities as intermediate inputs in its production process. This notably also includes compensation of employees.

The BEA uses its own classification, based on the NAICS classification, to define *both* commodities and industries. The most important feature is that Input-Output tables identify Industries and Commodities with the exact same codes. We refer to this classification simply as BEA classification. As most classifications, the BEA classification allows for different levels of aggregation: from the most aggregated 23 industries down to the 406 industries, with in-between 73 and 142 levels. The BEA then releases IO-tables on a yearly frequency at the "71 industries – 73 commodities" level and at the "402 industries – 402 commodities" level every five years.

Summary of available data

- **Imports**: monthly product-level data in the HS classification. Fine-grained level data at the disaggregated HS10 level. Are available: volume of imports (in $), calculated duties (in $) and import quantity (physical volume).
- **Input-Output tables**: yearly data for each industry-commodity combination in the BEA classification at the 71 industries – 73 commodities level. Supply tables show for each of the industries their supply (in $) of each commodity, but also total import volumes by commodity. Use tables show by industry the volume used (in $) of each commodity in the production process as intermediary inputs.

- **Industrial production**: monthly series available at the IP-code level. These IP codes are related to NAICS codes, with different levels of aggregation depending on the considered IP code.
- **Producer prices**: monthly series available at different NAICS levels (NAICS3-NAICS6 but not evenly) and for some NAICS at disaggregated industry-product level.

B Concordance between HS-NAICS-BEA classifications

Matching the several data sources that employ different classification schemes requires a number of concordance tasks. The reasoning behind why we would need each of these concordances will be apparent when defining the exposure measures in section C.1. This is a general approach and none of the derived concordances is restricted to the specific sample of sectors used later on in the empirical section.

HS10 and 20xx-NAICS: We use the concordance from Pierce and Schott (2012)[16] between US HS10 codes, revised on an annual basis, and NAICS6 codes.[17] As NAICS codes are actively revised every five years, the concordance works by blocs of five years. Considering for instance a code introduced in the 2012 NAICS revision and renamed in the 2017 revision, the concordance file will have HS codes associated to this NAICS between January 2013 and December 2017. Thus, in the process of translating HS-level import data to NAICS-level, we will only have import data using this specific NAICS code only between 2013 and 2017, and not over the full sample. For a simpler case of new codes introduced by the 2017 NAICS revision, NAICS6 codes 211120 "Crude Petroleum Extraction" and 211130 "Natural Gas Extraction" only appear in the import data following the Pierce & Schott concordance starting January 2018. This peculiar inner working of the HS10-NAICS6 concordance by five-year blocs will make it a struggle to build consistent 2017-NAICS time series of customs values and duties over the whole sample. It is also noteworthy to mention that as of summer 2024 the latest Pierce & Schott concordance was for codes of the year 2021 and this would force us to make some assumptions to have a sample encompassing both 2022 and 2023. To avoid confounding results from the pandemic our analysis is, however, limited to data up until January 2020.

20xx-NAICS to 2022-NAICS: After each NAICS revision the US Census provides concordance tables between old and revised codes that helps tracking changes. The nature of these changes are either a name change, a split or a merge. For instance, in the 2007 revision the

[16]See `https://sompks4.github.io/sub_data.html`.
[17]Here, "20xx-NAICS6" indicates any of the NAICS6 classification versions from 2002, 2007, 2012, 2017 or 2022.

NAICS6 code 111998 "All Other Miscellaneous Crop Farming" is split between NAICS6 111998 "All Other Miscellaneous Crop Farming" and NAICS6 112519 "Other Aquaculture". This example of a splitting code shows that despite the 2002-NAICS6 code 111998 still being present after the 2007 revision, the underlying composition of the NAICS6 code is not the same anymore. Utilizing all concordance files provided by the US Census we construct a NAICS6 tracking matrix that provides for any 20xx-NAICS6 code 2002-NAICS6 to 2022-NAICS6 equivalent(s). The emphasis here being on equivalent**s** since for a forward looking concordance, for instance tracking a 2007 NAICS6 code, the latter might end up being split in the following revisions and we associate to it all codes relevant in this split. This means that a 2007 code might be linked to another 2007 code in the matrix if in any (future) revision the first code end up being split an one of the codes emerging from the split is the second 2007 code. A similar situation happens if we were to try and find the 2002 equivalent of a 2012 code that emerged from a split in the 2007 revision, however in our study this is not relevant.

20xx-NAICS and BEA67: Liao et al. (2020) provide a set of utilities for matching products labeled in different international trade classification systems (see R package on *concordance*) . This includes the "2012-NAICS6 to 2012-BEA412" concordance that we take as a foundation for the work developed of this section. The concordance matches any 2012-NAICS6 code to one or more of the 2012 disaggregated 412 BEA industries. Going back on the presentation of the BEA classification from A we first note that the effect of the 2017 revision to BEA codes was to collapse the most disaggregated level of the 2012 classification from 412 industries to 406 industries in 2017.

We aim to extend and update this "2012-NAICS6 to 2012-BEA412" concordance to meet the following goal: we wish to match any NAICS6 code of other versions (2002-NAICS6, 2007-NAICS6 or 2017-NAICS6) to at least one 2017-BEA406 industry code. The final purpose is then go up the aggregation level –to use the yearly data from input-output tables– and finally obtain a "20xx-NAICS6 to 2017-BEA71" concordance. To that end we follow the procedure detailed below.

"20xx-NAICS6 & 2017-BEA406" concordance procedure:

For each of complete release of NAICS6 codes from 2002, 2007, 2017 and 2022 we perform the following procedure:

1. Match each 20xx-NAICS6 code to possibly more than one 2012-NAICS6 using the constructed NAICS tracking matrix

2. Use Liao et al. (2020) to convert the obtained 2012-NAICS6 code(s) to 2012-BEA412 equivalent(s)
3. For the few matched 2012 BEA codes among the ones impacted by the 2017 revision adjust to the new version
4. The concordance table "20xx-NAICS6 and 2017-BEA406" is obtained

Further important details on the output of the different steps:

- Step2: in the original work of Liao et al. (2020) the 2012-NAICS6 codes are only effectively matched to 392 out of the 412 different 2012-BEA codes.
  → Thus, not all 412 2012-BEA codes have (at least) one 2012-NAICS6 equivalent.
- Step4: considering all possible 20xx-NAICS6 codes, it appears they are ultimately only matched to a total of 389 different 2017 BEA codes out of the 406 available.
  → Despite this gap we still refer to any of the obtained concordances as "20xx-NAICS6 and 2017-BEA406".

With the yearly input-output tables only using a more aggregated view, namely the second tier of the BEA classification with 73 codes, the obtained concordances "20xx-NAICS6 and 2017-BEA406" need to go up the BEA classification tiers for our purposes. To that end we make use of the detailed table from the appendix of the 2018 comprehensive update of the Input-Output tables[18] that reads a complete breakdown of the BEA classification from the 23 sectors down to the most detailed 406 industries. It is then straightforward to obtain from the "20xx-NAICS6 and 2017-BEA406" concordances the "20xx-NAICS6 and 2017-BEA73" concordances. More specifically the 389 BEA codes to which the whole of the 20xx-NAICS6 are matched to only cover 67 out of the 73 2017-BEA codes of this aggregation tier. Thus, the final product we obtain from this section are the concordances tables: "20xx-NAICS6 and 2017-BEA73". We can already see that bits of the data from the 71x73 use/make tables will not be accounted for when translating the BEA industries codes to NAICS6 equivalents.

The latter concordances being solely *many to many* and not *one to many* (or *one to one*) will force us to make assumptions when computing the exposure measures. In this regard we note that, on the one hand 99% of BEA73 codes are associated to more than one 20xx-NAICS6 code. On the other hand a 20xx-NAICS code can also be associated to more than one BEA73" code but only around 1% of 20xx-NAICS codes are associated with more than one BEA73 code.[19] This issue thus affects mainly the concordance process of BEA labeled data to NAICS6 done in section C.3.

[18]See `https://apps.bea.gov/scb/issues/2018/08-august/pdf/0818-industry-tables.pdf`.
[19]For instance the 2002-NAICS code 326299 associated to BEA73 326 and 3364OT.

C Construction of the input-output exposure measures

We remain vague on the classification system used to define industry i and commodity j in the following two sections (C.1, C.2) since an entire section is dedicated to this practical issue C.3.

C.1 Input channel - Backward Exposure measure

An industry is thus exposed through commodities involved as intermediate inputs in its production process, we refer to this as backward exposure.

For each commodity j that industry i uses consider:

$$BW_{i,j,y} \equiv \frac{use_{i,j,y}}{M_{i,y} + CE_{i,y}} \times \frac{imp_{j,y}}{supply_{j,y}} = USE_{i,j,y} \times IM_{j,y} \tag{C.1}$$

Where:

- $use_{i,j,y}$: volume of commodity j used by industry i as an intermediate input in year Y_t
- $M_{i,y}$: total intermediate use of inputs by industry i in year Y_t
- $CE_{i,y}$: total compensation of employees paid within industry i in year Y_t
- $imp_{j,y}$: volume of imports of commodity j in year Y_t
- $supply_{j,y}$: total supply of commodity j (= domestic supply + imports) in year Y_t

From this definition, $USE_{i,j,y}$ represents industry i use share of commodity j in its production process in year Y_t. This term approximate the direct vertical linkage between commodity j and industry i and by making it time varying we avoid potential measurement errors due to technology changesThe evolution of industries' use of different commodities is thus embedded into the computation of the backward exposure measure. Then, $IM_{j,y}$ is simply the import share of commodity j in its total supply. Since the BEA use tables do not allow the use of commodity j by industries to be differentiated between use of *domestically* produced and imported j, we multiply $USE_{i,j,y}$ by the economy-wide import share of j (namely $IM_{j,y}$) to obtain a proxy. Finally, $BW_{i,j,y}$ represents the production process exposure of industry i to tariffs on commodity j. This is a direct quantification of the vertical the vertical linkage between industry i and commodity j, which had already been introduced in Flaaen and Pierce (2025) and Khalil and Weber (2022) but both lacked the yearly variations.[20] To specifically assess the exposure of industry i to tariffs

[20]Most likely due to two things: smaller time frame considered for their studies and the use of disaggregated I-O tables with 402 industries which are only available on a five-year basis.

imposed on imports of commodity j coming from a region/country we would simply multiply the aforementioned backward exposure $BW_{i,j,y}$ and the share of imports of commodity j coming from the considered region (also obtained from the Customs data).

C.2 Output channel - Forward Exposure measure

While the concept behind the definition of the backward exposure measure (C.1) had already been considered in other works such as Flaaen and Pierce (2025), Amiti et al. (2019) or Benguria and Saffie (2019) we introduce a second exposure measure that attempts to measure exposure to tariffs through output linkages.

The rationale is the following: an industry i produces multiple goods x and particularly one, say x, that another domestic industry j uses extensively. Let the state introduce a tariff hike on the specific product(s) that industry j produces. This sector is now "protected" by tariffs and *if* demand were to be redirected from foreign producers toward j we *could* expect its demand of inputs to increase, including x. If such protectionary channel were active, industry i would thus benefit from the introduction of tariffs on industry j through its product x output linkage. While potentially not directly using products in its own production process, an industry can thus still be exposed to tariffs through other industries to which it direct its output.

An impediment to its practical implementation comes from the fact that we cannot identify, from the BEA *make* and *use* tables, the direct linkage between an industry i domestically producing a commodity x and another industry j using this same commodity as an input. Indeed we only have total the dollar value of commodity x supplied by industry i and the total dollar value of commodity x used by j as an intermediate input. A proxy for the forward linkage between industry i and industry j through commodity x is then defined by:

$$FW_{i,j:x,y} \equiv \underbrace{\frac{supply_{i,x,y}}{supply_{x,y}}}_{\substack{\text{commodity } x\text{' } \\ \text{supply share} \\ \text{from industry } i}} \times \underbrace{USE_{j,x,y} \times (1 - IM_{x,y})}_{\substack{\text{industry } i \text{ domestic} \\ \text{demand of commodity } x}} \tag{C.2}$$

In this definition $USE_{x,j,y} \times (1 - IM_{j,y})$ is thus a proxy for the share of commodity j that industry x sources domestically, as this specific data is not made available by the I-O tables. Multiplying it with the domestic supply share of industry i yields a proxy for the the domestic sourcing of commodity j by x that is specifically addressed to industry i.

C.3 Practical implementation

The PPIs are widely available at the most dissagregated NAICS6 level, however this is not necessarily true for the industrial production series were the number of series available at this dissagregated level strongly shrinks. For the consistency of our results, we include in our sample only industries where output and price series are available. Similarly to Flaaen and Pierce (2025) we conduct our analysis, and subsequent regressions, at the four-digit NAICS industry level "Industry Group" as it appears to be the most dissagregated level where we manage to keep a consistent sample of industries for both output and price series. This is still a significantly disaggregated level to have meaningful variations in the different industry specific measures considered in this study.

Turning to the exposure measures, since all data that are used in the definitions (C.1) and (C.2) originate from the IO-tables of the BEA, the industry and commodity levels are given by the BEA classification: 71 industries and 73 commodities. However, since we conduct the analysis at the NAICS4 level we specifically convert the industry dimension. In addition as we will be interacting the defined exposure measures with tariff changes we also need to define tariff rates at the BEA commodity level. Hence we need to convert data following two stages:

1. Computing tariff rates at the BEA-commodity level ($\tau_{j=BEA}$) from HS labeled import data
2. Deriving $USE_{i=NAICS,j=BEA}$ from $USE_{i=BEA,j=BEA}$ and $w_{i=NAICS,j=BEA}$ from $w_{i=BEA,j=BEA}$, respectively for the backward and forward exposure measures

Computing tariff rates at the BEA commodity level[21]

We implement the following procedure:

1. Convert import data labeled with the HS10 classification to 20xx-NAICS6 using Pierce and Schott (2012) concordance.
2. Collapse at the 20xx-NAICS6 level.
3. In this step we wish to convert the obtained 20xx-NAICS6 data to BEA67. As previously mentioned, a NAICS6 code might be matched to several BEA67 codes. We take the following stance: for each 20xx-NAICS where we have data from step 2.[22], we count the

[21]Following Pierce & Schott it is straightforward to obtain the tariff rates at the NAICS industry level.

[22]The concordance procedures presented earlier make the conversion of all NAICS6 codes possible, but we underline that from the Pierce & Schott concordance of HS10 level data not all NAICS codes have associated import data

number of BEA codes it will be matched with when using the "20xx-NAICS6 and BEA67 concordance" of B and then **evenly allocate** the considered variable (duty or import value) for this NAICS6 between these associated BEA codes. For an imaginary NAICS code N1 that is matched with both BEA codes B1 and B2, the dollar values of duties and import volumes computed for N1 in step 2. are evenly allocated between B1 and B2. This is the assumption mentioned in the last paragraph of B. Such case remains uncommon as $<$1% of 20xx-NAICS6 codes for every reference year are matched to more than one BEA equivalent.

4. Collapse at the BEA67 level. Again we note that this does not mean that all 67 BEA level commodities will have import data and then tariff rates. In fact converting HS10 product data to BEA commodities yields 27 BEA commodity level tariff rates.

Computing use and supply share with NAICS industry and BEA commodity dimensions

We implement the following procedure:

1. From the *make* and *use* tables of the BEA, match the industry dimension using the "20xx-NAICS6 and BEA67 concordance" of B. Either 2017-NAICS6 for the case of the IP regression and 2022-NAICS6 for the PPI regression.[23] As mentioned in B a vast majority of BEA67 codes are matched to more than one 20xx-NAICS6 code, we then take the same approach as in the previous procedure: for each BEA67 code, we count the number of 20xx-NAICS6 codes it will be matched with when using the appropriate B concordance and then **evenly allocate** the considered variable (supply or use of j by i, where i is the dimension being converted) for this BEA67 industry between the matched NAICS6 codes.
2. Convert NAICS6 to NAICS4 by looking at the first four digits.
3. Collapse the data at the NAICS4 level.

As explained in A the coverage of the PPI and IP series are different at the most disaggregated NAICS6 level but this remains true even at NAICS4. Thus when merging the obtained use and supply share with NAICS4 industry dimension and the actual IP and PPI series, a larger number of PPI series are available. Since we want to maintain a coherent sample across PPI and IP series for the empirical approach we restrict the universe of NAICS4 industries to the NAICS4

[23]The use of different concordance tables here is due to the PPI and IP still using different NAICS6 reference years to identify the most dissaggregated industries. Even though we later aggregate the data to NAICS4 it is the safest way to ensure we correctly allocate data from NAICS6 to the corresponding NAICS4, as unlikely as it may happen that a NAICS6 revision causes a NAICS4 change.

industries where we have industrial production series. This restricts the regression analysis to industries classified in Utilities, Construction and mostly Manufacturing.

Table C.1: **List of NAICS4 industries forming the sample.**

NAICS4	PPI	IP	BEA67[†]	NAICS4 industry description
3111	3111	G3111	311FT	Animal Food Manufacturing
3112	3112	G3112	311FT	Grain and Oilseed Milling
3113	3113	G3113	311FT	Sugar and Confectionery Product Manufacturing
3114	3114	G3114	311FT	Fruit and Vegetable Preserving and Specialty Food Manufacturing
3115	3115	G3115	311FT	Dairy Product Manufacturing
3118	3118	N3118	311FT	Bakeries and Tortilla Manufacturing
3119	3119	G3119	311FT	Other Food Manufacturing
3121	3121	G3121	311FT	Beverage Manufacturing
3122	3122	G3122	311FT	Tobacco Manufacturing
3131	3131	G3131	313TT	Fiber, Yarn, and Thread Mills
3132	3132	G3132	313TT	Fabric Mills
3133	3133	G3133	313TT	Textile and Fabric Finishing and Fabric Coating Mills
3141	3141	G3141	313TT	Textile Furnishings Mills
3149	3149	G3149	313TT	Other Textile Product Mills
3211	3211	N3211	321	Sawmills and Wood Preservation
3212	3212	G3212	321	Veneer, Plywood, and Engineered Wood Product Manufacturing
3219	3219	G3219	321	Other Wood Product Manufacturing
3221	3221	G3221	322	Pulp, Paper, and Paperboard Mills
3222	3222	G3222	322	Converted Paper Product Manufacturing
3251	3251*	G325@4	325	Basic Chemical Manufacturing
3252	3252*	G325@4	325	Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing
3253	3253*	G325@4	325	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing
3254	3254	G3254	325	Pharmaceutical and Medicine Manufacturing
3255	3255*	G325@4	325	Paint, Coating, and Adhesive Manufacturing
3256	3256*	G325@4	325	Soap, Cleaning Compound, and Toilet Preparation Manufacturing
3259	3259*	G325@4	325	Other Chemical Product and Preparation Manufacturing
3261	3261	G3261	326	Plastics Product Manufacturing

Continued on next page

Table C.1: −*continued* **List of NAICS4 industries forming the sample**

NAICS4	**PPI**	**IP**	**BEA67**†	**NAICS4 industry description**
3262	3262	G3262	326	Rubber Product Manufacturing
3271	3271	G3271	327	Clay Product and Refractory Manufacturing
3272	3272	G3272	327	Glass and Glass Product Manufacturing
3273	3273	G3273	327	Cement and Concrete Product Manufacturing
3274	3274	G3274	327	Lime and Gypsum Product Manufacturing
3279	3279	G3279	327	Other Nonmetallic Mineral Product Manufacturing
3311	3311*	G3311A2	331	Iron and Steel Mills and Ferroalloy Manufacturing
3312	3312*	G3311A2	331	Steel Product Manufacturing from Purchased Steel
3313	3313	G3313	331	Alumina and Aluminum Production and Processing
3314	3314	G3314	331	Nonferrous Metal (except Aluminum) Production and Processing
3315	3315	G3315	331	Foundries
3321	3321	N3321	332	Forging and Stamping
3322	3322	N3322	332	Cutlery and Handtool Manufacturing
3323	3323	N3323	332	Architectural and Structural Metals Manufacturing
3325	3325	G3325	332	Hardware Manufacturing
3326	3326	N3326	332	Spring and Wire Product Manufacturing
3327	3327	G3327	332	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing
3329	3329	G3329	332	Other Fabricated Metal Product Manufacturing
3331	3331	G3331	333	Agriculture, Construction, and Mining Machinery Manufacturing
3332	3332	G3332	333	Industrial Machinery Manufacturing
3333	3333*	G3333A9	333	Commercial and Service Industry Machinery Manufacturing
3334	3334	G3334	333	Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing
3335	3335	G3335	333	Metalworking Machinery Manufacturing
3336	3336	G3336	333	Engine, Turbine, and Power Transmission Equipment Manufacturing
3339	3339*	G3333A9	333	Other General Purpose Machinery Manufacturing
3341	3341	G3341	334	Computer and Peripheral Equipment Manufacturing
3342	3342	G3342	334	Communications Equipment Manufacturing

Continued on next page

Table C.1: −*continued* **List of NAICS4 industries forming the sample**

NAICS4	**PPI**	**IP**	**BEA67**[†]	**NAICS4 industry description**
3343	3343	G3343	334	Audio and Video Equipment Manufacturing
3344	3344	G3344	334	Semiconductor and Other Electronic Component Manufacturing
3345	3345	G3345	334	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing
3351	3351	G3351	335	Electric Lighting Equipment Manufacturing
3352	3352	G3352	335	Household Appliance Manufacturing
3353	3353	G3353	335	Electrical Equipment Manufacturing
3359	3359	G3359	335	Other Electrical Equipment and Component Manufacturing
3361	3361	G3361	3361MV	Motor Vehicle Manufacturing
3362	3362	G3362	3361MV	Motor Vehicle Body and Trailer Manufacturing
3363	3363	G3363	3361MV	Motor Vehicle Parts Manufacturing
3364	3364	G3364	3364OT	Aerospace Product and Parts Manufacturing
3365	3365	N3365	3364OT	Railroad Rolling Stock Manufacturing
3366	3366	G3366	3364OT	Ship and Boat Building
3369	3369	N3369	3364OT	Other Transportation Equipment Manufacturing
3371	3371	N3371	337	Household and Institutional Furniture and Kitchen Cabinet Manufacturing
3372	3372*	G3372A9	337	Office Furniture (including Fixtures) Manufacturing
3379	3379*	G3372A9	337	Other Furniture Related Product Manufacturing
3391	3391	N3391	339	Medical Equipment and Supplies Manufacturing

* *A Producer Prices series is available at the considered NAICS4 level but a corresponding Industrial Production series is only available at a more aggregate level, which is chosen here and hence can appear more than once in the sample.*

Table C.2: **NAICS4 industries count by NAICS3 group.**

NAICS3 group	NAICS4 industries count
Food Manufacturing	7
Chemical Manufacturing	7
Fabricated Metal Product Manufacturing	7
Machinery Manufacturing	7
Transportation Equipment Manufacturing	7
Nonmetallic Mineral Product Manufacturing	5
Primary Metal Manufacturing	5
Computer and Electronic Product Manufacturing	5
Electrical Equipment, Appliance, and Component Manufacturing	4
Textile Mills	3
Wood Product Manufacturing	3
Furniture and Related Product Manufacturing	3
Beverage and Tobacco Product Manufacturing	2
Textile Product Mills	2
Paper Manufacturing	2
Plastics and Rubber Products Manufacturing	2
Miscellaneous Manufacturing	1

D Details on the empirical specification

Notations:

- τ_j : tariff rate on imports with all end-use in BEA67 industry j.
- τ_j^{Int} : tariff rate on imports with intermediate end-use in BEA67 industry j.
- τ_j^{NonInt} : tariff rate on imports with non-intermediate end-use in BEA67 industry j.
- τ_j^{Fin} : tariff rate on imports with final end-use in BEA67 industry j.
- τ_j^{Cap} : tariff rate on imports with capital end-use in BEA67 industry j.
- T_i : tariff rate on imports with all end-use in NAICS4 industry i.

D.1 Baseline Local Projection setting

Let $\mathcal{Y}_{i,t}$ denote either the log of the producer prices (PPI) or the log of the industrial production (IP) of the manufacturing sector NAICS4 industry i in month t. The estimation sample spans t = January 2005 to January 2020. Consider the following panel local projection specifications independently estimated for each $h = 0, 1, \ldots, 17$:

$$\Delta_c \mathcal{Y}_{i,t+h} = \alpha^{(h)} + \underbrace{\mu^{(h)} \Delta T_{i,t}}_{\substack{\text{Horizontal} \\ \text{channel}}} + \underbrace{\beta^{(h)} \mathbf{BW}_{i,t} \times \Delta \mathcal{T}_{i,t}^{Input}}_{\text{Input channel}} + \underbrace{\gamma^{(h)} \mathbf{FW}_{i,t} \times \Delta \mathcal{T}_{i,t}^{Output}}_{\text{Output channel}} + controls + \varepsilon_{i,t+h}^{(h)} \tag{D.1}$$

where $\Delta_c \mathcal{Y}_{i,t+h} = \mathcal{Y}_{i,t+h} - \mathcal{Y}_{i,t}$ is the cumulative change in $\mathcal{Y}$ between t and $t+h$. $\Delta T_{i,t}$ is the monthly change in the tariff rate applied in NAICS4 industry i. $\mathbf{BW}_{i,t}$ and $\mathbf{FW}_{i,t}$ are the aggregate backward and forward exposures defined as: $\mathbf{BW}_{i,t} = \sum_j BW_{i,j,y-1}$ and $\mathbf{FW}_{i,t} = \sum_j FW_{i,j,y-1}$. $\Delta \mathcal{T}_{i,t}^{Input}$ and $\Delta \mathcal{T}_{i,t}^{Output}$ are the weighted average monthly changes in the input and output tariffs faced by industry i, respectively defined as:

$$\Delta \mathcal{T}_{i,t}^{Input} = \sum_j \frac{BW_{i,j,y-1}}{\mathbf{BW}_{i,t}} \times \Delta \tau_{j,t}$$
$$\Delta \mathcal{T}_{i,t}^{Output} = \sum_j \frac{FW_{i,j,y-1}}{\mathbf{FW}_{i,t}} \times \Delta \tau_{j,t}$$

We control for a wide range of changes in economic conditions including lags of monthly changes in the dependent variable, industry fixed effects and industries' exposure to changes in the dollar international strength which could be correlated to tariff rates changes and charged price or production. Are included in the baseline specification:

- 12 lags of $\Delta \mathcal{Y}_{i,t}$
- An industry fixed effect f_i
- Levels of the backward and forward exposure $\mathbf{BW}_{i,t}$ and $\mathbf{FW}_{i,t}$
- 12 lags of the tariff shocks $\Delta T_{i,t}$, $\Delta \mathcal{T}_{i,t}^{Input}$, $\mathcal{T}_{i,t}^{Output}$ as well as $\mathbf{BW}_{i,t} \times \Delta \mathcal{T}_{i,t}^{Input}$ and $\mathbf{FW}_{i,t} \times \Delta \mathcal{T}_{i,t}^{Output}$.
- Lags 0-12 of the monthly changes in the log of the US real GDP
- Lags 0-12 of the monthly changes in the log of different energy prices: the S&P Goldman Sachs Brent Crude Index, the US City Average Price for Electricity and the Natural gas futures price 1st expiring
- Lags 0 to 12 of the monthly changes in the Federal Funds (effective) Rate
- Lags 0 to 12 of the monthly changes in the Wall Street Journal Dollar Index

D.2 Inter- and Intra-industry contributions

Let ($\mathbf{i}$) denote the BEA67 correspondance to the NAICS4 industry i (see Appendix B).We estimate the following h modified panel local projections to disentangle inter- and intra-industry contributions to the different transmission channels:

$$\Delta_c \mathcal{Y}_{i,t+h} = \alpha^{(h)} + \mu^{(h)} \Delta T_{i,t} + \underbrace{\beta^{(h)}_{intra} BW_{i,\mathbf{i},y-1} \times \Delta\tau_{\,\mathbf{i},t} \; + \; \gamma^{(h)}_{intra} FW_{i,\mathbf{i},y-1} \times \Delta\tau_{\,\mathbf{i},t}}_{\text{Intra-industry}}$$

$$+ \underbrace{\beta^{(h)}_{inter} \widetilde{\mathbf{BW}}_{i,t} \times \Delta\widetilde{\mathcal{T}}^{Input}_{i,t} \; + \; \gamma^{(h)}_{inter} \widetilde{\mathbf{FW}}_{i,t} \times \Delta\widetilde{\mathcal{T}}^{Output}_{i,t}}_{\text{Inter-industry}}$$

$$+ \; controls + \varepsilon^{(h)}_{i,t+h} \tag{D.2}$$

where the tilde signals variables computed excluding the corresponding BEA67 industry ($\mathbf{i}$):

$$\widetilde{\mathbf{BW}}_{i,t} = \sum_{j \neq \mathbf{i}} BW_{i,j,y-1} \quad \text{and} \quad \Delta\widetilde{\mathcal{T}}^{Input}_{i,t} = \sum_{j \neq \mathbf{i}} \frac{BW_{i,j,y-1}}{\widetilde{\mathbf{BW}}_{i,t}} \times \Delta\tau_{j,t}$$

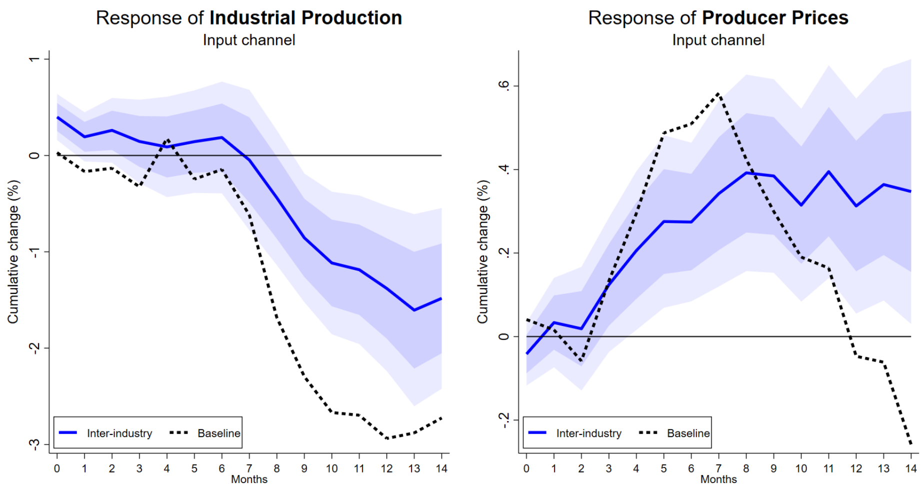
$$\widetilde{\mathbf{FW}}_{i,t} = \sum_{j \neq \mathbf{i}} FW_{i,j,y-1} \quad \text{and} \quad \Delta\widetilde{\mathcal{T}}^{Output}_{i,t} = \sum_{j \neq \mathbf{i}} \frac{FW_{i,j,y-1}}{\widetilde{\mathbf{FW}}_{i,t}} \times \Delta\tau_{j,t}$$

D.3 Inter- and intra-industry contributions when distinguishing intermediate and final goods tariff shocks

The results in Section 6.1 regarding different transmission of intermediate goods tariff shocks and final goods tariff shocks hold, when we adjust our local projection setting and decompose backward and forward channels into intra- and inter-industry contributions.

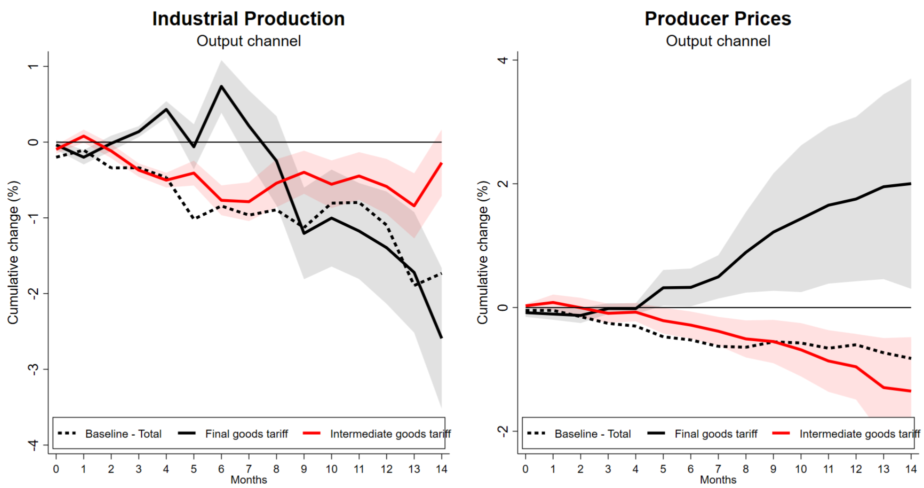
In particular, we repeat regression D.2 with the difference that for each channel we estimate in a joint regression the effects of intermediate goods tariff shocks and final goods tariff shocks. Figures D.9 and D.10 show the results. As in Section 6.2, also when we differentiate between intermediate goods tariff shocks and final goods tariff shocks, the effects via the backward and forward linkages are not solely driven by the strong intra-industry linkages as inter-industry linkages play a key role.

Figure D.9: Transmission of tariff increases through inter-industry linkages: the role of exposure to imported intermediates in the transmission of tariff shocks on intermediate goods



Cumulative response in %, weighted average tariff faced by an industry increases by 1pp. Average effect of inter-industry exposure measures across all industries (taken at 2022 mean). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.

Figure D.10: Transmission of tariff increases through inter-industry linkages: the role of forward exposure to sectors that face tariff shocks on intermediate goods or tariff shocks on final goods



Cumulative response in %, weighted average tariff faced by an industry increases by 1pp. Average effect of inter-industry exposure measures across all industries (taken at 2022 mean). Dashed lines show the 68% confidence bounds, standard errors are clustered at the NAICS4-level.