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The economic effects of trade policy uncertainty☆

Dario Caldara, Matteo Iacoviello*, Patrick Molligo, Andrea Prestipino, Andrea Raffo

Federal Reserve Board, Washington, DC 20016 United States

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ABSTRACT

This paper studies the effects of unexpected changes in trade policy uncertainty (TPU) on the U.S. economy. Three measures of TPU are constructed using newspaper coverage, firms' earnings calls, and tariff rates. Firm-level and aggregate macroeconomic data reveal that increases in TPU reduce business investment. The empirical results are interpreted through the lens of a two-country general equilibrium model with nominal rigidities and firms' export participation decisions. News and increased uncertainty about higher future tariffs reduce investment and activity.

1. Introduction

Trade negotiations and proposals for a new approach to trade policy have become the focus of increased attention among investors, politicians, and market participants. These developments have resulted in an increase in uncertainty about the outlook for global trade. For example, in January 2019, the Federal Reserve's Beige Book, a document that compiles anecdotal descriptions of economic conditions in the twelve Federal Reserve districts, contained several references—based on surveys of manufacturers, business contacts, and industry representatives—to uncertainty about the outlook for trade policy.

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* Corresponding author at: Division of International Finance, Federal Reserve Board, 20th and C St. NW, 20551, Washington, DC United States.
E-mail address: matteo.iacoviello@frb.gov (M. Iacoviello).

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For decades prior to these trade developments, there was limited volatility in trade policy, and thus limited study of the macroeconomic impact of uncertainty regarding trade policy. This paper takes a comprehensive approach to fill that gap—developing measures of trade policy uncertainty (TPU) at both the firm and aggregate levels, estimating the effects of these measures on investment, and then interpreting these effects through the lens of a two-country general equilibrium model with heterogeneous firms.

In the first part of the paper, we measure trade policy uncertainty and its effects. We build a firm-level measure of TPU and link it to firm-level investment data. We show that firms that experience larger increases in TPU accumulate less capital after one year. Aggregating the firm-level responses, the drop in investment that is accounted for by the increase in TPU in 2018 is about 1%, an estimate that abstracts from general equilibrium effects. We then construct two aggregate TPU indicators for the U.S. economy using newspaper coverage and data on import tariffs. We include these indicators in a vector-autoregressive (VAR) model of the U.S. economy and find that a shock that is sized to capture the rise in trade policy uncertainty in 2018 induces a decline in aggregate investment of between 1 and 2%.[1]

In the second part of the paper, we use a two-country general equilibrium model with nominal rigidities and firms' export decisions to trace out the channels by which changes in trade policy uncertainty affect economic activity.[2] In our benchmark experiment, we consider a surprise increase in both expected future tariffs and uncertainty about future tariffs that is sized to match the trade developments observed in 2018. We find that both news—first moment shocks—and increased uncertainty—second moment shocks—about future tariffs reduce investment and output, as in the aggregate data. In addition, exporters reduce investment to a greater extent than non-exporters, consistent with our firm-level evidence.

Our paper builds on the work of several authors that have studied the economic effects of economic and policy uncertainty. On the empirical side, we build on the insights of Fernandez-Villaverde et al. (2015), Baker et al. (2016), and Hassan et al. (2019), and apply their ideas to the measurement of trade uncertainty and the understanding of its effects. We do so by studying the effects of trade uncertainty both at the micro-level—exploiting heterogeneity across firms in their exposure to trade risk—and at the macro level—using measures of trade uncertainty based on newspaper searches and on stochastic volatility models. On the theoretical side, there are several strands of literature that are relevant to our work. Our analysis of the effects of news about future tariffs contributes to a large literature that has studied the transmission of news shocks in DSGE models. Much of this literature has focused on showing that news about future fundamentals can be an important driver of cyclical fluctuations within the RBC framework. In particular, Jaimovich and Rebelo (2009) show that when certain features on preferences and technology are introduced, it is possible to generate business cycles that preserve comovement between macroeconomic aggregates in response to news about aggregate and sectoral total factor productivity shocks, thus overcoming the original criticism of Barro and King (1984). We also incorporate in our model some of the insights introduced by Jaimovich and Rebelo (2009), namely preferences with no wealth effects on labor supply (GHH preferences) and investment adjustment costs. However, in the presence of nominal rigidities, these features are only needed to amplify the response of the economy to news about future tariffs. In fact, in our framework, comovement of consumption, investment, and hours worked emerges naturally from the fact that output is largely demand determined. A more recent literature originating from the contribution of Bloom (2009) has studied the macroeconomic effects of uncertainty shocks, e.g. Basu and Bundick (2017) and Fernandez-Villaverde et al. (2015). In particular, our analysis of the transmission of uncertainty about future tariffs borrows heavily from insights developed by Fernandez-Villaverde et al. (2015), who show that a rise in uncertainty about capital taxes depresses economic activity by inducing firms to raise markups. We find that, while fluctuations in tariffs and in capital taxes have different effects on the economy, trade policy uncertainty also induces a precautionary increase in markups. Finally, our focus on trade policy developments also connects our paper to a growing literature that studies the effects of trade policy uncertainty and news about trade policy. Handley and Limão (2017) and Crowley et al. (2018), for instance, study the impact of trade policy on China's export boom to the United States following its 2001 WTO accession. Similarly, Steinberg (2019) studies the implications of Brexit for the UK economy. Unlike these papers, ours is the first to jointly investigate and quantify the effects of both first and second moment shocks to trade policy in a New Keynesian DSGE model. We find that the presence of nominal rigidities is key for the transmission of trade policy uncertainty both directly, through the precautionary increase in markups stressed in Fernandez-Villaverde et al. (2015), and indirectly, through the interaction between sticky prices and wages and the discrete choice model of exporting.

Section 2 presents our measures of trade policy uncertainty. Section 3 describes the empirical effects of trade policy uncertainty. Sections 4 contains the model, and Section 5 shows the model experiments. Section 6 concludes.

2. Measuring trade policy uncertainty

In this section, we present three measures of trade policy uncertainty. We first describe the construction of our firm-level trade policy uncertainty measure. We then discuss two complementary measures of aggregate TPU, one based on newspaper coverage of TPU related news, and the other based on the estimation of a stochastic volatility model for U.S. import tariffs.

[1] These predictions are in line with independent survey evidence that directly asks firms how they reassessed capital expenditure plans in response to higher trade uncertainty. See the Survey of Business Uncertainty run by the Federal Reserve Bank of Atalanta (Altig et al., 2019).

[2] Our modeling of export decisions follows the work of Alessandria and Choi (2007). Imura (2016), and Imura and Shukayev (2019) also develop sticky price models of endogenous export participation.

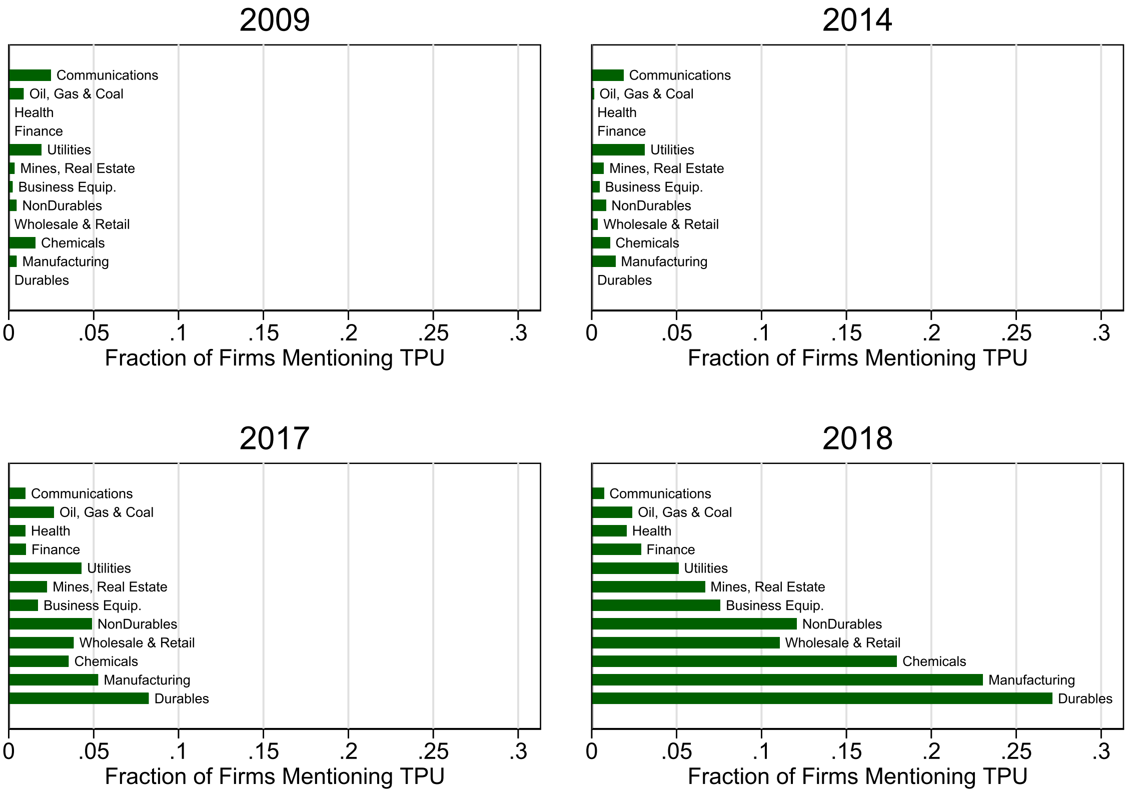

Fig. 1. Trade Policy Uncertainty by Industry over the Years. *Note:* The size of each bar indicates the average share of firms with positive TPU in a given sector. Firms are grouped according to the Fama-French 12 industries classification.

2.1. Firm-level trade policy uncertainty

We construct a time-varying measure of TPU at the firm level—$TPU_{i,t}$—based on text analysis of transcripts of quarterly earnings calls of publicly listed companies. Our methodology involves two steps. In the first step, we search each transcript for terms related to trade policy, such as *tariff*, *import duty*, *import barrier*, and *anti-dumping*.[3] We then construct the variable $TP_{i,t}$ that measures, for each transcript, the frequency of trade policy words, i.e. the number of mentions divided by the total number of words. The variable $TP_{i,t}$ proxies for the intensity of trade policy related discussions, irrespective of whether they center on risk or uncertainty. In the second step, we isolate discussions about TPU by further examining the pool of transcripts returning positive values for $TP_{i,t}$. We devise a list of terms indicating uncertainty, such as *uncertainty*, *risk*, or *potential*. The frequency of joint instances of trade policy and uncertainty terms in each transcript measures the overall uncertainty around trade policy perceived by a firm, $TPU_{i,t}$.[4]

Fig. 1 highlights the large degree of variation in TPU over time and across industries. We aggregate firm level trade uncertainty by first constructing, for each firm, a dummy variable $\mathcal{I}^{TPU}_{i,t}$ that takes value 1 if the transcript mentions trade policy uncertainty ($TPU_{i,t} > 0$), and 0 otherwise. The figure shows, for selected years, the share of firms with $\mathcal{I}^{TPU}_{i,t} = 1$ within an industry.[5] Sectoral trade uncertainty has evolved along two dimensions during the sample period. First, the number of firms concerned with trade policy uncertainty has increased over time across nearly all industries. In 2009, about 3% of firms in each industry expressed concerns about trade policy uncertainty. By the end of 2018, eight out of twelve industries, mostly in non-service sectors, had an average TPU share greater than 5%, with the largest value close to 30 % in the durable sector. Second, stronger sectoral variation in TPU is apparent in the data beginning in 2017. The cross-sectional standard deviation of TPU across sectors is 0.007 in 2009 and 2014, and rises to 0.03 and 0.07 in 2017 and 2018, respectively.

[3] The exact search terms can be found in the supplementary material.

[4] Our firm-level is inspired by the analysis of firm-level political risk in Hassan et al. (2019). One of their subindexes focuses on trade uncertainty, which is constructed at the firm level using trade-specific terms in combination with uncertainty terms. Unlike them, our search terms place more emphasis on "tariffs" than "trade" since an audit of earnings calls covering the 2017–2018 period indicated that "trade" terms such as "all trade" or "trade relations"—which account for a substantial portion of the variation in their index— contained far more false positives than "tariff" words. The supplementary material compares our aggregate based on firms' earnings calls with the analogous measure constructed by Hassan et al. (2019).

[5] We use the Fama-French 12 industry classification described in Ken French's data library.

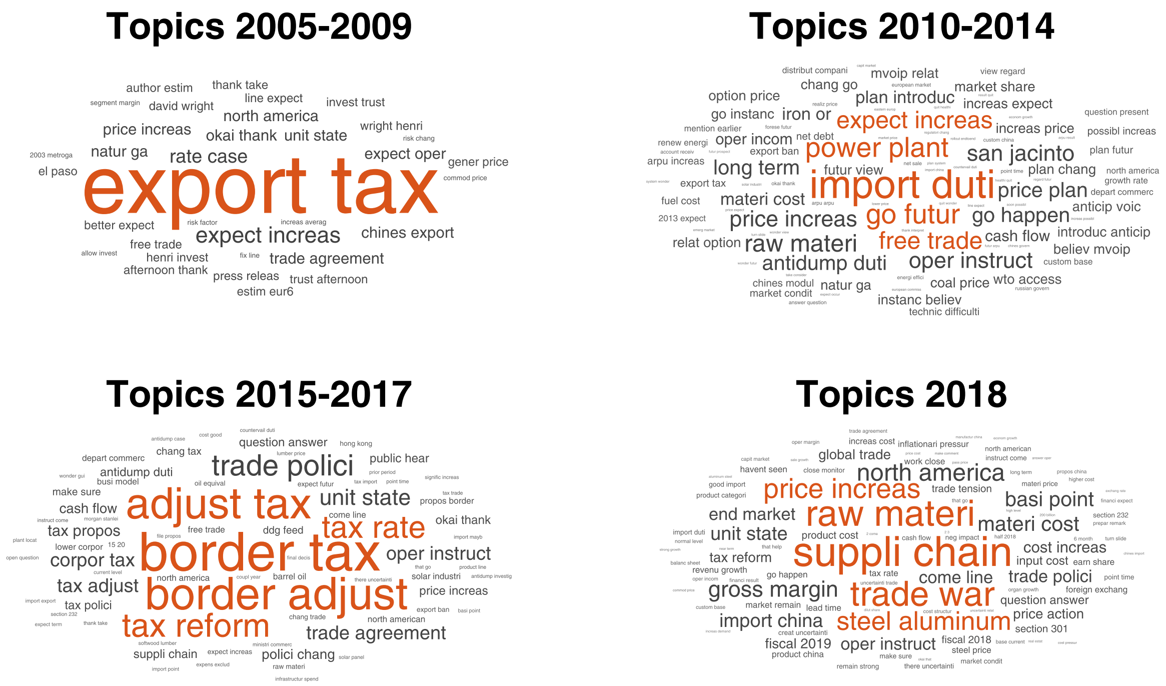

Fig. 2. Most Common Bigrams around Trade Policy Uncertainty terms in the Earnings Calls. *Note:* Word Clouds from the transcripts for four time periods.

Fig. 2 offers a window into the different types of concerns expressed by firms mentioning trade policy uncertainty. For each transcript classified as $\mathcal{I}_{i,t}^{TPU} = 1$, we isolate the bigrams appearing within 50 words of the trade uncertainty terms. The figure uses word clouds—where the font size of each bigram in the cloud is approximately proportional to its frequency—to show the most recurring bigrams for four time periods. In the periods 2005–2009 and 2010–2014, discussions about trade policy are frequently revolving around risks associated with either export or import taxes, respectively. Between 2015 and 2017, the key sources of risks are uncertainties surrounding the international implications of corporate tax policy, in particular uncertainties regarding the 2017 border tax adjustment proposal. Finally, the 2018 escalation in global trade tensions is reflected in concerns about supply chain disruptions and higher costs of raw materials.

2.2. *Aggregate trade policy uncertainty*

We complement the firm-level index of TPU with two measures of economy-wide TPU constructed using aggregate data.

The first measure is based on searches of newspaper articles that discuss trade policy uncertainty. We run—starting in 1960—automated text searches of the electronic archives of seven newspapers: Boston Globe, Chicago Tribune, Guardian, Los Angeles Times, New York Times, Wall Street Journal, and Washington Post. In constructing this aggregate index we closely follow the approach employed for the construction of the firm-level index. We make minor modifications to the list of search terms to better capture changes in the use of words over time. For instance, the list of search terms includes *import surcharges*—a term commonly used to refer to President Nixon's trade tariffs in the early 1970. We require that the trade policy terms appear along with uncertainty terms in the same article.[6] The final aggregate measure represents the monthly share of articles discussing trade policy uncertainty. We index the resulting series to equal 100 for an article share of 1 %.[7]

The second measure of trade policy uncertainty is estimated using a stochastic volatility model for import tariff rates. Following Mendoza et al. (1994) and Fernandez-Villaverde et al. (2015), we construct a quarterly measure of tariff rates, computed as $\tau_t = CD_t/(M_t - CD_t)$, where CD denotes customs duties and M denotes nominal imports of goods (inclusive of customs). The sample runs from 1960Q1 through 2018Q4. We posit that both the level of tariffs, τ_t, and their volatility, σ_t,

[6] The set of trade policy terms is: *tariff**, *import dut**, *import barrier**, *trade treat**, *trade polic**, *trade act**, *dumping*, *import fee**, *tax** (within ten words of *foreign good**, *foreign oil*, or *import**), and *import** (within 10 words of *surtax** or *surcharge**). The set of uncertainty words is: *uncertain**, *risk**, *potential**, *danger**, *dubious*, *unclear*, *probabl**, and *predict**.

[7] Baker et al. (2016) also construct a trade policy uncertainty index using newspaper searches. Compared to their index, our measure starts in 1960, adding an additional 25 years of data. In addition, our search terms differ slightly, as we do not explicitly search for mentions of legislation or institutions such as NAFTA and the WTO. The supplementary material compares our news-based index with theirs.

Table 1
Tariff rule: parameter estimates.

Parameter	Median	5-th ptile	95-th ptile
ρ_τ	0.99	0.99	0.99
σ	−6.14	−6.73	−5.47
ρ_σ	0.96	0.87	0.99
η	0.37	0.29	0.47

Note: The entries in the table denote the median, 5-th and 95-th percentiles of the posterior distribution of the parameters of the stochastic volatility model described in equations (1) and (2).

follow an autoregressive process given by:[8]

$$\tau_t = (1-\rho_\tau)\mu_\tau + \rho_\tau \tau_{t-1} + \exp(\sigma_t)\varepsilon_t, \quad \varepsilon_t \sim N(0,1), \tag{1}$$

$$\sigma_t = (1-\rho_\sigma)\sigma + \rho_\sigma \sigma_{t-1} + \eta u_t, \quad u_t \sim N(0,1) \tag{2}$$

This formulation for the tariff process incorporates two independent innovations. The first innovation (ε_t) captures unexpected changes in the level of tariffs. The second innovation (u_t) affects the spread of values for tariffs and acts like a volatility shock: A value σ_t higher than usual indicates increased uncertainty about tariff rates. We estimate the model using Bayesian techniques.[9]

Columns 2 to 4 in Table 1 report the median and 95% credible sets of the posterior distribution of the model parameters. Our estimates indicate that both the tariff rule and the tariff volatility process are very persistent. Innovations to the level of tariffs (ε_t) have an average standard deviation of $100 \times \exp(-6.14) = 0.22$ % points. A one-standard deviation innovation to the volatility of tariffs (u_t) increases the standard deviation of innovations to tariff shocks to about $100 \times \exp(-6.14 + 0.37) = 0.31$ % points.[10]

2.3. An historical overview of movements in aggregate TPU

Fig. 3 plots the news-based index of TPU, and Fig. 4 shows the tariff volatility series. For the latter, we plot the median and the 90% posterior probability interval. The series measures the percentage point increase in tariffs that would have resulted from a one-standard deviation innovation to the tariff shock at different points in time. The two figures allow us to build an historical account of uncertainty about trade policy. The news-based TPU and the tariff volatility series share two major spikes in 1971 and 1975. The first spike coincides with what historians often refer to as the "Nixon shock," an unanticipated policy shift in which the U.S. Administration imposed an across-the-board tariff on dutiable imports. The second spike begins with the January 1975 State of the Union address in which President Ford announced measures to address the energy crisis by, among other things, increasing taxes on oil imports. The interesting aspect of President Ford's actions is that they were implemented just weeks after Congress had voted on the 1974 Trade Act, which contained a strong push towards opening markets and granting more powers to the President to liberalize trade. Thus, the Ford Administration's use of trade policy instruments to deal with rising oil prices represented a surprising shift in the scope and use of trade policy.

While both measures provide a relatively accurate account of U.S. trade policy, they also suffer from a few shortcomings. The tariff volatility measure requires, by construction, changes in tariff rates to signal changes in tariff uncertainty. Hence, it does not increase in response to negotiations and proposals that do not result in actual changes in tariffs. The news-based TPU index better captures episodes of trade policy uncertainty that did not result in high tariff volatility, such as the two spikes at the beginning of Kennedy's presidency—when he proposed a rethinking of America's trade policies—and around the negotiation of NAFTA in the early 1990s. However, absent an empirical model, changes in the news-based TPU index are difficult to describe in economic units, as with similar measures of economic policy uncertainty. Notwithstanding these methodological differences, it is reassuring that the two measures describe similar patterns in U.S. history of trade policy.

As a final check on our news-based TPU measure, Fig. 5 compares the news-based TPU index with an index that measures the proportion of firms that mention TPU in their conference calls. The figure shows how companies' and media's

[8] The approach is similar to Fernandez-Villaverde et al. (2015), who estimate uncertainty about capital taxes. We also experimented with a level equation that includes feedback from the state of the economy (measured as the cyclical component of output), the level of debt (as a ratio of GDP), and the current account (as a ratio of GDP). Overall, our parameter estimates were not much different but the sample size shrank. Hence, we decided to have the simpler rule as our benchmark specification. The White (1980) and Breusch and Pagan (1979) tests indicate that the null hypothesis of homoskedastic shocks to tariffs is rejected at the 1% level.

[9] We use the particle filter algorithm of Born and Pfeifer (2014) to estimate the stochastic volatility process, taking 60,000 draws from the posterior distribution of the parameters, and discarding the first 10,000 draws.

[10] For comparison, Fernandez-Villaverde et al. (2015) find that the average standard deviation of capital income taxes is 0.75% points. Our estimates are about half as large, consistent with the conventional view that uncertainty about tariff policy over the past decades has been low compared to other fiscal policy instruments.

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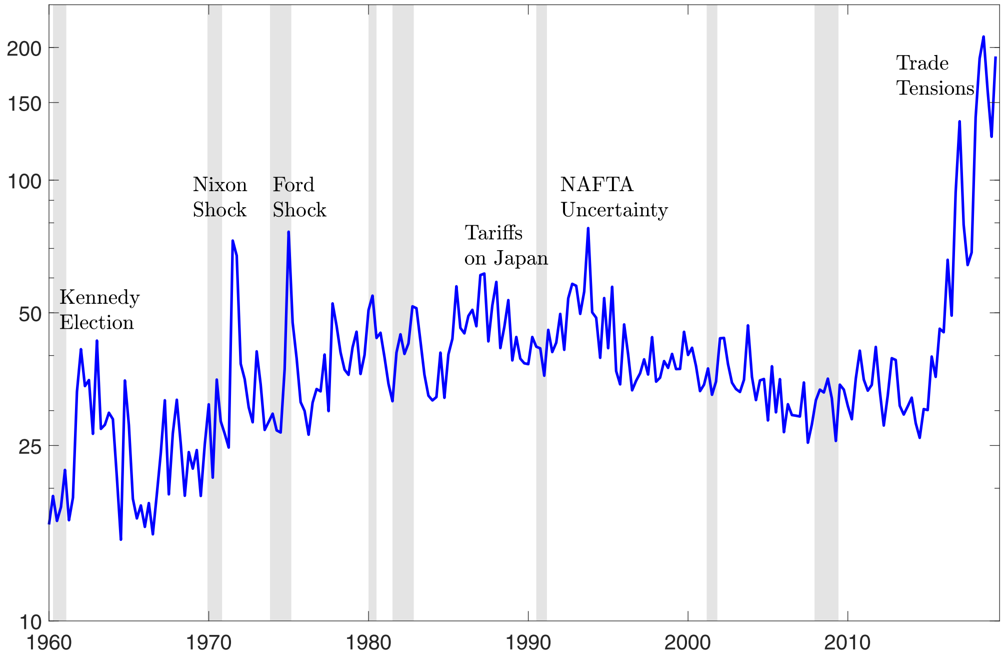

Fig. 3. News-Based Index of Aggregate Trade Policy Uncertainty. *Note:* Quarterly news-based trade policy uncertainty index extending through 2019Q2. A value of 100 indicates that one percent of all newspaper articles discuss trade policy uncertainty. The vertical gray areas represent NBER recession dates. The y-axis uses a log scale.

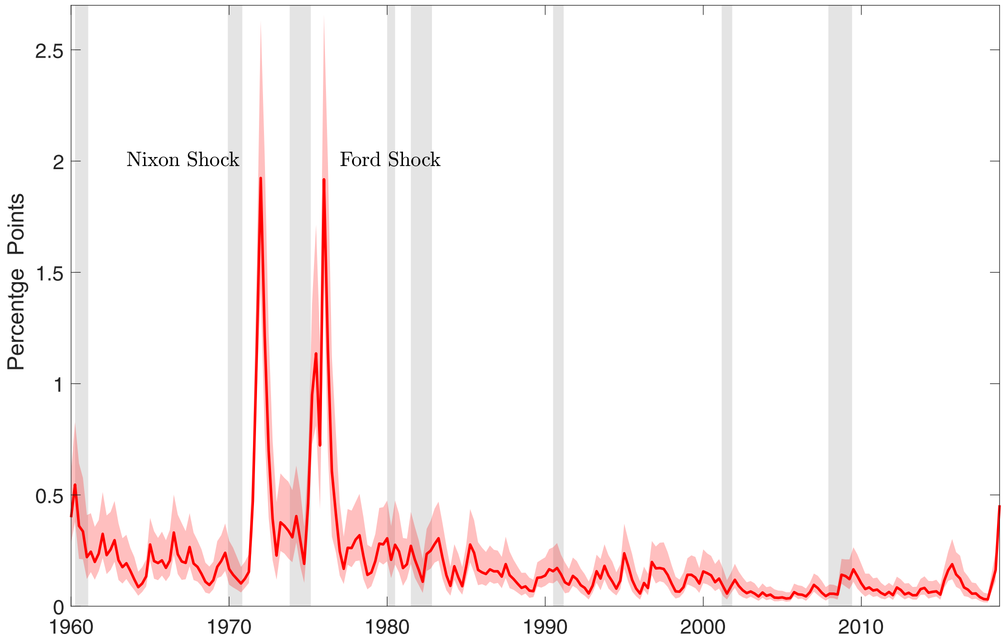

Fig. 4. Tariff Volatility Measure of Trade Policy Uncertainty. *Note:* The red line plots the median of the filtered series of tariff volatility—expressed in percentage points—estimated using a stochastic volatility model. The red shaded area surrounding the solid line represents the 90-percent point-wise credible sets, while the vertical gray areas represent NBER recession dates. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

perceptions of trade uncertainty are remarkably well-aligned. In particular, the fact that the news-based TPU index tracks very closely the aggregated firm-level trade uncertainty measure corroborates the use of news-based indicators as proxies for the concerns of economic agents.

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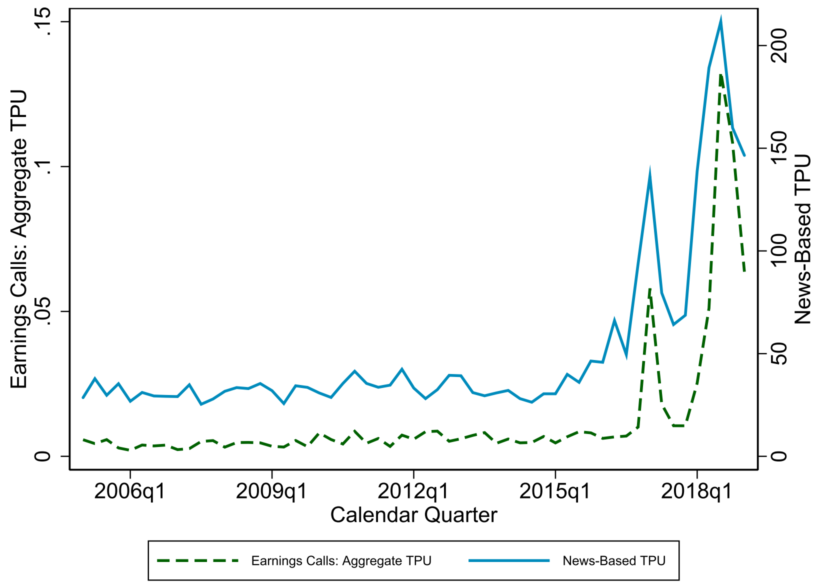

Fig. 5. Trade Policy Uncertainty in Firms Earnings Calls. *Note:* In each quarter, aggregate TPU from earnings calls measures the fraction of firms mentioning trade policy uncertainty in their earnings call. Newspaper Trade Uncertainty is the percent share of articles from seven major newspapers mentioning trade uncertainty. The latter series is indexed to 100 for an article share of 1 %.

3. The effects of trade policy uncertainty

We now use our TPU measures to estimate the economic effects of trade policy uncertainty.

3.1. Firm-level responses to trade policy uncertainty

We start by estimating the dynamic effects of changes in firm-specific $TPU_{i,t}$ on firm-level investment.[11] Disaggregated data allow us to exploit the wide range of variation in actual and perceived trade policy uncertainty across firms and over time. To this end, we combine the firm-level $TPU_{i,t}$ measure with quarterly data from Compustat, which contain balance-sheet variables for the near-universe of publicly listed firms. Our strategy is to regress investment at various horizons against contemporaneous values of firm-level $TPU_{i,t}$, the frequency of mentions of trade uncertainty in the firms' earnings calls. More precisely, we estimate:

$$\log k_{i,t+h} - \log k_{i,t-1} = \alpha_i + \alpha_t + \beta_h \; TPU_{i,t} + \mathbf{\Gamma}'\mathbf{X}_{i,t} + \varepsilon_{i,t} \qquad (3)$$

where $h \geq 0$ indexes current and future quarters. The goal is to estimate β_h, the dynamic effect on investment of variations in trade uncertainty at the firm level. Our investment measure is $\log k_{i,t+h} - \log k_{i,t-1}$, where $k_{i,t}$ is the capital stock of firm i at the start of period t, following Ottonello and Winberry (2018) and Clementi and Palazzo (2019). We include in the regression firm fixed effects (α_i) and quarter fixed effects (α_t). We denote by $\mathbf{X}_{i,t}$ firm-level control variables: Tobin's Q, cash flows, openness, one lag of the growth rate of the capital stock, and one lag of the trade policy uncertainty measure.[12] Table 2 displays key summary statistics.

In our baseline specification, we focus our analysis on the 2015Q1-2018Q4 period.[13] As discussed in Section 2, prior to 2015, there is little movement in aggregate and idiosyncratic TPU. While only 0.3 percent of firm-quarter observations mention TPU (i.e., $\mathcal{I}^{TPU} = 1$) for the years 2005–2014, this share of mentions jumps to 3.1 %, on average, from 2015 through 2018. In addition, we restrict the baseline sample to firms in the sectors of agriculture, mining, and manufacturing, thus leaving out wholesale and service sectors. Agriculture, mining, and manufacturing account for about one half of the firms in our sample and are the only sectors with data available to construct our openness measure. From 2015 through 2018, firms

[11] Hassan et al. (2019) study the effects of firm-specific policy uncertainty on investment within a static regression framework. Unlike them, our goal is to study the dynamic effect of trade policy uncertainty on capital accumulation.

[12] We measure capital as net property, plant, and equipment (PPENTQ) except in the first period where we initialize the firm's capital stock using the gross level (PPEGTQ). We measure Tobin's Q as the market value of equity plus the book value of assets minus book value of equity, all divided by the book value of assets (Gulen and Ion, 2015). Cash flows are calculated as cash and short-term investments (CHEQ) scaled by beginning-of-period property, plant, and equipment. Both Tobin's Q and cash flows are winsorized at the 1st and 99th percentiles. Finally, openness is the ratio of exports to usage—where usage is gross output plus imports less exports—at the industry level. Gross output by industry is from the Industry Economic Accounts Data published by the Bureau of Economic Analysis. Exports and imports data are from the U.S. Census Bureau U.S. International Trade and Goods and Services report.

[13] We use investment data up to 2019Q2, and TPU data and other controls up to 2018Q4.

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Table 2
Summary statistics for firm-level analysis.

	$100 \times \Delta \log K_{i,t}$	$TPU_{i,t}$	$\{TPU_{i,t} \mid TPU_{i,t} > 0\}$	$Openness_j$
Mean	0.801	0.001	0.024	0.179
Median	0.113	0.000	0.018	0.193
Standard deviation	10.41	0.007	0.017	0.062
Observations	13,903	13,903	700	13,903

Note: Summary statistics for the key variables used in the firm-level empirical analysis over the baseline sample from 2015Q1-2018Q4. $\Delta \log K_{i,t}$ and $TPU_{i,t}$ are investment and trade policy uncertainty, respectively, for firm *i*. $Openness_j$ is a measure of trade exposure for industry *j* at the 3-digit NAICS level.

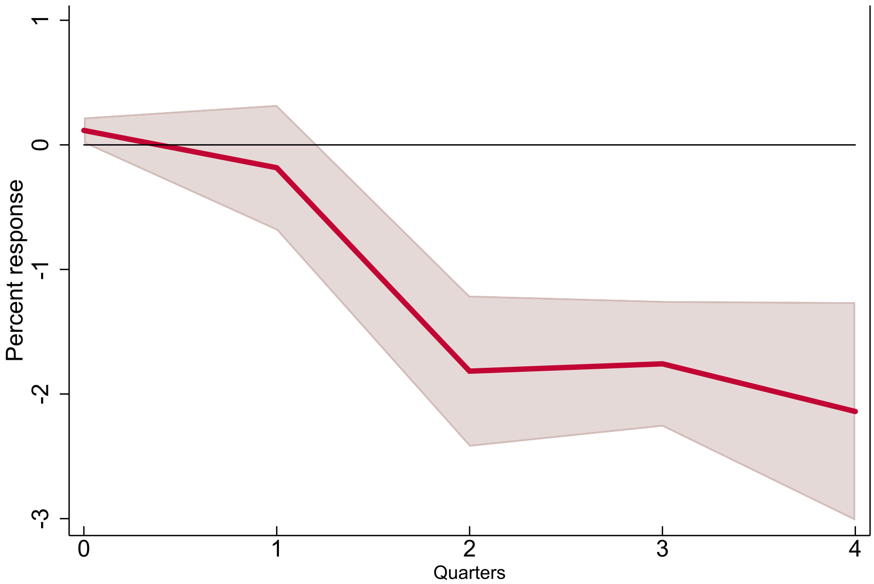

Fig. 6. Response of Capital to Firm-Level TPU. *Note:* Response of the stock of capital at different horizons following an increase in firm-level TPU from 0 to 0.0176, its median value when TPU is greater than 0. The shaded areas denote 1 standard error confidence interval. Standard errors are two-way clustered by firm and quarter.

in these sectors also mention trade uncertainty more frequently (4.7 vs. 1.7%) than in remaining sectors. All told, the baseline specification includes a total of 13,903 observations on 1482 firms. We estimate equation (3) at horizons $h = 0, 1, 2, 3, 4$.

Fig. 6 shows the response of firms' capital after an increase in TPU from 0 to 0.0176, the median value of TPU among firms with non-zero observations on TPU. The figure traces over time the differential impact on capital between a firm that is concerned about TPU and another one that is not concerned. The impact of higher TPU on the capital differential is negligible on impact, but builds over time. Four quarters after the increase in TPU, the capital stock of firms that are worried is 2% lower.[14]

Fig. 7 summarizes results for alternative specifications of our econometric framework. In Panel 1, we replace in equation (3) $TPU_{i,t}$ with $TPX_{i,t} = TP_{i,t} - TPU_{i,t}$, the frequency of words mentioning trade policy that are not related to uncertainty, which likely captures implemented trade policy measures at the firm level. As the panel shows, the effects of $TPX_{i,t}$ are smaller, and more imprecisely estimated, than those of $TPU_{i,t}$. Our interpretation for this result is that $TPX_{i,t}$ captures implemented trade policy actions that can either benefit or harm firm-level investment, thus resulting in smaller effects. Panel 2 shows the response of investment after dropping $\mathbf{X}_{i,t}$ from the baseline specification, while still controlling for lagged investment and lagged TPU. Our results hold irrespective of whether we control for any contemporaneous correlation between TPU and other variables capturing firms' investment opportunities, thus allaying the reverse-causation concern that firms mention TPU as a justification when business is not doing well. Panel 3 includes all firms (not only manufacturing firms), and Panel 4 extends the sample back to 2005 to 2018. In both cases, the results are similar to the baseline specification, thus suggesting that the effects of trade uncertainty at the firm level are stable across industries and

[14] The supplementary material reports quotes from the transcripts associated with some of the most influential observations in our sample that feature a large negative contribution of trade uncertainty to investment. While some mentions of trade uncertainty refer to an aggregate component, most of the discussions refer to sector-specific policies, to country-specific policies that affect firms doing business in particular region, or to a combination of the two.

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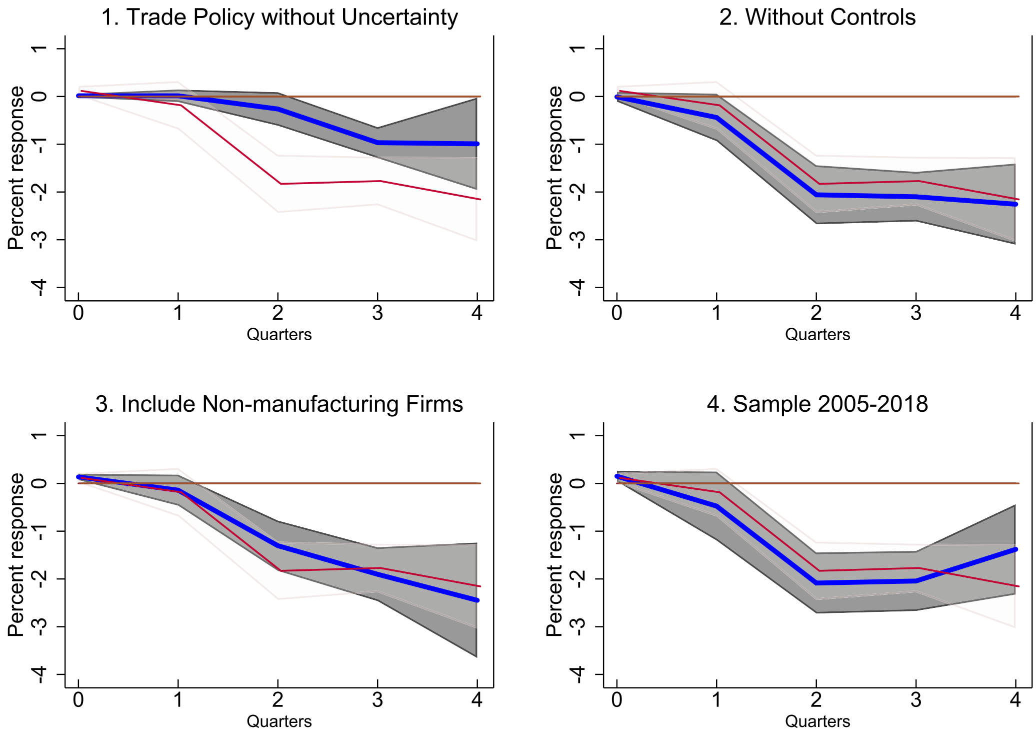

Fig. 7. Response of Capital to Firm-Level TPU: Additional Analysis. *Note:* The thin red line is the response in the baseline experiment of Fig. 6. Grey shaded areas denote 68% confidence intervals. Standard errors are two-way clustered by firm and quarter. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

over time. Under both specifications, the effects of an increase in trade policy uncertainty on investment remain negative, but the confidence intervals around the estimates are slightly larger.

Our firm-level approach does not directly answer the question of how aggregate trade uncertainty affects aggregate investment, since it "differences out" any aggregate general equilibrium effect. However, if we abstract from such general equilibrium effects, such as aggregate demand responses or spillovers across firms, we can gauge the quantitative importance of the aggregate effects by simply aggregating the direct firm-level effects. The share of firms that mention trade policy uncertainty in the earnings calls went from 2.8% in 2017 to 13.2% in 2018. Multiplying this 10.4 % point increase by the 2.14% response—after one year—of capital for a firm that is worried about TPU yields an aggregate decline of the capital stock of 0.22%. Since agriculture, mining, and manufacturing account for 43% of total assets in 2018, the decline in total capital for all listed firms can be estimated to be $0.104 \times 2.14 \times 0.43 = 0.096$ %. Multiplying this number by the stock of private nonresidential fixed assets, $24 trillion, gives a dollar effect of $23.4 billion. This drop amounts to about a 1% decline in private nonresidential fixed investment.

Trade Uncertainty, Actual Tariffs, and Industry Investment in 2018.

We conclude the firm-level analysis by zooming in on the industry effects of TPU for the year 2018, the year in our sample witnessing the largest increase in trade policy uncertainty. Our goal is to complement the local projections above with a simple analysis of the differential industry effects of heightened trade tensions in 2018. We construct industry-level changes in capital growth between 2017 and 2018, grouping firms according to the Fama–French 49 industry classifications. By the same token, we construct a variable measuring the change in trade uncertainty at the industry level between 2017 and 2018. The first column of Table 3 reports the results of the cross-sectional regression:

$$\Delta \log k_{j,2018} - \Delta \log k_{j,2017} = \alpha + \beta \Delta STPU_{j,2018} + u_j. \tag{4}$$

where $\Delta \log k_{j,t}$ denotes the log change from $t-1$ to t in the capital stock for industry j, and $\Delta STPU_{j,2018}$ measures the standardized change from 2017 to 2018 in trade uncertainty for industry j.[15] The estimated value of β is -1.57. To interpret this number, consider an industry that experienced an increase in TPU that is two times the cross sectional standard deviation

[15] Specifically, we denote by $\log k_{i,2018}$ the firm's capital stock at the end of 2018. The change in the capital stock for industry j at the end of year t is constructed as the weighted average of the change in the capital stock of the firms in the industry, $\Delta \log k_t = \sum_i \omega_i \Delta \log k_{it}$, where ω_i denotes the sectoral capital share of firm i in industry j at $t-1$. Trade uncertainty at the industry level is constructed as the yearly average of firm-level trade uncertainty by industry.

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Table 3
Trade Uncertainty and Industry Investment in 2018.

	(1) $\Delta \log K_{2018} - \Delta \log K_{2017}$	(2) $\Delta \log K_{2018} - \Delta \log K_{2017}$
$\Delta STPU_j$ in 2018	-1.574^{**}	-2.083^{**}
	(0.716)	(0.883)
New Tariffs in 2018		1.110
		(0.920)
Observations	47	42
R-squared	0.097	0.125

Note: Standard errors in parenthesis. * and ** denote significance at the 10 and 5 % level, respectively. Columns (1) to (2) regress change in industry investment (2018 vs 2017) against the standardized change in trade uncertainty at the industry level in 2018. Industries are grouped according to Fama and French 49-industries classification. We drop utilities, banks and financial institutions, as well as industries where we do not have data on new tariffs.

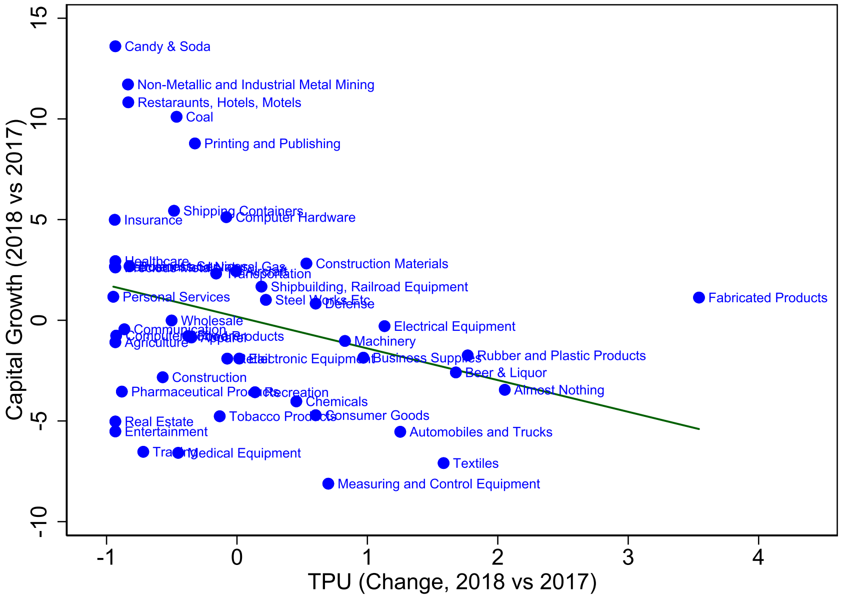

Fig. 8. Investment and Industry TPU in 2018. *Note:* Change in TPU in 2018 and change in capital growth in 2018 across the Fama-French 49 industries. TPU is normalized to have a mean of zero and unit standard deviation. The change in capital growth is indicated in percentage points.

of sectoral TPU changes in 2018. This industry is predicted to have reduced its capital growth by about 3.2 %. Fig. 8 offers a visual representation of the strong negative correlation between industry TPU and industry investment in 2018.

In 2018 certain tariffs themselves increased, beckoning the question whether this instance of high TPU simply captures the negative effects of higher tariffs. For each industry, we calculate the share of costs subject to new tariffs in 2018.[16] Column 2 enriches the specification above by controlling for new tariffs in 2018. The coefficient on new tariffs is statistically insignificant, thus indicating that the impact of tariffs on industry investment has been small.

3.2. Macroeconomic effects of trade policy uncertainty

There are two important challenges for our firm-level approach. First, how do we interpret firm-specific trade policy uncertainty when there is a large common component? One interpretation is that firm-specific trade uncertainty captures idiosyncratic exposure to a trade policy "shock" that has a strong aggregate component, but whose microeconomic ramifications affect firms and industries differently at different points in time. For instance, two firms in the same industry may buy inputs from suppliers in countries subject to differential trade policy shocks. Another interpretation is that firm-specific uncertainty captures differential risk aversion and expectations of managers regarding the same aggregate phenomenon. Under both interpretations, our cross-sectional evidence supports the notion that trade uncertainty deters investment.

[16] We thank Aaron Flaaen for sharing this measure with us. The share is constructed by combining input-output tables with the product list subject to new tariffs published by the U.S. Trade Representative.

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Second, how do we convert firm-level responses into aggregate responses when the common component is important? In the previous section, we have provided an estimate of such aggregate effects by abstracting from general equilibrium effects of TPU. An alternative approach to identify the effects of aggregate trade policy uncertainty relies on estimating a quarterly VAR.

We estimate three VAR models. The first is a bivariate VAR with the news-based TPU index and real business fixed investment per capita. The second model is a bivariate VAR that replaces news-based TPU with our measure of tariff volatility shocks. The third model adds to the first VAR actual tariffs, real GDP per capita, the Jurado et al. (2015) macroeconomic uncertainty index, the broad dollar index, and the tax rate on capital income. All these variables help purging the TPU index of movements unrelated to trade policy uncertainty.[17] We estimate these models over the sample 1960–2018. In all specifications, we apply a recursive identification scheme where we order TPU measures first, reflecting our assumption that our series of tariff volatility are exogenous to the macroeconomy (the supplementary material provides evidence that the identified TPU shocks are plausibly exogenous).

Fig. 9 plots TPU and investment in response to a 2-standard deviation shock to trade uncertainty under the three VAR models. The size of the shock is calibrated to mimic the spike in trade uncertainty in 2018.[18] The three models provide results that are in the same ballpark. In response to a TPU shock, trade uncertainty rises on impact and remains elevated for about three years. This prolonged period of uncertainty reduces investment, which declines between 1 and 2% for about a year, with the largest effects in the news-based specification.[19] We interpret this evidence as broadly consistent with the findings of the firm-level analysis, with the VAR results pointing to larger effects, possibly due to general equilibrium channels (see also the discussion in Caldara et al., 2019).

4. The model

In this section, we study the transmission of trade policy risk and uncertainty in a two-country model with heterogenous firms. We augment a New-Keynesian open-economy framework á la Gali and Monacelli (2005) and Corsetti et al. (2010) to allow for a discrete choice model of entering and exiting the export market as in Alessandria and Choi (2007). Intermediate goods producing firms specialize in the production of a differentiated good that can be exported provided that the firm finds it profitable to incur an up-front sunk cost to enter the export market, and a smaller period-by-period continuation cost to stay in the export market.

The economy consists of a home (H) country and a foreign (F) country that are isomorphic in structure. We denote foreign variables with an asterisk. Agents in each economy include households, retailers, wholesale firms, distributors, capital good producers, producers of intermediate goods, and the government.[20]

4.1. Households

Households in the home country choose final good consumption (C_t), differentiated labor supply and wages for their members ($l_{j,t}$ and $W_{j,t}$ for $j \in HH$), and a portfolio of assets $\{B_t(a)\}_{a \in A}$ to maximize expected lifetime utility:

$$E_s \sum_{t \geq s} \beta^{t-s} U\left(C_t, \left\{l_{j,t}\right\}_{j \in HH}\right), \tag{5}$$

subject to the budget constraint

$$P_t C_t + \sum_{a \in A} B_t(a) + \int AC^w_{j,t} dj \leq \int l_{j,t} W_{j,t} dj + \sum_{a \in A} B_{t-1}(a) R^B_t(a) + \Pi^{HH}_t + T_t, \tag{6}$$

where $AC^w_{j,t}$ is the cost for household member j of adjusting its wage, $R^B_t(a)$ is the return on asset $B_{t-1}(a)$, Π^{HH}_t are the aggregate profits of the firms in the home country (which are owned by the home consumers), T_t is a lump-sum transfer from the government, and P_t is the price index of the final good. The wage adjustment cost function is increasing in the aggregate level of employment (L_t) and quadratic in the desired wage change:

$$AC^w_{j,t} = \frac{\rho_w}{2} \left(\frac{W_{j,t}}{W_{j,t-1}} - 1 \right)^2 L_t. \tag{7}$$

[17] All models include two lags of the endogenous variables and a constant. We use the median of the filtered, instead of the smoothed, tariff volatility series estimated using the stochastic volatility model described in the previous section, so that we can condition on information at time t. Per capita variables are constructed using the quarterly civilian non-institutional population. We detrend data prior to estimation using a linear trend.

[18] For the tariff volatility measure, such a shock corresponds to an increase in volatility from its mean of 0.3 to a higher value of 0.9% points. This is about half the size of the Nixon and Ford shocks shown in Fig. 4, and is comparable to an out-of-sample estimate of the rise in volatility that would follow a gradual increase in average tariffs from 2 to 8 %. Tariff uncertainty as measured by our stochastic volatility model does not substantially rise in 2017 and 2018, mostly because the model infers changes in volatility from changes in actual tariffs, which have been modest in 2017 and 2018. For the news-based measure, the average shock in 2018 was about 2.5 standard deviations in size.

[19] The larger investment effects in the news-based specifications may reflect the nature of news-based TPU, which in practice incorporates both negative first-moment and second-moment information about trade policy.

[20] The main text only includes the optimality conditions that are key for the transmission mechanisms of the model. The supplementary material contains all the equilibrium equations of the model.

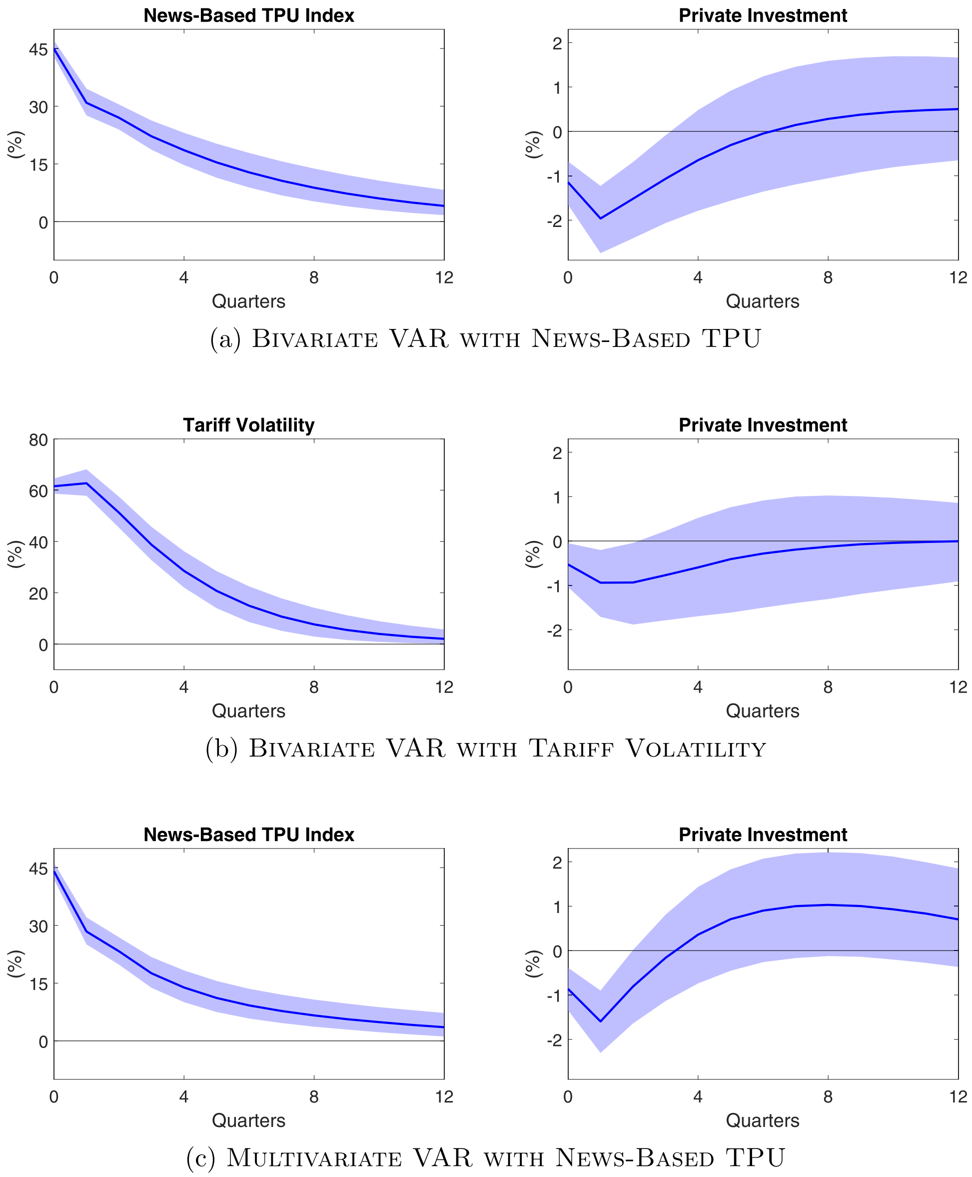

Fig. 9. The Investment Effects of TPU and Tariff Volatility Shocks. *Note:* The solid lines depict median responses of trade uncertainty indicators and private investment to a trade policy uncertainty shock of size two standard deviations. The VAR model is estimated on quarterly data from 1960 to 2018. The shaded bands represent the 70-percent point-wise credible sets.

where ρ_w is an adjustment cost as in Rotemberg (1982). In setting the wage, household member j takes as given intermediate good producers' labor demand:

$$l_{j,t} = \left(\frac{W_{j,t}}{W_t}\right)^{-\varepsilon_w} L_t, \tag{8}$$

where ε_w governs the elasticity of substitution across differentiated labor inputs.

4.2. Retailers

Competitive retailers in the home country combine differentiated goods varieties to produce a final good Y_t according to the constant-elasticity of substitution (CES) aggregator:

$$Y_t = \left[\int Y_t(i)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} di\right]^{\frac{\varepsilon_p}{\varepsilon_p - 1}}, \tag{9}$$

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where $\varepsilon_p \geq 0$ determines the elasticity of substitution between varieties. Profits for the retailers are given by $\Pi^R_{Y,t} = P_t Y_t - \int P_t(i) Y_t(i) di$, where $P_t(i)$ is the price of each individual variety i.

4.3. Wholesale firms

Each country features a continuum of monopolistically competitive wholesale firms that produce differentiated varieties by combining bundles of intermediates produced in the home country (D_{Ht}) and bundles produced and exported by the foreign country (D_{Ft}) according to:

$$Y_t(i) = \left[\omega^{\frac{1}{\theta}} (D_{Ht})^{\frac{\theta-1}{\theta}} + (1-\omega)^{\frac{1}{\theta}} (D_{Ft})^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{10}$$

where $\theta \geq 0$ is the elasticity of substitution between domestic and foreign bundles and ω governs the relative share of domestically produced consumption bundles.

Wholesale firms profits are

$$\Pi^W_{Y,t}(i) = P_t(i) Y_t(i) - P_{Ht} D_{Ht} - P_{Ft}(1 + \tau^m_t) D_{Ft} - AC^P_t(i) \tag{11}$$

where P_{Ht} and P_{Ft} are, respectively, the price indexes of the domestic and foreign intermediates, τ^m_t is the tariff that the home country may impose on imported intermediates, and $AC^P_t(i)$ is a quadratic cost incurred to adjust prices.

For any given level of production $Y_t(i)$, cost minimization yields the demand functions

$$D_{Ht}(i) = \omega \left[\frac{P_{Ht}}{MC_t(i)}\right]^{-\theta} Y_t(i), \tag{12}$$

$$D_{Ft}(i) = (1-\omega) \left[\frac{P_{Ft}(1+\tau^m_t)}{MC_t(i)}\right]^{-\theta} Y_t(i), \tag{13}$$

where $MC_t(i)$ is the marginal cost of production:

$$MC_t = \left[\omega (P_{Ht})^{1-\theta} + (1-\omega)(P_{Ft})^{1-\theta}(1+\tau^m_t)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{14}$$

These expressions imply that higher tariffs in the domestic country raise the relative cost of imported intermediate inputs and hence shift demand away from imported inputs towards domestically-produced intermediate inputs, that is:

$$\frac{D_{Ht}(i)}{D_{Ft}(i)} = \frac{\omega}{(1-\omega)} \left[\frac{P_{Ht}}{P_{Ft}\left(1+\tau^m_t\right)}\right]^{-\theta}. \tag{15}$$

Moreover, since tariffs are imposed on intermediate goods, higher tariffs raise wholesale firms' marginal costs.

4.4. Distributors

Competitive distributors specialize in the production of (CES) bundles of intermediates purchasing intermediate varieties produced both in the home country and in the foreign country:

$$D_{Ht} = \left[\int y_{Ht}(j)^{\frac{\varepsilon_D - 1}{\varepsilon_D}} dj\right]^{\frac{\varepsilon_D}{\varepsilon_D - 1}}, \tag{16}$$

$$D_{Ft} = (N^*_t)^{-\lambda \frac{\varepsilon_D}{\varepsilon_D - 1}} \left[\int_{j \in E^*_t} y_{Ft}(j)^{\frac{\varepsilon_D - 1}{\varepsilon_D}} dj\right]^{\frac{\varepsilon_D}{\varepsilon_D - 1}}, \tag{17}$$

where $\varepsilon_D > 1$ determines the elasticity of substitution between varieties. As in Alessandria and Choi (2007), the aggregator for foreign varieties includes the fraction of foreign intermediates available in the home country $\left(N^*_t\right)$, and the parameter λ allows separation of the love-of-variety effect from market power, which depends on ε_D. The set E^*_t includes foreign exporting firms. Distributors maximize profits given by:

$$\Pi^D_{Ht} = P_{Ht} D_{Ht} - \int P_{Ht}(j) y_{Ht}(j) dj, \tag{18}$$

$$\Pi^D_{Ft} = P_{Ft} D_{Ft} - \int_{j \in E^*_t} P_{Ft}(j) y_{Ft}(j) dj. \tag{19}$$

4.5. Capital goods producers

The supply of aggregate capital is determined by the problem of competitive capital good producers facing investment adjustment costs as in Christiano et al. (2005).[21] The increase in the aggregate capital stock is given by

$$I_t^k = K_t - (1-\delta)K_{t-1}, \tag{20}$$

where δ is the depreciation rate. If the investment level remains constant, $I_t^k = I_{t-1}^k$, new capital goods are produced one for one by employing the final good. However, when capital goods producers adjust their investment, they incur additional quadratic adjustment costs, given by $\frac{\kappa}{2}\left(\frac{I_t^k}{I_{t-1}^k}-1\right)^2$ per unit of I_t^k. Their problem is then to choose I_t^k to solve:

$$\max E_s \sum_{t\geq s} \beta^{t-s}\Lambda_{s,t} I_t^k \left(p_t^k - \left[1 + \frac{\kappa}{2}\left(\frac{I_t^k}{I_{t-1}^k} - 1\right)^2 \right]\right), \tag{21}$$

where $\Lambda_{s,t}$ is the household stochastic discount factor from s to t and p_t^k is the price of capital goods in real terms, i.e. expressed in units of the final good.

4.6. Producers of intermediate varieties

Our model of intermediate varieties producers follows Alessandria and Choi (2007). In each country, a unit mass of monopolistically competitive firms is indexed by $j \in [0, 1]$. Each firm produces output for the domestic market (y_{Ht}) and, if it decides to export, for the foreign market $\left(y_{Ht}^*\right)$, according to a constant returns to scale technology:

$$y_{Ht}(j) + m_t(j) y_{Ht}^*(j) \leq A_t z_t(j) k_t(j)^\alpha l_t(j)^{1-\alpha}, \tag{22}$$

where $m_t(j) \in \{0, 1\}$ is an indicator function denoting whether or not firm j decides to export in the current period, A_t is an autoregressive aggregate productivity shock, $z(j)$ is an idiosyncratic i.i.d. productivity shock, $k_t(j)$ is the producer's capital stock, and $l_t(j)$ is the amount of labor used in production. Within-period real profits are

$$\Pi_t^P(j) = p_{Ht}(j) y_{Ht}(j) + m_t(j) Q_t p_{Ht}^*(j) y_{Ht}^*(j) - w_t l_t(j) - p_t^k i_t(j), \tag{23}$$

where $p_{Ht}(j) = \frac{P_{Ht}(j)}{P_t}$ is the price of intermediate good variety j expressed in unit of the final domestic good, and analogously $P_{Ht}^*(j) = \frac{P_{Ht}^*(j)}{P_t^*}$, Q_t is the real exchange rate, and w_t is the aggregate real wage.

When a firm decides to export ($m_t = 1$), it incurs a fixed cost $f(m_{t-1})$ in units of labor that depends on its export status in the previous period. Specifically, firms pay a sunk cost to enter the export market, denoted by $f(0)$, that is higher than the fixed cost of continuing exporting in each period $f(1)$. If a firm exits the export market, it must repay the sunk cost $f(0)$ to reenter.[22] Firms accumulate capital according to the law of motion

$$k_{t+1}(j) = (1-\delta)k_t(j) + i_t(j). \tag{24}$$

An intermediate good producer with individual state (z_t, m_{t-1}, k_t), solves the following dynamic recursive problem

$$V_t(z_t, m_{t-1}, k_t) = \max_{m_t, i_t, k_{t+1}, l_t, p_{Ht}, p_{Ht}^*, y_{Ht}, y_{Ht}^*} \Pi_t^P - w_t m_t f(m_{t-1}) + E_t \Lambda_{t,t+1} V_{t+1}(z_{t+1}, m_t, k_{t+1}) \tag{25}$$

given the production technology (22, the law of motion for capital (24), and the demand schedules of competitive distributors in the domestic and foreign markets:

$$y_{Ht}(j) = \left[\frac{p_{Ht}(j)}{p_{Ht}}\right]^{-\varepsilon_D} D_{Ht} \tag{26}$$

$$y_{Ht}^*(j) = N_t^{-\lambda\varepsilon_D} \left[\frac{p_{Ht}^*(j)}{p_{Ht}^*}\right]^{-\varepsilon_D} D_{Ht}^*. \tag{27}$$

The optimal price setting requires charging a constant markup over marginal costs

$$p_{Ht}(j) = Q_t p_{Ht}^*(j) = \frac{\varepsilon_D}{\varepsilon_D - 1} \frac{w_t l_t}{(1-\alpha)\left[A_t z_t k_t^\alpha l_t^{1-\alpha}\right]}, \tag{28}$$

Using the optimal pricing conditions (28) and the demands for intermediate goods in (26) and (27), in the production function (22) yields a labor demand function:

$$l_t = (k_t)^{1-\nu} (A_t z)^{(\varepsilon_D - 1)\nu} \left(\frac{w_t}{\xi}\right)^{-\varepsilon_D \nu} \Gamma_t(m_t)^\nu \tag{29}$$

[21] This specification bears predictions for investment dynamics that match both macro and micro evidence (see for instance Eberly et al., 2012).

[22] In the Alessandria and Choi (2007) formulation, the fixed costs are per variety cost of starting exporting. This assumption rules out economies of scale to exporting, that is, the possibility that a single firm pays the sunk cost and exports multiple varieties of intermediate goods.

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where the term $\Gamma_t(m_t)$ captures how the size of the market that firms serve depends on its export decision m_t:

$$\Gamma_t(m_t) = p_{H,t}^{-\varepsilon_D}\left(D_{Ht} + m_t N_t^{-\lambda\varepsilon_D} D_{Ht}^*\right), \tag{30}$$

and where the parameters $\nu = \frac{1}{1+\alpha(\varepsilon_D-1)}$ and $\xi = (1-\alpha)\frac{\varepsilon_D-1}{\varepsilon_D}$ depend on the labor share and the elasticity of substitution across intermediate goods. Under our maintained assumption that intermediate goods are substitutes, i.e. $\varepsilon_D > 1$, both ν and ξ are between 0 and 1.

The optimality condition for investment is

$$p_t^k = E_t \Lambda_{t,t+1} V_{k,t+1}(j). \tag{31}$$

Since the idiosyncratic technology shocks z_t are i.i.d. across firms, Eq. (31) implies that k_{t+1} depends on the firm's export status in the following period (m_t), but is independent of z_t. Consequently, the distribution of capital across firms degenerates to two mass points:

$$k_{t+1} = \begin{cases} K_{t+1}^0 & if\ m_t = 0 \\ K_{t+1}^1 & if\ m_t = 1. \end{cases} \tag{32}$$

The decision to enter the export market can be summarized by the productivity threshold z_{mt} that equates the maximal values of exporting and not exporting for a firm entering time t with export status $m_{t-1} = m$:

$$V_t^1(z_{mt}, m, K_t^m) = V_t^0(z_{mt}, m, K_t^m). \tag{33}$$

Using the pricing rule and the labor demand in Eqs. (28) and (29), we can write (33) as:

$$p_t^k\left(K_{t+1}^1 - K_{t+1}^0\right) + w_t f(m) = \left[z_{mt}^{(\varepsilon_D-1)\nu}(1-\xi)\left(\frac{w_t}{\xi}\right)^{1-\varepsilon_D\nu}(K_t^m)^{1-\nu}\right]\left[\Gamma_t(1)^\nu - \Gamma_t(0)^\nu\right]$$
$$+ E_t \Lambda_{t,t+1}\left[V_{t+1}\left(z', 1, K_{t+1}^1\right) - V_{t+1}\left(z', 0, K_{t+1}^0\right)\right]. \tag{34}$$

The left-hand side of (34) represents the extra costs faced by firms to export, that is, a larger capital investment required to serve a larger market, $\left(K_{t+1}^1 > K_{t+1}^0\right)$, and the fixed cost to either enter $(m_{t-1} = 0)$ or stay $(m_{t-1} = 1)$ in the export market. The right-hand side represents the benefits of exporting, that is, the gains from serving a larger makert immediately, captured by the term $\left[\Gamma_t(1)^\nu - \Gamma_t(0)^\nu\right]$, and the expected larger continuation value of entering in the following period as an exporter. The continuation value includes the benefit for exporters of only paying the continuation costs $f(1) < f(0)$ to continue to export.

Finally, the fraction of exporters N_t evolves according to the law of motion

$$N_t = [1 - \Phi(z_{1t})]N_{t-1} + [1 - \Phi(z_{0t})](1 - N_{t-1}), \tag{35}$$

where $\Phi(\cdot)$ is the *cdf* of the log-normal variable $\log z_t \sim \mathcal{N}(0, \sigma_z)$.

4.7. Government policy and equilibrium

The monetary authority follows a Taylor rule that responds to inflation only:

$$R_t = \frac{1}{\beta}(\beta R_{t-1})^{\rho_R}\left(\pi_t^{\phi_\pi}\right)^{1-\rho_R} \tag{36}$$

where ρ_R is the inertial parameter and ϕ_π is the weight on inflation, $\pi_t = P_t/P_{t-1}$. The government balances its budget each period:

$$\frac{\tau_t^m}{1+\tau_t^m} P_{Ft} D_{Ft}^C = T_t, \tag{37}$$

where tariffs τ_t^m follow a first-order autoregressive process with stochastic volatility:

$$\tau_t^m = (1-\rho_\tau)\mu_\tau + \rho_\tau \tau_{t-1}^m + \exp\left(\sigma_{t-1}^m\right)\varepsilon_t^\tau + \varepsilon_{t-1}^N, \tag{38}$$

$$\sigma_t^m = (1-\rho_{\sigma^m})\sigma^m + \rho_{\sigma^m}\sigma_{t-1}^m + \eta u_t, \tag{39}$$

and ε_{t-1}^N denotes an innovation (news) about tariffs that is announced in period $t-1$ and materializes in period t. Aggregate productivity follows a first-order vector autoregressive process:

$$Z_t = M Z_{t-1} + \varepsilon_t^Z, \tag{40}$$

where M is a matrix of coefficients, $Z = \left[A_t, A_t^*\right]'$, and $\varepsilon_t^Z = \left[\varepsilon_t^A, \varepsilon_t^{A*}\right]' \overset{i.i.d.}{\sim} N(0, \Sigma)$. As mentioned earlier, the idiosyncratic productivity shock is such that $z_t(j) \overset{i.i.d.}{\sim} N(0, \sigma_z^2)$.

The definition of equilibrium is standard.

Table 4
Calibration.

Parameter	Symbol	Value
(a) Preferences		
Discount Factor	β	0.99
Risk Aversion	γ	2
Habit	b	0.75
Disutility of Hours	ψ	29.07
Inverse Frisch Elasticity	μ	1
(b) Rigidities		
Cost of wage adjustment	ρ_w	6908
Cost of price adjustment	ρ_p	575
(c) Technology – Unions, Wholesale Firms, and Distributors		
Elasticity of labor demand	ε_w	10
Elasticity of goods demand	ε_p	10
Trade elasticity	θ	1.5
Home bias	ω	0.85
Elasticity of substitution between bundles	ε_D	5
(d) Technology – Intermediate Good Producers		
Capital share	α	0.36
Capital depreciation rate	δ	0.025
Love-of-variety	λ	0
Investment adjustment cost	κ	10
Fixed sunk export cost	$f(0)$	0.0799
Fixed continuation export cost	$f(1)$	0.0115
Idiosyncratic TFP volatility	σ_z	0.5
(e) Monetary Policy Parameters		
Coefficient on inflation	ϕ_π	1.25
Inertia coefficient	ϕ_r	0.85
(f) Technology process		
Autoregressive coefficient	$M_{11} = M_{22}$	0.95
Spillover coefficient	$M_{12} = M_{21}$	0
Standard deviation	σ_Z	0.007

Note: The entries in the table denote the calibrated parameters of the DSGE model.

5. Model results

We solve the model using a third-order perturbation method. As discussed in Fernandez-Villaverde et al. (2015), shocks to volatility have direct effects only through third-order terms.

5.1. Calibration

In our experiments, asset markets are incomplete and only noncontingent bonds are traded (subject to a small quadratic adjustment cost that guarantees stationarity in the net foreign asset position). The calibration is described in Table 4. We assume a GHH utility function that features habits in consumption:

$$U(C, L) = \frac{\left[(C_t - bC_{t-1}) - \frac{\psi}{1+\mu} L_t^{1+\mu}\right]^{1-\gamma}}{1-\gamma} \tag{41}$$

where b is set equal to 0.75, the Frisch inverse elasticity parameter μ is 1, and the risk aversion parameter γ is 2. We assume a discount factor β of 0.99. The use of GHH preferences is well established in open-economy models (Mendoza, 1991 and Raffo, 2008) as well as in analysis of news shocks (Jaimovich and Rebelo, 2009). Habits in consumption induce a gradual response of consumption to tariffs and tariff uncertainty shocks. The robustness section compares our baseline formulation with an alternative that uses separable preferences of the form $\frac{(C_t - bC_{t-1})^{1-\gamma}}{1-\gamma} - \frac{\psi}{1+\mu} L_t^{1+\mu}$.

We set the wage and price stickiness parameters $\left(\rho_w, \rho_p\right)$ to a value that would replicate, in a linearized setup, the slope of the wage and price Phillips curve derived using Calvo stickiness with an average duration of wages and prices of 8 quarters. The elasticity of labor and goods demands associated with these monopolistically competitive pricing decisions $\left(\varepsilon_w, \varepsilon_p\right)$ is equal to 10. We set the trade elasticity (θ) to 1.5, as in Backus et al. (1994). The home bias parameter (ω) is 0.85. The capital share of traded goods (α) is 0.36, the depreciation rate (δ) is 0.025, and the parameter governing investment adjustment costs (κ) is 10, a value that yields an unconditional standard deviation of investment that is about twice as large as that of GDP.

The parameters for the production of intermediate goods follow Alessandria et al. (2018). We set the elasticity of intermediate goods demand (ε_D) to 5. The fixed export costs $f(0)$ and $f(1)$ and the dispersion of idiosyncratic productivity (σ_z) are set to target annualized exit rates of 4 %, an export participation rate of 22 %, and an exporter premium of 7 %. We tie

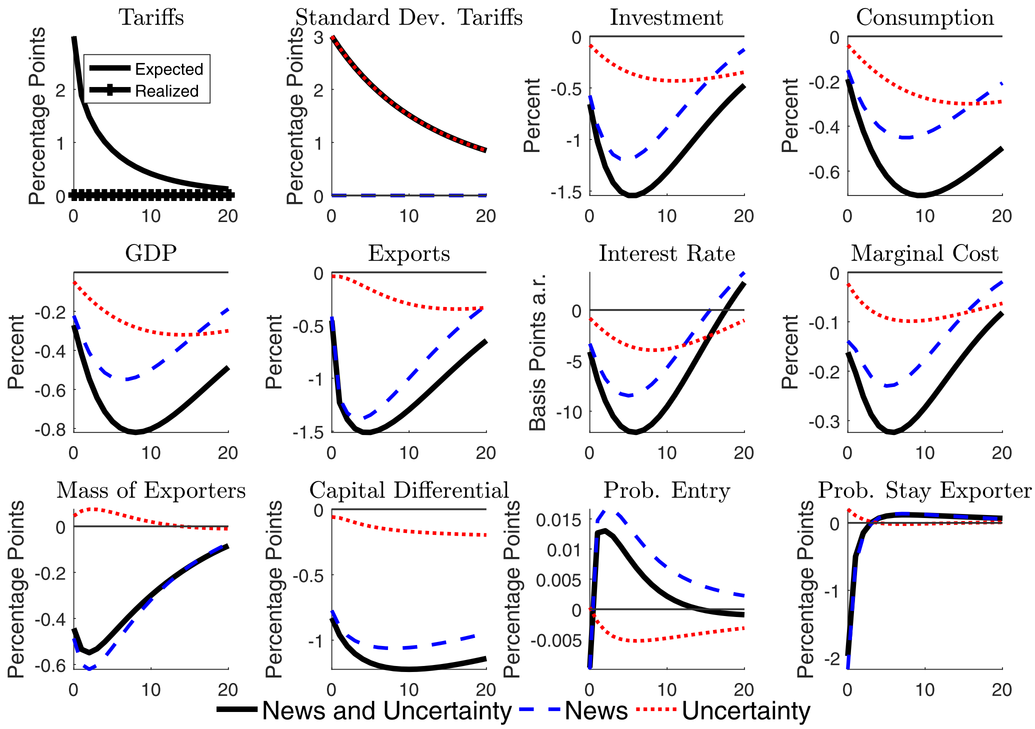

Fig. 10. Impulse Responses to News and Uncertainty Shocks. *Note:* Impulse responses to news and to uncertainty shocks in the baseline model. The horizontal axis measures quarters since the shock. Variables are in deviation from their steady state.

the love-of-variety to the elasticity of substitution across varieties and set $\lambda = 0$. In the Taylor rule (36), the inertia coefficient (ρ_R) is 0.85 and the coefficient on inflation (ϕ_π) is 1.25. Finally, we set the parameters describing the process for the tariff rate to the median estimates reported in Table 1. The parameters governing the remaining exogenous processes are taken from Alessandria and Choi (2007).

5.2. Model experiments

We model a rise in trade tensions as both a first moment shock (i.e. an increase in the *expectation* of future tariffs) and a second moment shock (i.e. an increase in the *uncertainty* about future tariffs) affecting simultaneously both countries. In all the experiments we trace the response of the economy to the shocks considered starting from the risk-adjusted steady state and assuming that all other shocks are equal to zero. This approach allows us to isolate the effects of news and uncertainty from those that reflect implemented trade policy actions.

As in the empirical section, our baseline experiment is largely calibrated following the trade policy developments of 2018. We size the initial increase in both the expected level of future tariffs, i.e. shock ε_0^N in (38), and the uncertainty of future tariffs, i.e. shock u_0 in (39), by using the threatened level of tariff rates on U.S. imports. Specifically, we assume that in the first period agents learn that trade negotiations between the two countries have begun. Agents forecast that, with probability $p_0 = 0.5$, tariffs on imports in the home and foreign countries will rise by 6 % points.[23] As a consequence, expected tariffs rise by 3 % points, $\varepsilon_0^N = E_0(\Delta\tau_1^m) = 0.5 \times 0.06 = 0.03$. In addition, the standard deviation of tariffs rises by 3 % points, $\exp(u_0) = \boldsymbol{\sigma_b}(p_0) \times 0.06 = 0.03$, where $\boldsymbol{\sigma_b}(p)$ is the standard deviation of a Bernoulli distribution with success probability p. Thereafter, the standard deviation of tariffs σ_t reverts back to its long-run value according to the stochastic process described in (39). We also assume that, as agents observe no rise in tariffs, beliefs about the future increases in tariffs are revised consistently with the path for the volatility process σ_t. That is, $\varepsilon_t^N = 0.06 \times \boldsymbol{p}(\sigma_t)$, where $\boldsymbol{p}(\sigma_t)$ satisfies $\boldsymbol{\sigma_b}(\boldsymbol{p}(\sigma_t)) = \sigma_t$.

Fig. 10 presents the response of the economy to the rise in trade tensions together with the effects in isolation of news of possible future higher tariffs and of higher tariff volatility. A rise in trade tensions leads to a sizable decline in investment,

[23] The expected increase in tariffs of six percentage points roughly captures tariff increases that have been threatened on imports from China and on imports of autos and motor-vehicle parts over the course of 2018 and the first half of 2019. Some announcements did eventually result in tariff increases as of June 2019. Our calculations are based on the timeline and quantitative analysis of tariff announcements and threats produced by Chad Bown at the Peterson Institute for International Economics (see https://www.piie.com/blogs/trade-investment-policy-watch/trump-trade-war-china-date-guide). In the absence of real-time survey evidence on expectations about future tariffs, we assume that agents assign an equal probability to both events.

consumption, GDP, and exports. As demand falls, so does inflation, and monetary policy responds by cutting interest rates. Given nominal rigidities, the decline in marginal costs indicates that wholesale firms increase their markups, contributing to a reduction of hours worked and consumption. The expectation of a smaller export market leads to a reduction in the mass of exporters—largely driven by an increase in exit—and a lower accumulation of capital by exporting firms compared to non-exporters. Importantly, the dynamic response of the capital differential closely matches the shape and the magnitude of the estimated responses from the firm-level analysis.[24] This contraction in aggregate demand and trade happens in the absence of any increase in realized tariffs, with news of higher future tariffs explaining about two-thirds of the declines in macroeconomic aggregates.[25]

Our baseline results are broadly in line with the empirical evidence discussed in Section 3. The decline in aggregate investment, which accounts for a significant portion of the contraction in GDP, falls within the range of responses estimated in our VAR section, even though the VAR impulse response was not a direct target of our calibration. In addition, to the extent that the exporting firms in the model are representative of the Compustat firms that experienced sizable increases in their TPU, a rise in trade tensions reduces exporters' capital accumulation to a greater extent than non-exporters', consistent with our firm-level regression results.

5.3. Anticipation effects of tariff shocks

A large literature studies trade policies in macroeconomic models.[26] This literature finds that tariffs shift demand from imports to domestically produced goods and act as a tax on labor and capital because they increase consumption and investment prices. Temporary trade policy changes have additional consequences via intertemporal substitution effects. Here we make use of these insights to study the effects of news about future tariff changes.

Fig. 11 presents the effects of news about higher expected tariffs in both countries together with sensitivity analysis to key features affecting transmission. Starting with the "Baseline" experiment, higher expected tariffs involve an intertemporal substitution channel and an aggregate supply channel that work in opposite directions. The intertemporal substitution channel pushes up current consumption and investment in anticipation of higher prices in the future. News about higher future tariffs, however, also increase the expected cost of imports, which reduces expected firms' profits and expected households' wages, implying lower demand for investment and consumption. Moreover, anticipating higher marginal costs in the future wholesale firms increase their markups, which acts as a tax on labor and further pushes down hours worked and consumption. Under the inertial Taylor rule, the decline in inflation calls for a reduction in the policy rate, but this reduction is not large enough to prevent a contraction in both consumption and investment decline. In addition, higher expected tariffs lower the benefit of exporting by shrinking the expected size of the export markets and hence the expected future gain from participation in the export market. Consequently, exports, the mass of exporters, and the relative investment of exporters all decline.[27]

Sticky prices are a central feature to deliver large contractionary effects of news about higher expected tariffs. With "Flexible Prices and Wages", tariff news reduce investment, while the intertemporal substitution channel drives up consumption on impact, thus creating negative comovement between aggregate variables.[28] Turning to the external sector, the decline in exports and in the mass of exporters under flexible prices is also smaller than in our benchmark model. This is due to the decline in the real interest rate which cushions the decline in the expected gain from exporting.

Firm heterogeneity and GHH preferences play an important role in the amplification of tariff news. When we shut down the Alessandria and Choi (2007) bloc of the model—by setting the sunk and continuation costs of exporting equal to zero ("No Export Cost")—the baseline economy reduces to a standard macroeconomic model with Armington trade. Overall, the response of the main macroeconomic variables is somewhat smaller than in the baseline economy, but transmission is not greatly affected. Similarly, with "Separable Preferences," the declines of investment, consumption, and output are attenuated as news about higher future tariffs increase labor supply through negative wealth effects.

The last experiment shows how the formulation of investment adjustment costs shape the investment response. When we assume an alternative formulation in which the adjustment costs depend on the stock of capital ("K adj. cost"), the re-

[24] The firm-level local projections in Fig. 6 trace the differential impact on capital over time between a firm that is concerned about TPU and a firm that is not concerned. To facilitate the comparison with such evidence, the model counterpart in Figs. 10–12 plots the time-0 expectation of the differential impact on capital over time between a firm that exports and one that does not when the initial shock occurs. Note that, unlike the other variables plotted, the capital differential conditions on time-0 information only and hence does not respond to shocks that materialize from period 1 onward. See the supplementary material for details.

[25] Our assumption of global shocks, balanced steady-state trade, and equally-sized countries implies that neither international borrowing and lending nor the exchange rate are affected by an increase in aggregate trade policy uncertainty. If we depart from the assumption of equally-sized countries and adjust the import shares to maintain balanced trade, relatively smaller countries would suffer larger output losses than larger countries because the appreciation of their currencies would provide an additional hit to exports.

[26] For recent contributions, see for instance Barattieri et al. (2018), Erceg et al. (2018), and Chari et al. (2019).

[27] The decline in the mass of exporters largely reflects the exit of exporting firms from the foreign market. Non-exporters, in contrast, benefit from the fall in fixed costs associated with lower wages, see Eq. (34), and the number of firms entering the export market is almost unchanged.

[28] This result is in line with the literature showing that the neoclassical growth model fails to reproduce macroeconomic comovement in response to aggregate and sector-specific TFP news (Jaimovich and Rebelo, 2009). Alessandria and Mix (2019) study the transmission of expected trade policy changes in a framework similar to ours but under flexible prices. Their simulations also show negative comovement in the responses of consumption and investment to tariff news.

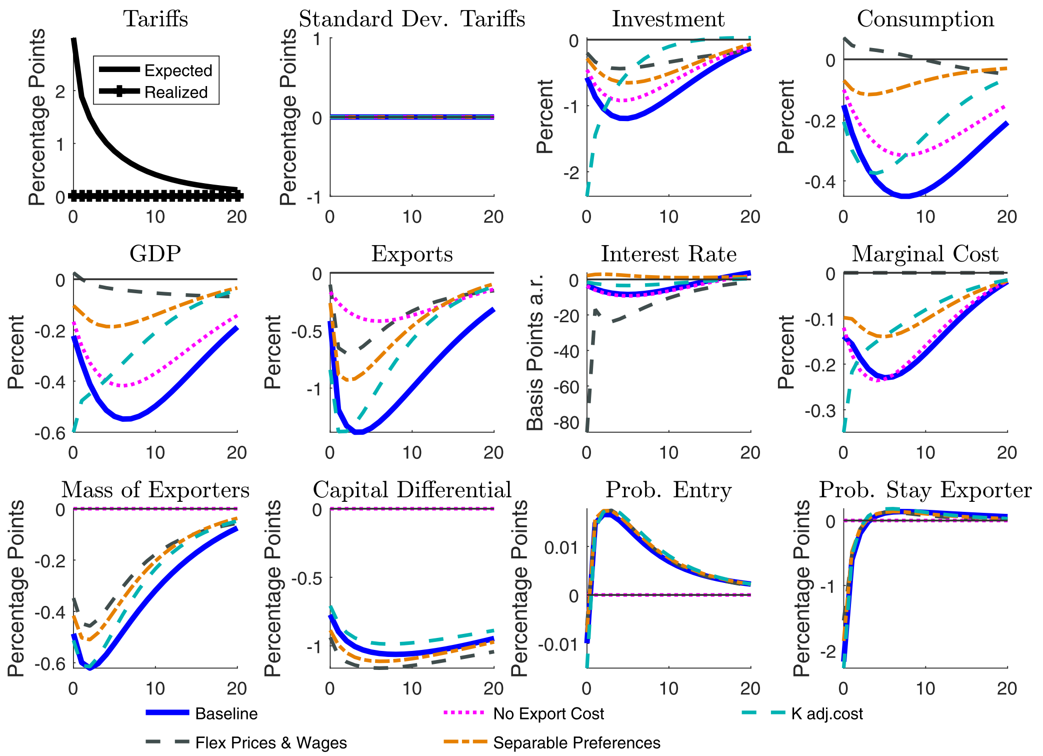

Fig. 11. Impulse Responses to News about Future Tariffs. *Note:* Robustness Analysis: Model impulse responses to news shocks. The horizontal axis measures quarters since the shock. Variables are in deviation from their steady state.

sponses of investment and output become front-loaded, but the main model properties do not change.[29] The VAR evidence in Fig. 9 suggests that investment bottoms out between one and two quarters after an increase in TPU, thus lending some appeal to the formulation with adjustment costs on the stock of capital. However, we prefer the benchmark formulation with investment adjustment costs for two main reasons. First, the flow adjustment cost has been shown to reproduce key dynamic properties of aggregate investment in a large class of medium-scale DSGE models. Second, there is some uncertainty on the shape of the empirical response of investment to trade policy uncertainty shocks. In the VAR evidence presented in Fig. 9, the response of investment is front-loaded when we consider news-based measures of TPU but hump-shaped when we consider tariff volatility shocks. Similarly, in Caldara et al. (2019) we document, using VAR estimates from monthly data on activity in the United States and abroad, that increases in trade policy uncertainty gradually reduce global economic activity, with effects that are more persistent and accumulating over several quarters.

5.4. Uncertainty effects of tariff shocks

Fig. 12 presents the effects of an increase in uncertainty about future tariffs in both countries together with a sensitivity analysis to key parameters affecting transmission. Besides standard precautionary saving motive weighing on households' consumption, higher uncertainty about future tariffs reduces investment, consumption, and GDP through two main channels. First, wholesale firms increase markups because of an upward bias pricing, as in Fernandez-Villaverde et al. (2015). Second, intermediate good firms find it less profitable to export. We next describe each channel in greater detail.

Nominal rigidities and markups are central to the transmission of tariff uncertainty shocks. Higher uncertainty about future tariffs leads to higher variance of future desired prices. When adjusting prices is costly, wholesale firms respond to higher tariff uncertainty by increasing markups in order to avoid selling at a relatively low price in the future. This precautionary increase in markup is a result of the fact that wholesale firm's losses from pricing below the period by period profit maximizing level, and hence serving a relatively larger market with low or negative markups, are larger than the losses from overpricing, as in this case the decline in market size is mitigated by larger unit markups. Higher markups then reduce hours worked, consumption, investment, and thus output. As discussed in Fernandez-Villaverde et al. (2015),

[29] We calibrate the capital adjustment cost parameter to deliver the same volatility of investment relative to GDP as in the baseline model.

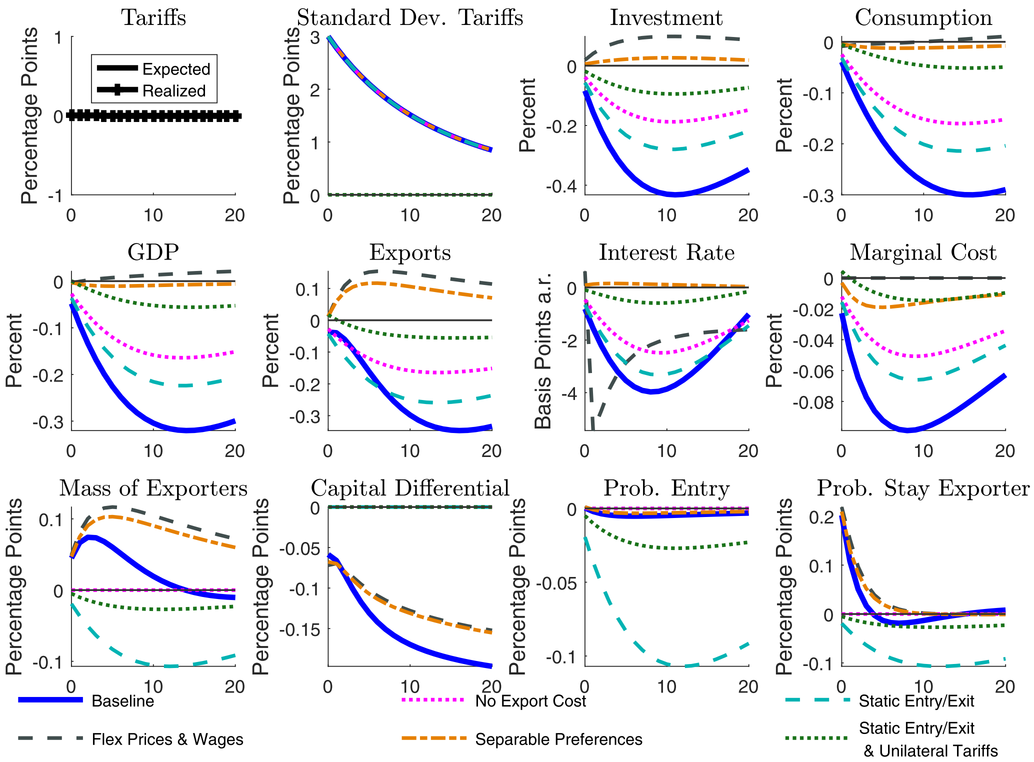

Fig. 12. Impulse Responses to Higher Uncertainty about Future Tariffs. *Note:* Robustness analysis: Model impulse responses to uncertainty shocks. The horizontal axis measures quarters since the shock. Variables are in deviation from their steady state.

the strength of this mechanism depends on the elasticity of substitution across goods and, more importantly, on a positive correlation between firms' demand and marginal costs.[30]

Turning to the external sector, higher uncertainty about future tariffs reduces exports, as the increase in foreign retailers' markups lowers foreign import demand. Exporting firms respond to this decline in foreign demand by reducing their scale of operation, and they do so more aggressively than non-exporting firms, leading to a decline in the capital differential. Therefore, in our simulations both first and second moment shocks lead to a larger decline in investment by exporters, in line with our firm-level evidence.

Our simulations indicate that the two features that are key for transmission of uncertainty shocks about tariffs are nominal rigidities and GHH preferences. In an economy with flexible prices and wages, markups are constant, and hence the main channel that is responsible for the contraction in economic activity in our baseline is simply not operative. The simulations labelled "Flex Prices and Wages" show that, absent nominal rigidities, increased uncertainty about tariffs causes investment and GDP to expand but consumption to decline, as households self-insure through capital accumulation. Under "Separable Preferences," uncertainty shocks have negligible effects on macroeconomic variables as the labor supply distortion created by higher markups is partially offset by the incentive to work more because of negative wealth effects. Consequently, higher uncertainty reduces consumption but increases investment. Overall, our findings suggest that GHH preferences and sticky prices are likely to be key ingredients of general equilibrium models interested in preserving comovement among macroeconomic variables in response to changes in uncertainty.[31]

To shed light on the quantitative role of the endogenous export decision, the "No Export Cost" experiment shows that eliminating the sunk and continuation costs of exporting attenuates the decline in investment, consumption, and output. Hence, firms' heterogeneity and endogenous export decisions allow the model to provide an interpretation of our firm-level empirical evidence and to bolster the transmission mechanism of uncertainty shocks.

In our calibration, higher trade policy uncertainty *increases* export participation despite fixed export costs. This outcome may appear puzzling in light of recent work by Handley and Limão (2017)—HL, henceforth—who argue that, in the presence of sunk export costs, trade policy uncertainty unequivocally reduces export participation. While HL abstract from capital

[30] Our simulations indicate that variation in tariffs induces aggregate demand and marginal costs to covary. This result may appear surprising because tariff increases depress demand and boost the price of intermediate inputs and, consequently, marginal costs. While that is the case, we find that the increase in marginal costs is extremely short-lived and firms anticipate that marginal costs and demand eventually decline together.

[31] Using separable preferences, Bloom et al. (2018) also find negative comovement between consumption and investment in the context of second moment productivity shocks and conjecture that the complementarity between consumption and hours in GHH preferences would restore comovement.

accumulation and the possibility of exiting the export market, in our model the heterogeneity in investment choices between exporters and non-exporters introduces a trade-off between export participation and differential capital investment.[32] This trade-off can be seen by inspecting equation (34), which shows that a smaller capital differential (i.e. a decrease in $K^1_{t+1} - K^0_{t+1}$) lowers the cost of exporting and hence, ceteris paribus, increases entry and reduces exit from the export market (i.e. $z_{m,t}$ falls). In the "Static Entry/Exit" simulations in Fig. 12, we shut down this channel by setting entry and continuation costs equal, so that the firm's choice to serve the foreign market only depends on its idiosyncratic productivity and the aggregate state of the economy, but is independent of its export status. In this experiment, there is no capital differential between exporting and non-exporting firms, as the marginal value of capital is identical across firms, regardless of their export participation choice. Accordingly, the dynamics of the mass of exporters closely track the response of trade to trade policy uncertainty. As in HL, higher trade policy uncertainty reduces export participation, as relatively high continuation costs induce more exporters to exit the foreign market. Finally, the experiment "Static Entry/Exit and Unilateral Tariffs" considers the same framework with equal entry and contination costs to study the shock considered in HL, i.e. an increase in trade policy uncertainty only in the foreign country. This simulation shows that increased trade policy uncertainty in one country reduces export participation and exports in the other country, although the effects are quantitatively smaller.

6. Conclusion

The renegotiation of major trade arrangements in Europe and North America as well as the increasing number of trade disputes across countries suggest that the prospects for global trade integration are far from certain. This paper provides a first attempt at quantifying the macroeconomic effects of changes in trade policy uncertainty, both empirically and theoretically. We present three TPU measures constructed from textual analysis of firms' earning calls as well newspaper coverage, and from aggregate tariff rates. Notwithstanding the different methodological approaches, all measures suggest that uncertainty about trade policy shot up in 2017 and 2018 to levels not seen since the 1970s. We then assess empirically the implications of unexpected increases in trade policy uncertainty on economic activity. Our firm-level estimates suggest that uncertainty about trade policy in 2018 may have lowered aggregate U.S. investment by 1 %. Our aggregate evidence based on VAR analysis points to larger effects. Finally, we studied the transmission of trade policy uncertainty in a two-country general equilibrium model with heterogeneous firms and endogenous export decision. We find that both higher expected tariffs and increased uncertainty about future tariffs deter investment, with exporters accumulating less capital than non-exporters. Both predictions are in line with our empirical evidence. Our framework emphasizes the role of nominal rigidities and fixed costs of export as important transmission mechanisms of the effects of trade policy uncertainty.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2019.11.002.

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[32] There are many differences between our economy and the one studied in HL. As mentioned above, firms in HL make only one dynamic choice, whether to enter the export market or not, given a constant level of productivity and an exogenous exit rate. In our model, by contrast, each firm accumulate capital and makes an export participation decision in each period which depends not only on the aggregate state of the economy, but also on the firm's current export status and relative productivity level, which is i.i.d. across firms and over time. In addition, HL largely focus on partial equilibrium effects and abstract from the feedback effects of tariffs on aggregate demand, labor supply, wages, exchange rates, and international borrowing and lending. Last, HL consider unilateral increases in uncertainty about tariffs.

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