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ABSTRACT

Trade policy uncertainty (TPU) has become an important source of economic uncertainty and research. We review the main sources and measures of TPU. We then provide a conceptual framework for modeling TPU and methods of estimating and quantifying its effects. We analyze its role in trade agreements and discuss open questions for future research.

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1 Introduction

Starting in 2016, trade policy uncertainty (TPU) became a major source of economic uncertainty and research.[1] The Brexit referendum and Trump's election signaled a reversal in the U.K. and U.S.'s traditional support for low protection and stable agreements. The subsequent renegotiation and eventual exit from long standing trade agreements and the 2018 trade war spread this uncertainty globally while raising important questions. How do we measure TPU? What are its impacts? How is it affected by agreements? Researchers tackled these questions by building on earlier analyses that recognized predictability was a core objective of trade agreements and examined the impacts of changing TPU, e.g. in China's WTO accession. Each section in the review reflects an area where research has made considerable progress in answering these basic questions: measurement, modelling, estimation and the role of agreements. We conclude with basic lessons, open questions and suggestions for future research.

In section 2 we discuss conceptual issues and alternative measures of TPU reflecting variation over time, countries, products and firms. In section 3 we outline a framework of trade investments under uncertainty that is central to this research. When firms make irreversible investments under uncertainty they have an option value of waiting; increases in TPU can increase this value and reduce current investments. This insight has been adapted to trade decisions involving sunk costs such as export entry and adoption of inputs or technologies in the context of demand or cost uncertainty. We note key implications of TPU for input and output trade and the role of policy downside risks for firm profits in identifying them empirically. We also discuss how large TPU shocks affect industry prices and thus consumers and import competing firms.[2]

The option value framework is a useful tool and it also captures the following views of policymakers' on the value of agreements and the costs of TPU. According to a former WTO Director General: "Businesses and consumers benefit every day from certainty and predictability about access to products and markets.[...] The world would not end because of trade policy uncertainty. But there would be a price to pay. Without predictability, growth and job creation would be slower and more fragile [...]. Investment and consumption decisions would be postponed, many of them indefinitely. All this would translate to lower productivity [...]."[3] We now have estimates of some of the 'price to pay' for TPU.

In section 4 we review estimates of the direct trade effects of TPU. Early research focused on the role of trade agreements (TAs) in affecting TPU and explored effects across products with differential tariff risk. There is evidence that TAs reduce TPU and increase export values and entry by securing prior tariff liberalization, reducing tariff bindings or lowering the probability of trade wars. TPU has played a central role in important episodes of trade integration (e.g. China's WTO accession) and disintegration (Brexit). Moreover, its effects extend to prices and tend to occur in industries with sunk costs of exporting. TPU can also affect sourcing and productivity but more research is needed. Recent evidence indicates that TPU on inputs dampens firm imports of intermediates and credible TAs can curb this by reducing the reversal probability of negotiated and pre-existing tariff cuts.

If TPU has large direct trade impacts then it also affects broader outcomes. In section 5 we first discuss the usefulness of TPU to identify impacts of trade shocks. We then summarize research on profits, investment,

[1] This is illustrated by the TPU news index for the U.S. in Figure 1 and by the number of google scholar articles using TPU, which was five times higher in 2016-2020 than in the previous five years.

[2] In other settings TPU can generate diversification investments or distort short-run production or inventory.

[3] "SPEECHES — DG ROBERTO AZEVEDO: To modernize the WTO, we will need vision and determination." https://www.wto.org/english/news_e/spra_e/spra301_e.htm (accessed 8/19/2021)

employment and other aggregate outcomes of TPU in the context of China's WTO accession, Brexit and the 2018 trade war. The empirical analysis identifies partial equilibrium effects, which in some cases are used to identify parameters and quantify general equilibrium outcomes.

The research on the effects of TPU generally assumes the policy regime is exogenous. But policy reflects the preferences of policymakers and their institutional constraints, so TPU is endogenous and can be changed. In section 6 we focus on a few studies where endogenous trade policy is not deterministic and have some insight for two broad questions. (1) How can uncertainty affect the incentives to set trade policies? (2) How can agreements affect TPU and when is this valuable? Future research explicitly incorporating endogenous TPU in TAs can improve the estimation and quantification of their impacts.

2 Sources and Measurement

We discuss conceptual issues in measuring TPU, some of its sources, and measures used in estimation.

Defining and measuring TPU presents challenges relative to standard economic variables. One difficulty is that trade policies are diverse and can target prices, quantities or quality for example. We focus the discussion on a price policy—tariffs—because they are commonly used, have a clear interpretation and are easily measured.[4] Another difficulty is that, unlike an exchange rate, there is no market to aggregate agent beliefs about trade policies. Therefore we must define what shapes agents' beliefs about future policies. We concentrate on firm decisions and discuss what informs their beliefs and how they may be measured.

What is an ideal measure of TPU? Suppose a firm's profit depends on a set of policies, τ_s, with different levels for each state of the world s. In this case, a standard forward looking decision made at time t would require a probability distribution over the policy levels, H_t. Using this distribution we could obtain a relevant measure of TPU for a particular model, e.g. variance or tail risk (capturing worsening conditions). Most research focuses on changes in uncertainty; to determine if an event leading to a new distribution H' increased TPU we would ideally measure whether or not H_t second-order stochastically dominates (SSD) H'.

Researchers have used different measures of TPU, which we classify into two broad categories. One relies on textual-analysis to identify certain terms related to TPU to construct broad time-varying indices. The other approach identifies events, e.g. entering an agreement, that change the probabilities of different states and proxies those states with focal tariff levels such as free trade, MFN or trade war. Below we describe each approach.

2.1 Trade Policy Indices

One measure of TPU is based on news indices that could inform firms' beliefs. These indices compute the fraction of newspaper articles on trade policy that also contain keywords related to TPU.[5] In Figure 1 we plot such an index for the U.S. using the data in Caldara et al. (2020). We note two features. First, the index was substantially higher under Trump but since 2020 it is returning to its earlier average. Second, the index rises around specific events—e.g. passage of NAFTA or WTO and Brexit vote—but then subsides as they exit the news. Thus the index may be useful at identifying certain events but not necessarily their

[4]Some of the insights apply to non-tariff barriers for which we can compute an advalorem tariff equivalent.

[5]Typical trade policy keywords include tariffs, quotas, trade policy, anti-dumping, etc. The uncertainty key words include risk, uncertain, unpredictable, unstable, etc.

longer term impact on TPU, i.e. whether TPU is lower under NAFTA. It is also not obvious that these indices inform or reflect the beliefs of the relevant firms.

Alternative indices based on company reports and investor conference calls attempt to directly capture firms' views on uncertainty. These indices have been applied in the context of political risk (Hassan et al. 2019), Brexit (Hassan et al., 2020) and the U.S. trade war (Benguria et al., 2020).[6] The index approach can capture high frequency changes in a broad measure of uncertainty across firms. The usefulness of these indices partly depends on whether the agents use uncertainty keywords in a way consistent with the models we estimate.[7] Even when that is the case we may require TPU measures that more clearly map to a model.

2.2 Trade Policy Regimes

The second approach identifies potential events leading to a policy regime switch, e.g., an agreement, and exploits policy variation to estimate the impacts of TPU. A trade policy regime has different characteristics; here we focus on two important ones. Trade policy is set by governments at discrete points in time, and we denote the probability of a new policy level arriving by γ. Conditional on such a change the new policy is drawn from some distribution, H, which is characterized by some risk measure. A regime is defined by these two characteristics and we say it reflects higher TPU if it has either higher policy volatility, γ, and/or riskier distribution.[8]

2.2.1 Policy Volatility

We first compare the volatility of trade policy with and without trade agreements (TAs). Research on TAs generally focuses on how they lower applied tarifffs and thus their mean. There is also increasing evidence that reciprocal TAs can lower the likelihood of policy changes between members. For example, Limão and Maggi (2015) find that the realized volatility of the average U.S. tariff was about twice as high in 1860-1933 than in 1934–61—the latter period includes the Reciprocal Trade Agreement Act (1934) and the signing of GATT (1948). Groppo and Piermartini (2014) find that WTO members in 1996-2001 were less likely to increase tariffs in products where they negotiate maximum rates, i.e. bindings. The realized volatility of agricultural trade policies falls after entering preferential trade agreements (Cadot et al., 2010).

TAs can reduce policy volatility but they do not eliminate it. Even long-standing reciprocal agreements allow for changes in tariffs and possibly other instruments. Moreover, as NAFTA and Brexit show, even when the realized tariff volatility is low there is a potential for large policy changes via renegotiation or abrogation of a TA. New governments and economic shocks can also affect policy volatility. For example, import protection was negatively correlated with economic growth before 2008 (Bown and Crowley, 2013), so shocks to domestic demand that are difficult to predict may increase the probability of trade policy changes and lead to a new regime, as Carballo et al. (2018) explore using the 2008 crisis.

[6]More generally, there is a rich literature on economic policy uncertainty that explores country-specific indices such as those available at the website www.policyuncertainty.com maintained by Baker et al. (2016). Most of them focus on all economic policies, rather than just trade.

[7]A potential issue in this regard is that textual indices show increases in uncertainty if keywords associated with it are commonly used to describe realized negative outcomes, e.g. increases in applied tariffs. Handley and Li (2020) discuss how using sufficient controls and testing predictions for the interaction of uncertainty proxies with other variables can alleviate this concern, but not eliminate it.

[8]In practice both characteristics can differ across regimes and generate changes in both first and second moments. In section 3.3 we discuss a sufficient measure of risk.

Certain unilateral tariff schemes can increase the volatility of policy. One example is the Generalized System of Preferences (GSP) whereby the U.S. and others grant lower than MFN tariffs to developing countries. GSP is subject to regular government review and in the case of the U.S. it has lapsed repeatedly (10 out of the last 14 renewals).[9] The TPU associated with GSP and other non-reciprocal TAs lead countries to seek less uncertain regimes. One example was the European Union's reform to increase the GSP review period from 3 to 10 years. Another example was the U.S. replacing unilateral temporary preferences to Peru and Colombia with stable reciprocal TAs, which these countries argued was important for export investments (cf. USITC, 2008).

An event that marked a clear regime switch is China's 2001 WTO accession. Most research examines the change in TPU in U.S. policy towards China. Chinese exports to the U.S. faced MFN tariffs since 1980 but this 'Normal Trade Relations' (NTR) status was subject to annual congressional reviews after the Tianmen Square protests. In the 1990's, Congress voted to revoke MFN yearly and the House passed the bill three times, but it was never implemented by the President. After accession China obtained permanent NTR status, which eliminated the renewal uncertainty. In section 4 we discuss estimates of the change in this probability of renewal.

How can we measure if economic agents expect a trade policy or regime to change? In principle, these beliefs could be directly elicited from well designed surveys. For example, Bloom et al. (2019) has a mix of managers qualitative assessments of their degree of uncertainty in addition to specific questions about the exact probability, each year, that the UK would leave the EU following the Brexit referendum.[10] Another alternative is using the probability of an event that is expected to change policy, e.g. polling for an election or referendum focused on trade. There are now several prediction markets that effectively aggregate beliefs about certain events and legislation and, under certain conditions, can be interpreted as probabilities.[11] One advantage of these measures is that even if an event did not occur we can use its probability to investigate some of its impacts via TPU on forward looking firms. Graziano et al. (2021) use prediction markets to measure the probability that 'Leave' wins the Brexit referendum and find an impact on firms even before the referendum.

2.2.2 Policy States and Tariff Risks

Firm decisions depend not only on whether a policy will change but by how much. Frequent changes that move a tariff within 1 percentage point say, will have smaller impacts than if the tariff can change by 10 percentage points. We now discuss tariff measures that have been useful in examining how much risk firms face if a tariff changes and how it varies across products and countries.

Suppose that, after a policy change, firms believe the new value is drawn from a fixed distribution, $H(\tau_s)$. What shapes those beliefs and what are some plausible measures of the distributions? A firm can associate a tariff τ_s imposed by an importer on a given product with a state of the world s. There are many possible tariff states but a few are focal and potentially informative. These states include duty-free, MFN and historical or non-cooperative tariffs. Within each of these there is additional variation, which we describe below.

An essential source of information for firms and researchers is published tariff schedules. In some countries

[9] The U.S. president can also unilaterally revoke GSP and did so for India and Turkey in 2019.

[10] An example is "'What do you think is the percentage likelihood (probability) of the U.K. leaving the E.U. (after the end of any transitional arrangements) in each of the following years: 2019; 2020; 2021; 2022; 2023 or later; Never."

[11] In the context of climate policies, Meng (2017) uses prediction market prices to infer the probability a carbon tax bill is passed by the U.S. Congress.

these schedules map tariff rates in each product to specific states. For example, an exporter of socket wrenches to the U.S. faces a zero tariff in a preferential tariff state; 9 percent if in the MFN state (e.g. a WTO exporter) and up to 45 percent under non-cooperation.[12] These potential states are relevant for a Mexican firm receiving duty-free preferences, which may lapse to MFN or to a higher level if there is a dispute. They are also informative for a UK exporter currently facing MFN but with some expectation of a preferential TA or trade war. So the possible states may be common across exporting countries, but the probability of facing MFN is higher for UK than for Mexican firms. So agreements can change the distributions and TPU by changing the probabilities of each state.

There is considerable variation in a country's tariffs across goods in any given state, which is important to identify TPU effects. The tariff distribution for any particular good could be described by the three tariff values, τ_s, as described for U.S. wrenches, and the probabilities of each state, η_s. In certain cases these probabilities are common across goods for a given importer-exporter, i.e., if the U.S. had withdrawn MFN status for China it would do so for all the products. If that occurs then two goods have different distributions if and only if their MFN and/or non-cooperative tariffs differ. Moreover, a common shock to η_s can then have heterogeneous effects on goods with different tariff states, as we will see in section 3.

We illustrate the variation of U.S. tariff states across goods and draw implications for tariff risk. Figure 2 plots the ln(1+tariff rate) of U.S. tariffs for HS6 products in 2000. The horizontal axis is MFN and the vertical axis is the column 2 rates. Since the minimum tariff is zero for all goods, the vertical axis also measures the range, and thus shows very different dispersion across goods. Using specific probability values, η_s, we could compute alternative measures of risk. However, in section 3 we will see that a standard option value theory of investment predicts that TPU works through the downside risk. This implies that if an exporter currently faces the MFN, then the relevant risk is proportional to the increase to column 2—the vertical distance from the 45 degree line labelled as "exporter tariff threat".

The relevant tariff threat depends on the location of the firm and the initial state. The main threat that Chinese exporters faced before the WTO was column 2, and is prominent in the studies we review. Products above the dashed line in Figure 2 have a threat above the bottom tercile of the sample and include knitted textiles and toys with variation even within those industries. We also see that there are large threats for products with either low or high MFN. For duty-free exporters, e.g. Mexico, the most relevant threat is the increase to MFN, which varies substantially across goods. For U.S. import competing firms the relevant threats are tariff reductions below MFN, or reductions in TPU faced by foreign firms, which we discuss in section 3.3.3.

Table 1 summarizes properties of focal tariff states in selected economies. It reports simple means over all HS6 for a country in a given year with standard deviations in parenthesis. Similarly to Figure 2 we use the ln(1+tariff rate) and report differences in log points (lp). An exporter to the U.S. under the MFN state faces an average tariff of 3.7 lp and a potential increase to 28.8 lp under column 2, so this exporter faces an average difference of about 25 lp. Other countries do not report the equivalent of the U.S. column 2 but researchers can use alternative measures for non-cooperative states. For example, during the Chinese unilateral liberalization in the 1990's there was some probability of reverting to pre-reform levels, which averaged about 42 lp in 1992 (Handley et al., 2020). There is also considerable variation across products, which is useful for identification. The historical values are also high for Brazil and India, whose reforms are

[12] The latter is measured by the column 2 tariff, and is applied or used as a threat for countries without a "normal trade relationship".

extensively studied without accounting for TPU.

Additional data and states may be relevant to firms in certain settings. U.S. tariffs since 2018 can inform current exporters about the trade war state. But a trade war has always been a possibility, particularly since the 2008 crisis. What could firms and researchers use as trade war threats before 2018 and for other countries? There is a growing literature on the determinants of non-cooperative tariffs and evidence that it is strongly correlated with a country's import market power. Estimates of optimal tariffs reflecting that market power across products are strongly correlated with the U.S. column 2 tariff and Chinese tariffs pre-WTO for example (Broda et al., 2008). Table 1 shows this measure of non-cooperative tariffs is high on average, particularly for large economies, the EU (51) and U.S. (66), but also India (31); so even small probabilities of a war could significantly affect firm decisions. Optimal tariff measures are noisy but contain information across products that may inform exporters; the probabilities firms assign to those tariffs is an empirical question and depends on the setting.[13]

There is uncertainty even within some of the focal states. We discussed uncertainty surrounding non-cooperative tariffs; we now consider MFN. We described MFN protection for a product-importer as a single tariff, but, in practice, WTO members can set its level anywhere below the negotiated maximum or binding. For several developed countries the applied MFN is close to the binding, as seen by the average in the second column of Table 1 for the U.S., Japan and E.U. But there are substantial gaps for other countries showing they can unilaterally increase tariffs without violating WTO rules. Australia can raise the MFN from 2.3 to 8 lp on average whereas Brazil can double it. India could triple its tariff on average for the 73% of products that it has bound, and is unconstrained on the remaining products. Worldwide, only about 70% of WTO member rates are bound and the applied MFN is below the binding in about half of those.[14] So exporters face uncertainty in specific products and markets where domestic political or economic shocks can change applied MFN tariffs. In section 4 we review research showing this type of TPU reduces trade. The possibility of lower MFN tariffs also creates uncertainty for import competing firms.

TPU also extends to non-tariff barriers (NTBs). Some sectors are particularly affected by NTBs but these are hard to measure. If the NTB was applied at some point then we can estimate an ad valorem equivalent or restrictiveness index (cf. Kee et al., 2009). The difference between applied and potential restrictiveness indices can then be used to estimate the impacts of uncertainty in instruments other than tariffs.[15]

TAs affect both features of a regime we highlighted: the likelihood of a policy change and the distribution. The TA changes the probabilities of states, e.g., higher for MFN and lower for a trade war for WTO members, and potentially their values, e.g., lower negotiated bindings. Variation in risk across products is useful to estimate changes in probabilities and the impacts of TPU. TAs can also reduce TPU by restricting alternative protection instruments, providing monitoring and predictable dispute systems. It would be interesting to measure some of these dimensions and estimate their impacts.

In sum, there has been progress in identifying and measuring central features of TPU. Some measures map the theory directly to estimation and others are more useful for descriptive and reduced form analysis; both are valuable as will be clearer in sections 4 and 5.

[13]For example, Graziano et al (2021) find that a higher probability of Brexit in 2015-16 lowered EU-UK trade in products with a higher MFN threat but the non-cooperative tariff threat was insignificant. Carballo et al (2018) find larger reductions in U.S. firm exports in the 2008 crisis in country-industries with higher non-cooperative threats.

[14]Bound shares are 2007 data from Beshkar et al. (2015).

[15]One example is Ahmad et al. (2020) who use services' preferential trade restrictiveness indices applied between the E.U. and U.K. before Brexit and the MFN threat they face without a deal.

3 Conceptual Framework

How can TPU affect firm decisions and what are its impacts? Uncertainty can affect short-run decisions, e.g., pricing and inventories, and longer-run investments, e.g., market entry. In this section, we focus on a framework that emphasizes long-run investments with two main goals. The first, is to show how this framework can guide the estimation, interpretation and quantification of different TPU effects discussed in sections 4 and 5. The second is to show how TPU modifies two important results: the determinants of bilateral trade and the consumer gains from trade.

We structure the section as follows. We start by describing how monopolistically competitive heterogeneous firms decide when to make sunk costs investments to enter a market, adopt a technology or new inputs. In this framework, TPU increases the firm's option value of waiting and can thus reduce investments.[16] We then examine output and input TPU separately. First, we consider output TPU, e.g. a tariff on a final good, and how it affects market entry. Interestingly, the relevant measure of TPU reflects only how the downside risk of policies affects profits. This measure of tail risk is prominent in recent studies and central to obtaining a "TPU-augmented gravity" equation. We outline how output TPU affects industry prices (via exporter and domestic firm entry), which is a key channel for import competition and consumer effects from trade. Extensions to alternative firm investments and input TPU provide additional insights and confirm the importance of policy tail risks. We conclude with a discussion of approaches that focus on risk aversion by managers or inventory decisions.

3.1 Firm decisions

We provide a simple model of sunk investments applicable to trade models.[17] Firms are monopolistically competitive and have heterogeneous marginal cost, c. We summarize output or input **market conditions** by a_s, where s indexes states of the world that depend on trade policy. The firm chooses production quantities each period after observing a_s. The operating profit for an incumbent firm takes a standard form that is decreasing in its marginal cost and increasing in a_s. The profit function also depends on whether the firm incurred an investment, e.g. entry into exporting, which is denoted by $z = \{0, 1\}$.

$$\pi_{sz} = \pi\left(a_s, c, z\right) \tag{1}$$

The investments we consider are made under uncertainty about future market conditions and have three properties. First, the firms can time their investment. Second, these are at least partially irreversible, which along with the timing is necessary to generate an option value of waiting. Third, the investments are complementary to market conditions in the sense that the change in profits due to the investment, $\Delta\pi\left(a_s, c\right) \equiv \pi_{s1} - \pi_{s0}$, is increasing in a_s. For example, a firm's operating profit is increasing in market demand but only after it pays the export sunk cost to enter that market. Thus, the investment decision depends on current conditions, and thus on any trade policy affecting a_s, as well as future conditions and TPU.

It is useful to contrast the decisions with and without uncertainty. Investors are risk neutral and the

[16] The key insights of irreversibility and the option value framework appear in Bernanke (1983) and Dixit (1989). Early applications in trade were focused on aggregate export dynamics under exchange rate uncertainty with homogeneous firms (Baldwin and Krugman, 1989).

[17] We follow the approach Handley and Limão (2015) generalized to incorporate subsequent extensions.

expected profit after investing is $\Pi(a_s, c, r) = \pi_{s1} + \mathbb{E}_s \Sigma_{t=1}^{\infty} \beta^t \pi_{s1}$, where $\beta < 1$ is a discount factor (reflecting the exogenous probability of firm or investment death) and $\mathbb{E}_s$ denotes firm expectations over future a_s; these expectations depend on the policy regime r, described in the next section. If investors believe a_s is fixed then $\Pi(a_s, c, r) = \pi_{s1}/(1-\beta)$, and we obtain a standard investment decision. Specifically, only sufficiently productive firms choose to pay the sunk cost K, i.e. only those firms with $c \le c_s^D$ where the marginal investor is defined by $\Delta\pi\left(a_s, c_s^D\right) = (1-\beta)K$.

Uncertainty generates an option value of waiting and thus lowers the incentive to invest at any given a_s. We provide intuition for this result and how it implies a stricter investment cutoff, $c_s^U < c_s^D$. Under uncertainty the firm is not simply comparing the gain from investing or not, but of investing today or in the future. Thus the marginal investor in state s has cost c_s^U, which equates the value of investing today and the expected value of operating profits if the firm chooses not to invest today but does so in the future after conditions improve, Π_w. Thus, the marginal firm has cutoff defined by $\Pi\left(a_s, c_s^U, r\right) - K = \Pi_w\left(a_s, c_s^U, r\right)$. Unanticipated increases in TPU lower Π relative to Π_w, which implies $c_s^U < c_s^D$. To see why, consider an increase in the probability of policy changes, so both better and worse conditions are more likely. The higher probability of better conditions increases Π, but it also increases Π_w by the same amount, since the marginal firm will take advantage of better conditions and invest. However, the higher probability of worse conditions lowers Π by more than Π_w since the firm avoided some of this downside risk while waiting. This asymmetric effect of uncertainty on investment where the downside risk dominates the investment decision is known as the "bad news principle" (Bernanke, 1983).

We highlight two insights from real options theory that are important in recent TPU research. The first is that uncertainty increases the "hurdle" to invest (Dixit and Pindyck, 1994). Below we describe applications where this higher hurdle can be characterized by an uncertainty factor $\tilde{U}(a_s, r) \in (0,1]$ such that the marginal firm has a cost defined by

$$\Delta\pi\left(a_s, c_s^U\right)\tilde{U}(a_s, r) = (1-\beta)K. \tag{2}$$

Without uncertainty $\tilde{U} = 1$ and the condition reflects a standard PDV condition for investment. Uncertainty reduces $\tilde{U}$ and thus would require a firm to be more productive to be willing to invest. So $\tilde{U}$ is a sufficient statistic for the investment effects of TPU; moreover it will reflect the bad news principle, i.e. how uncertainty lowers investment via the downside risk of market conditions. Next we operationalize this measure by linking trade policy to market conditions and showing how TPU works by increasing potential protection.

3.2 Trade Policy Regimes

We characterize firm beliefs about future trade policy and how events such as agreements may affect them.

Consider a policy τ_s, e.g. an ad valorem tariff, that affects operating profits through market conditions, a_s. As discussed in section 2 it is convenient to characterize whether the policy is likely to change and if so by how much. We can capture this by a regime $r = \{\gamma, H\}$ where γ is the probability the policy will change and H the distribution from which the new policy (and thus the new a) is drawn.

We can characterize TPU in terms of the policy regime as follows. There is no uncertainty if $\gamma = 0$, otherwise there is uncertainty and the policy has some persistence ($\gamma \in (0,1)$) or is i.i.d. ($\gamma = 1$). The policy persistence may vary by industry and country; it can change over time due to agreements or other events described in section 2. The impact of a policy change depends on its magnitude and thus the riskiness of H. Trade agreements can also affect this risk by constraining the policies that countries can use, e.g. via tariff bindings. If firms take the regime as given and independent of the current state then we can capture increases in TPU by examining exogenous increases in γ and the risk of H. We defer discussion of how governments can affect TPU to section 6.

3.3 Output TPU

What are the effects of import tariff uncertainty on final goods sold in a country? We first describe how industry export values can be described by a TPU-augmented gravity equation. We then discuss the impact of TPU on domestic firm entry and on consumer prices. The effects of TPU can be fully captured by a wedge between the deterministic and uncertainty cutoffs—consistent with the general hurdle expression (2)—and we show how to interpret and measure this wedge.

This section relies on the following additional structure. Consumer demand is $q_{vs} = D_s p_{vs}^{-\sigma}$ with constant elasticity of substitution $\sigma > 1$ across varieties v and an aggregate demand shifter D_s. Foreign firms face ad valorem tariff factors $\tau_s \geq 1$ and receive p_{vs}/τ_s per unit whereas domestic firms face no tariffs. Production is chosen each period after observing a_s, as described in section 3.1, so the equilibrium price equals a constant markup over marginal cost, $p_{vs} = \tau_s c_v \sigma / (\sigma - 1)$, and yields a standard operating profit expression for an incumbent, $\pi(a_s, c_v) = a_s c_v^{1-\sigma}$, where $a_s \equiv \tau_s^{-\sigma} D_s \tilde{\sigma}$. When labor is the only factor and its cost is normalized to unity then $1/c_v$ reflects the fundamental productivity, which is heterogeneous across firms.

3.3.1 Exports

To highlight the role of TPU via export entry we first consider a baseline industry gravity equation without TPU. Assume there are n producers heterogeneous only in their cost, which is drawn from a distribution F. Firm sales are proportional to profits so we can write the industry exports to a market without TPU as $R\left(a_s, c_s^D\right) \propto n \int_0^{c_s^D} a_s c_v^{1-\sigma} dF(c)$. For given market conditions, TPU will affect this industry gravity equation via changes in the export entry cutoff.

We first consider a small exporter, so TPU has negligible impact on importer aggregate variables, i.e. $D_s = D$. In this case Handley and Limão (2015) show that firms invest to start exporting if their cost is below the deterministic cutoff by an uncertainty factor defined by $U_s \leq 1$.

$$c_s^U = c_s^D \times U_s = \left[\frac{a_s}{(1-\beta)K}\right]^{\frac{1}{\sigma-1}} \times \left[1 + \tilde{\beta}\left(\omega_s - 1\right)\right]^{\frac{1}{\sigma-1}}. \tag{3}$$

In the absence of uncertainty $U_s = 1$ and the cutoff equals the deterministic one, so U_s is a sufficient statistic for TPU.[18] The uncertainty factor reflects two important features of the policy (i) its expected duration under a new state, $\tilde{\beta} \equiv \gamma\beta / (1 - \beta(1-\gamma))$, and (ii) its tail risk, $\omega_s - 1$. The latter is given by the expected proportion of operating profit lost after the policy changes. If there is a probability η of a tariff increase to τ^{hi} above the current level, τ_s, and this is the only possible increase then $\omega_s - 1 = -\eta\left[1 - \left(\tau^{hi}/\tau_s\right)^{-\sigma}\right]$. The term in [.] captures a tariff risk measure commonly used in empirical work and can be computed using the data in Figure 2 for the U.S. for example.

[18] Rewriting the first equality to represent profits we obtain the investment hurdle equation in (2) where $\tilde{U} = U^{\sigma-1}$.

This cutoff expression has the following implications for empirical work. First, a change in trade regime that increases the probability of higher protection, $\gamma\eta$, will decrease the cutoff and thus export entry. Second, that decrease is larger for products with higher tariff risk, so the variation across goods in risk discussed in section 2 is important. Third, U is a summary statistic for the impact of TPU on entry and so we do not require any impact of the trade regime change on other moments of market conditions.[19]

TPU augments the standard gravity equation to reflect the lower industry exports from reduced entry. We aggregate the sales of active exporters in a given industry. In a stationary period the gravity expression is the same we provided above without TPU except we evaluate it at the new cutoff, $R\left(a_s, c_s^U\right)$.[20] Defining the export entry elasticity by $k_c \equiv \frac{\partial \ln R\left(a_s, c_s^U\right)}{\partial \ln c^U} \geq 0$ we can decompose changes in exports as follows

$$d \ln R\left(a_s, c^U\left(a_s\right)\right) = k_c d \ln U_s + \left(1 + \frac{k_c}{\sigma - 1}\right)\left(-\sigma d \ln \tau_s + d \ln D\right) + d \ln n. \tag{4}$$

The key difference relative to a standard gravity equation is the TPU term, and its impact reflects the export entry elasticity. The remaining terms capture possible changes in applied tariffs, as well as aggregate effects independent of tariffs: domestic demand, D, and the number foreign producers, n.

The tariff elasticity plays a key role in trade models. While some research addresses threats to identifying this elasticity under certainty, omitting TPU adds the following novel threat. Conditional on U_s, the tariff elasticity shown in (4) has a standard interpretation in models without TPU: $-\sigma$ reflects the intensive margin contribution and the remaining the extensive margin. Suppose there is no change in the policy regime but applied tariffs fall. The increased exports from lower tariffs are attenuated by an increase in tariff risk since firms now have more to lose.[21] An important insight for studies evaluating trade reforms is the need to control for changes in TPU; if such a measure is not available then the tariff elasticity should be allowed to change to reflect its TPU impact.[22]

3.3.2 Extensions and Implications

We highlight some extensions of this approach and additional implications for exports.

- Additional policies. This approach applies directly to any other industry policy with an operating profit ad valorem equivalent, e.g. export or profit taxes and any regulations with costs proportional to export values (cf. Ahmad et al., 2020, for an application to services). Regulations affecting the sunk cost of exporting can also be incorporated.

[19] However, one can also decompose the effects as in Handley and Limao (2015). For example, if a regime has a distribution H SSD H' then its tail risk is lower, i.e. $\omega_s' \leq \omega_s$, at any a_s. Increases in γ when a_s is at its long-run mean capture a mean-preserving spread effect.

[20] In a stationary period there are exactly $nF\left(c_s^U\right)$ active exporters. But their number is higher if current conditions are worse than at some point in the past, in which case there are legacy firms that already incurred the sunk cost and continue to export until they die. Exports in non-stationary periods are discussed in the extensions. Throughout we assume a constant number of active foreign producers, n.

[21] If there are also changes in regime and we are estimating using variation across products then the bias can go in either direction depending on the correlation between changes in U and τ.

[22] Under the standard untruncated Pareto productivity with dispersion k we have $k_c = k - (\sigma - 1)$ so the total tariff elasticity is $\frac{-\sigma}{\sigma-1}k$. Omitting U there would be an additional partially offsetting term $-k_c \frac{d \ln U_t}{d \ln \tau_t}$ that is generally not constant even under Pareto. Key results on gains from trade rely on constant trade elasticities and recent research highlights the importance of allowing for variable elasticities, e.g. via productivity distributions other than untruncated Pareto (cf. Melitz and Redding, 2015), or variable markups (Arkolakis et al., 2019). Uncertainty generates variable tariff elasticities even with Pareto, CES and monopolistic competition.

- Technology/quality investments by incumbents. An incumbent exporter may invest to lower its marginal cost, access higher demand or a higher quality segment. If the investment is sunk and the outcomes increase operating profit proportionally then the approach in the previous section applies. An example is Handley and Limão (2017) where exporters can lower marginal costs by a constant factor; the hurdle condition (2) applies to the resulting upgrading cutoff and they show the uncertainty factor is the same as for entry (i.e. $c^U_{sz}/c^D_{sz} = U_s$ if z =entry, upgrade). Thus TPU can also impact continuing firms directly and the gravity equation (4) remains valid for them.

- Negative shocks and transition dynamics. In a stationary state there are no firms with costs above the current cutoff, so the mass of exporters is $nF\left(c^U_s\right)$, and exports are given by (4). If conditions deteriorate then some firms continue exporting even if their cost is above the current cutoff because they already incurred the sunk cost (and there are no period fixed costs). These legacy firms generate transition dynamics in their number and sales until conditions recover or they die.[23] We note three implications. First, there is sluggish adjustment to negative shocks and thus their short-run impact is attenuated relative to the long-run, so we may need to control for lagged negative shocks. Second, the adjustment to positive shocks is immediate in this model since firms can invest to take advantage of improvements (Graziano et al., 2021a, find some evidence for this asymmetry). Third, while exit rates are exogenous, measured gross exit still increases when TPU rises.[24]

3.3.3 Prices and Domestic Entry

Significant TPU shocks, such as the U.S. granting permanent normal trade relations (PNTR) to China, affect domestic outcomes, e.g. U.S. domestic production and consumers. We outline how TPU affects domestic firm entry and consumer real income via an ideal price index.

We capture the price effect on the demand for differentiated goods as follows. The demand shifter is micro founded as $D_s = \mu E P_s^{\sigma-1}$ where μE is a constant fraction of consumer income spent on differentiated goods and $P_s = \left[\int_{v\in\Omega_s}\left(p_{vs}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$ is the associated price index. Higher tariffs increase P_s by reducing the set of varieties, Ω_s, and increasing the consumer prices of the remaining ones. Handley and Limão (2017) show TPU also increases P_s by reducing foreign varieties, as seen before, and also domestic ones, as we now explain.

To isolate the effects of TPU relative to a baseline deterministic setting we define exact changes for each variable, e.g. $\hat{c}_s \equiv c^U_s/c^D_s$. The cutoff condition (3) for a small exporter can be written as $\hat{c}_s = U_s$, whereas for a large exporter it is now $\hat{c}_s = U_{s,g} \times \hat{P}_s$. The direct TPU effect, $U_{s,g}$, remains very similar and still lowers entry due to profit tail risk, but there is a new offsetting effect from the higher price level under uncertainty.[25]

Domestic firms making entry decisions also face uncertainty via the price effect. The domestic entry cutoff

[23] With a constant survival rate β the exports after a cutoff change $c'^U < c^U$ are a weighted average of the stationary values. Suppose TPU increases (at given policy values), then t periods after the shock we have $R_t = R\left(a_{is}, c'^U_{is}\right) + \beta^t\left[R\left(a_{is}, c^U_{is}\right) - R\left(a_{is}, c'^U_{is}\right)\right]$—where the second term captures legacy firms.

[24] Carballo et al. (2018) show this in a setting with discount factor $\beta = (1-\delta)(1-d)$, where δ and d are the probabilities of firm and export capital death respectively. After a capital death shock the firm can re-enter by paying K if it is below the cutoff so in stationary states the share of exports of non-continuing firms in the data is δ, since the firms that lost their export capital re-enter. The same is true if conditions improve. But otherwise the measured exit will exceed δ since some surviving firms that lost their export capital do not re-enter.

[25] This price effect is also reflected in the direct effect $U_{s,g}$ and is what distinguishes it from U_s.

ratio is $\hat{c}_s^h = U_{s,h} \times \hat{P}_s$. The key difference relative to exporters is that the direct TPU term, $U_{s,h} < 1$, reflects domestic profit tail risk that occurs if tariffs *fall* (leading to lower P). If the initial protection is sufficiently low, as in the U.S., then domestic firms have limited risk of tariff liberalization so $U_{s,h}$ is sufficiently close to one. Thus the framework implies that U.S. granting PNTR decreased U.S. domestic entry and production indirectly via a lower price index, as we discuss in section 5.

In sum, the direct effect of TPU is to reduce entry and thus real consumer income. The price increases when protection is uncertain, $\hat{P}_s > 1$, and reflects lower export entry—from potential tariff increases—and domestic entry—from potential decreases. In Handley and Limão (2017) the consumer real income reduction is then simply $\hat{P}_s^{-\mu}$, and we discuss a quantification of this 'price to pay' for TPU in section 5.3.[26]

3.4 Input TPU

A large fraction of imports is in intermediate inputs. We highlight some common insights relative to output TPU and modifications required to address interdependent input choices.

Handley et al. (2020) model firms' adoption decisions of inputs subject to price uncertainty. They build on a trade-off that is well understood in a static setting: increasing input variety can reduce marginal costs but adoption is costly (cf. Halpern et al., 2015; Antràs, et al., 2017; Blaum et al., 2018). When the adoption cost is sunk (e.g., input search, customization or technology change) then the decision becomes a dynamic one and there is a role for uncertainty.

We assume firms are monopolistically competitive with operating profits denoted by $\pi(\mathbf{n}_s, \tau_s)$, which is increasing in the number of imported inputs and decreasing in their unit prices. Firms that are sufficiently productive adopt new inputs and the optimal level depends on uncertainty. Without uncertainty the number of varieties of any input j equates their marginal benefit to the sunk cost of adoption: $\partial\pi/\partial n_j = (1-\beta) K$, and it is decreasing in own price, τ_j, and that of other inputs, $\tau_{\text{-}j}$, the latter reflects a complementarity effect across inputs in production.

Firm adoption of any input j is decreasing in the risk of price increases for j and other inputs due to an option value of waiting effect. After incurring a sunk cost to adopt n_j varieties the firm optimally continues to use them, due to a love-of-variety input production function. The unit cost of an imported variety is increasing in its tariff, τ_j, and potential increases in tariffs lower the value of adoption and this is one source of the option value of waiting to adopt. The risk of tariff increases in other inputs also lower the marginal benefit of using j and contribute to lower adoption. The option value of waiting in Handley et al. (2020) can be characterized by a hurdle equation similar to (2) for any given input, $\partial\pi/\partial n_j \tilde{U}_j(\tau_s, r) = (1-\beta) K$. The uncertainty factor, $\tilde{U}_j(\tau_s, r) \leq 1$, shares a key feature with the output case: it reflects how operating profits fall after a tariff increase in j relative to the current input tariffs. The authors also show how $\tilde{U}_j$ reflects the aggregate risk of tariff increases in all other inputs.

In sum, reductions in TPU can increase input adoption, expenditure on intermediate imports and profits. Moreover, omitting TPU will bias the elasticity of input demand with respect to tariffs, similarly to what we described for output TPU. We discuss evidence consistent with these predictions in section 4.2.

[26] They also show that if initial protection is high then TPU may lower domestic entry and thus consumer welfare below the autarky level.

3.5 Additional Applications and Frameworks

The sunk cost approach to TPU has several extensions and broader applications. We can incorporate interacting policy and economic shocks (Carballo et al., 2018) or firm sourcing decisions with fixed costs and endogenous exit (Carballo, 2016). It can be extended to simultaneously include output and input uncertainty from trade or other economic policies that affect operating profits. We emphasized adoption and output/input decisions but these naturally affect profits, employment and broader outcomes described in section 5.

We focused on a framework where the direct effect of TPU is to lower investment but showed indirect effects in the opposite direction, e.g., on import competing firms. Alternative frameworks imply TPU can have positive direct effects on certain investments and types of trade, e.g., if investments are fully reversible and based on the expected value of profits. In this case an increase in TPU that generates a mean-preserving spread in a firm's output price will increase expected profits when they are convex in prices. This convexity force is typically counteracted by introducing individual income risk aversion. Firm managers may also be risk averse and this may generate investments to diversify the source of inputs (Gervais, 2021) or export destinations (Esposito, 2020); both papers predict that welfare is decreasing in uncertainty.

Uncertainty can also affect short-run decisions if firms are uncertain about demand before producing and must adjust inventories to meet it. The implications for trade depend on the specific setting, e.g. in Alessandria et al. (2019) incumbent firms's shipments are made before tariffs are realized and increase if new barriers are anticipated in the short-run. Since holding inventory is costly, TPU still lowers average imports as it forces firms to deviate from their optimum order schedule. These inventory effects are interesting and relevant for understanding TPU and the short-run dynamics of trade.

4 Direct Trade Impacts

We organize the empirical research on TPU impacts by outcomes. This section focuses on direct trade impacts and section 5 on broader variables and general equilibrium effects. The conceptual framework guides the estimation in several papers and we use it to compare their results and contrast it with other methodologies.

4.1 Output

To identify the effect of output TPU on an outcome it is useful to start with a structural relationship to guide the estimation. For example, the TPU-augmented gravity in section 3.3 implies we can write exports to country i from firms in country-industry xV at time t as follows

$$y_{ixVt} = \varepsilon_U^y \ln U_{ixVt} + \varepsilon_\tau^y \ln \tau_{ixVt} + \alpha + u_{ixVt}. \tag{5}$$

Identifying a causal effect of uncertainty, ε_U^y, requires conditioning on a policy's current value, τ. It also generally requires conditioning on fixed effects, α, that can control for (at least) bilateral shocks and bilateral-industry characteristics, so as to minimize the potential for omitted variables in the error, u. To achieve this we require variation in uncertainty over both time and industries.

4.1.1 Exports

We discuss applications of the estimation framework to export outcomes in preferential, multilateral and other policy contexts.

We can interpret the coefficients in (5) using the gravity equation (4). The fixed effects in α control for aggregate import and export factors, D and n respectively. The coefficient ε_U^y maps to a constant export elasticity of entry. Constructing U would require probabilities about different scenarios, which are generally unobserved, but can be inferred. One approach is to derive an approximation to U and explore policy variation across industries and potential shocks to beliefs about policy changes over time. For example, a first order approximation around $\gamma = 0$ when there is a probability η_t of higher tariffs yields $\ln U_{ixVt} \approx -\frac{1}{\sigma-1}\frac{\beta\gamma_t\eta_t}{1-\beta}\left[1-\left(\tau_{ixV}^{hi}\big/\tau_{ixVt}\right)^{-\sigma}\right]$. The term in [] is what we define as a *tariff risk measure* and captures the percent reduction in operating profits under higher protection, all else equal. Variations of this risk measure are commonly used as a regressor and changes in its coefficient over time, e.g. after an agreement, reflect changes in the probability of worsening conditions, $\gamma_t\eta_t$. If this measure captures all product variation in tail risk then the coefficient on applied policies, ε_τ^y, reflects the tariff elasticity without TPU, otherwise it will be biased, as explained in section 3.3.

Preferential Agreements. Preferential trade agreements (PTAs) are widespread and a successful source of trade integration. This success is puzzling in the context of standard models where all that PTAs do is to eliminate tariffs from the already low MFN levels to zero (Limão, 2016). But several PTAs do more than this; including reducing TPU and thus spurring trade.

Handley and Limão (2015) estimate how securing existing tariff preferences expands exports. Portugal and Spain joined the European Community (EC) in 1986. Before accession Portuguese exporters already benefited from tariffs below MFN when exporting to the EC and to Spain. Importantly, these preferences were not permanent; they were potentially GATT-illegal and hence uncertain. Reversal of those preferences would impose MFN tariffs on Portuguese exports averaging 8% in the EC and 14% in Spain.

The relevant tariff risk measure for Portuguese exporters is then $1-\left(\tau_{iV}^{MFN}/\tau_{iVt}\right)^{-\sigma}$ and varies across industries and destination. They estimate (5) in changes between 1987 and 1985. The number of exporting firms (and export values) is decreasing in tariff risk before the agreement—with an implied probability of reversal to MFN of about one third—but not after, so the accession secured existing preferences. The predicted trade policy effects accounted for a substantial fraction of the large observed growth in export entry (61%) and values (87%). Holding TPU fixed, the reduction in applied tariffs accounts for only a small share of predicted growth in entry (20%) and values (30%). So when we allow for TPU in tariffs this instrument by itself can play an important role in explaining the trade effects of credible PTAs.[27]

Preference uncertainty is a key issue for developing countries. For example the U.S. Generalized System of Preferences (GSP) to developing countries is renewed periodically and has expired multiple times (Hakobyan, 2015). Similar concerns with the E.U.'s GSP system led to a 2014 reform to 'enhance stability and predictability' and 'improv(e) certainty for business operators' by extending the duration of preferences before review. Borchert and Di Ubaldo (2020) estimate this reform increased GSP exports to the E.U. by about 7%.

What happens if a country demands renegotiation of a PTA or threatens to leave it? Brexit has provided

[27] The authors also decompose the TPU effect and find over half is accounted for by a mean-preserving compression of tariffs.

a perfect setting to answer this question. Most studies focus on the unexpected outcome of the June 2016 referendum and, in the context of TPU, how it increased the probability of a U.K.-E.U. regime with higher protection. Crowley et al. (2020) construct tariff risk measures assuming a reversal to MFN; they find the referendum lead to larger reductions in U.K. exporting firm entry (and higher exit) in riskier products. Douch et al. (2019) use a similar approach and find that U.K. exporters of riskier products diverted exports toward non-E.U. countries.

Graziano et al. (2021a) argue Brexit TPU effects are present even before the referendum. Conservatives were elected in May 2015 and since that date prediction markets (and polls) provided high frequency probabilities for a leave outcome in the referendum promised by the new government. These probabilities can proxy for exporter beliefs about a change in regime and Graziano et al. (2021a) interact them with tariff risk measures in case of a reversal to MFN or to a trade war. They find reductions in bilateral U.K.-E.U. trade values between 11-20% and reductions in trade participation at the product level.[28] The effects are only present for the MFN threat and in industries with sunk costs—consistent with the option value approach. Two methodological points are worth noting. First, this approach can be applied even if a trade reform or agreement never occurs, which extends the scope of empirical analysis and potentially removes confounding effects after an event is realized. Second, it can generate TPU effects for any probability of the event.

Services represent an increasing fraction of trade and about 40% of U.K. exports. There is a dearth of research due to the lack of data at a disaggregated level and the difficulty of measuring services restrictions. Ahmad et al. (2020) explore new data that overcomes these difficulties. They use sectorial services and trade restrictiveness indices for the E.U. and U.K. at the preferential and MFN level to construct risk measures; these are interacted with a probability of Brexit from prediction markets between 2016Q1-2018Q4. They find significant negative effects of Brexit TPU on services.

Economic downturns can trigger import protection, or be correlated with it, and magnify the impacts of TPU. Carballo et al. (2018) model how uncertainty-reducing PTAs can provide insurance to exporters by preventing trade policy from magnifying economic shocks.[29] Their model predicts that increases in income uncertainty lower net entry of exporters to that market, particularly in the absence of a PTA. They examine this in the 2008 crisis where the large economic downturn and uncertainty generated an expectation of a trade war. They find a larger extensive margin export reduction of U.S. firms towards non-PTA than PTA destinations. Moreover, that differential was larger in industries with higher threat tariffs that would result in case of a trade war and in markets with high income uncertainty.

In sum, credible PTAs reduce TPU and thus promote trade between members. Brexit shows this integration can be reversed and highlights the risks of threats to exit or restrict preferences, which were used in the renegotiation of NAFTA. Future research can examine the impact of renegotiations on the credibility of PTAs as well as the TPU impacts on non-members and via inputs.

Multilateral Agreements. The World Trade Organization also shapes beliefs about trade policy. TPU research has focused on two key features in this context: the role of tariff bindings and domestic tariff commitments.

One of the stated principles of the WTO is to provide 'predictability through binding and transparency;'

[28] Graziano et al. (2020) apply this approach to U.K. trade with non-E.U. PTAs and find similar effects.

[29] Ruhl (2008) argues that PTAs can generate export entry by permanently lowering tariffs, which then increases the response of trade to other macro shocks.

since “Sometimes, promising not to raise a trade barrier can be as important as lowering one, because the promise gives businesses a clearer view of their future opportunities.”[30] Countries negotiate over the maximum legal MFN tariff, the so-called tariff binding. The difference between the current applied tariff and binding can be large, as documented in section 2 and Table 1.

Countries can increase tariffs to the binding level without facing a WTO sanctioned retaliation. Handley (2014) argues this is a plausible threat faced by exporters and constructs a tariff binding risk measure for Australian products. He then examines the effect of new or reduced bindings negotiated in the Uruguay Round on exports to Australia. He finds that reductions in this risk increased the probability of new country-product variety exports. Reductions in applied tariffs increase varieties conditional on risk, but this effect is partially attenuated if the tariff reduction increases risk, i.e. if it falls by more than the binding.[31] Deason (2014) and Osnago et al. (2015, 2018) extend this work to multiple countries and find higher binding gaps reduce the probability of exporting and the volume of exports. Exporters also respond more to this form of TPU when institutions are weak or in the presence of global value chains (where multiple products or stages may be impacted). Gnutzmann-Mkrtchyan and Henn (2018) find that bindings in the WTO Information Technology Agreement increased exports in those products.

WTO binding commitments seem to reduce risk along one dimension, but does the WTO reduce the probability of large scale trade wars? There were no large scale trade wars between WTO members (until 2018), but to understand if it lowered their probability we can examine accessions. A particularly useful and important episode is China’s accession in 2001, which reduced the probability of facing trade-war level tariffs in the U.S. Before accession, Chinese exports to the U.S. faced MFN tariffs. But this ‘Normal Trade Relations’ (NTR) status was subject to annual congressional reviews; revoking NTR would trigger Smoot-Hawley era tariffs and lead to an average increase of more than 30%. This would likely have been met by Chinese retaliation. The U.S. threat tariffs were known and listed in column 2 of its tariff schedule. WTO accession removed this threat and lead to *permanent* NTR, which the Chinese government viewed as ‘eliminating the major long-standing obstacle to the improvement of Sino-U.S. (...) economic relations and trade.’[32] But how much of a deterrent was this threat to Chinese exports and how did accession change its probability?

Handley and Limão (2017) provide evidence that China’s accession lowered the TPU it faced in the U.S. leading to large export value and price effects. They extend the sunk cost framework to large countries and apply the basic econometric approach in section 4.1 in changes between 2000-2005. The tariff risk measures capture the change in Chinese profits for different products of moving from MFN to column 2. The estimated reduction in TPU explains over one-third of China’s exports to the U.S. in this period. The export effects (for values and product entry) are only present in industries with export sunk costs; and it is robust to various controls and specifications.

The model in Handley and Limão (2017) allows key structural parameters to be inferred and used to compute general equilibrium effects for exports and other outcomes. The implied probability of revoking NTR before accession was small, around 13%, but the resulting barriers were high enough to generate export effects equivalent to a permanent tariff increase of 5 percentage points. We discuss estimated prices and general equilibrium effects below.

[30] “Principles of the WTO System”, (https://www.wto.org/english/thewto_e/whatis_e/tif_e/fact2_e.htm,accessed July 27, 2021).

[31] This is an example of the attenuation effect discussed after equation (4).

[32] “China-U.S. trade volume increases 32 times in 23 years - Xinhua reports” BBC Summary of World Broadcasts, 2/18/2002.

The effects of U.S. PNTR on Chinese exports are confirmed by other studies that use different data, focus on alternative mechanisms and/or different outcomes. For example, Pierce and Schott (2016) use U.S. import transaction data and focus on U.S. manufacturing employment (see section 5). Feng et al. (2017) propose a model where expected lower tariffs increase Chinese firm entry into the U.S. and focus on unit values (see section 4.1.2). Feenstra and Sasahara (2018) estimate an implied probability of MFN revocation of 15% for final goods. Alessandria et al. (2019) focus on the pre-accession period and provide evidence that the Congressional revocation votes changed tariff expectations. Chinese exports to the U.S. increase in the months leading up to a vote and then decline. Consistent with their inventory model, firms distort their purchase timing if there is a higher probability of a tariff increase in the near future.[33]

The WTO affects TPU in alternative ways and there are open avenues for research. Crowley et al. (2018) find that if an exporter in China is hit by tariff increases in a product then others in the same region (or industry) are less likely to start exporting that product because they believe it is risky; this happens before accession but subsides afterwards. The WTO also addresses anti-dumping, safeguards and NTBs; it would be interesting to examine how changes in rules or outcomes of disputes affect trade for countries other than China, e.g. by changing threat levels. Finally, it would be interesting to examine if the WTO lowered the probability of trade wars more generally, e.g. by examining how the threat of non-cooperative tariffs affects trade before and after accession.

Other applications and measures. There are alternative measures of TPU that are not tied to specific trade agreements. Greenland et al. (2019a) augment a gravity equation with country-specific indices of policy uncertainty and find negative effects only through the extensive margin; Constantinescu et al. (2020) confirm these results. Hlatshwayo (2018) uses a TPU index and finds it can increase trade. The author interprets this as an anticipatory effect of agreements but it could reflect mismeasurement: the index increases before agreements possibly due to uncertainty about the timing of signing and implementation.

A concern with country-level TPU indices is their correlation with other aggregate conditions. Nonetheless these indices may be useful if interacted with cross-sectional risk measures. For example, TPU news indices for the U.S. can be interacted with tariff risk of column 2 rates to examine U.S. imports before and after the 2016 presidential election (Li, 2020) or non-cooperative tariff risk during the 2018 trade war (Benguria and Saffie, 2019). The latter study finds evidence of TPU driving part of the trade reductions following the rise of U.S. protectionism in 2018. Another alternative is to construct TPU indices with time and firm variation. The text-based measures based on company filings and earning calls are one such example and below we discuss its applications.

4.1.2 Prices

Output TPU can directly increase prices because of reduced entry and upgrading investment, as noted in section 3. We discuss evidence for industry and firm prices and directions for future research.

Handley and Limão (2017) derive and estimate the pass-through from U.S. TPU to its prices. Specifically, changes in the price index of Chinese exports to the U.S. in an industry are increasing in U.S. TPU and take a form similar to exports in equation (4) but with a different elasticity. The estimation then follows a version

[33] Their model implies the probability of revocation of 4.5%, which is lower than Handley and Limão (2017) but this may simply reflect the absence of entry decisions and the focus on short-run responses. Alessandria et al. (2021) allow entry decisions and look at a longer sample period to infer an 11% probability of revocation.

of (5) where the dependent variable is changes in ideal CES price indices by product, and account for changes in prices and number of varieties. The reduction in U.S. TPU lowered the Chinese export price index by 17 log points. Using estimated structural parameters they show the counterfactual effect of re-introducing TPU in 2005 would be to raise the U.S. overall manufacturing price index by 0.5 log points, the equivalent of a 13 log point permanent increase in tariffs. Amiti et al. (2020a) also estimate a reduction in China's export price indices to the U.S. with lower TPU playing an important role via new Chinese varieties.

Feng et al. (2017) examine the same episode but focus on Chinese firm-product outcomes. They find increased export entry in products with higher tariff risk and lower prices for those entrants relative to exiting firm-products. Both findings are consistent with the basic framework we discussed where the cutoff changes induce entry and upgrading, but the authors provide a different interpretation based on their model.

There is some evidence that Brexit affected U.K. prices, possibly through TPU. Fernandes and Winters (2021) find lower entry and prices received by Portuguese firms exporting to the U.K. (relative to other markets) after the referendum; but they can't separately identify if it is due to TPU or the exchange rate depreciation. Graziano et al. (2021b) find relative increases in (euro) export price indices to the U.K. in riskier industries due to Brexit uncertainty before the referendum using the approach in Graziano et al. (2021a).

How does TPU affect consumer prices? The direct effect of TPU on exporter prices discussed above will increase consumer prices similarly—but the magnitude depends on the share in consumption (and on the price pass-through rate). The risk of higher protection also has indirect effects on consumer prices as import competing firms adjust to new exporter prices. Amiti et al. (2020) find a relative increase in non-Chinese prices for riskier products due to lower variety, and a decline in prices for continuing varieties, perhaps due to variable markups (or intermediate availability). Jaravel and Sager (2019) use the column 2 tariff measure as an instrument for Chinese import penetration growth, which is matched to and shown to decrease the relevant U.S. CPI product components.

There are interesting open questions. First, TPU can also directly increase domestic price indices by lowering domestic variety through the risk of low protection, the $U_{s,h}$ factor in section 4.1.2. There is no empirical evidence for this channel in the PNTR or Brexit studies because initial protection was already low in both settings. One context to explore this channel would be the Chinese liberalization, discussed below. The importance of this channel can still be obtained from counterfactual exercises in a structural model. Second, future research should complement the empirical partial equilibrium analysis with general equilibrium quantification that incorporates channels other than the price index, for example, variable markups and intermediates.

4.2 Inputs

A large fraction of trade is in intermediates and firms using those inputs face sunk costs to search and adopt them. We now review studies that distinguish between final and intermediate goods explicitly, and try to isolate how TPU affects input decisions for importing firms.

4.2.1 Intermediate Imports

Imbruno (2019) examines the impact of China's WTO tariff bindings on final and intermediate products. He proxies TPU with an indicator equal to one when a product's applied tariff equals the negotiated bound rate—so it has lower risk of increasing—and includes it in a gravity regression estimated with product data between 2000-2006. Chinese imports are increasing in this indicator and the effect is stronger for intermediates than for final products. In addition, he finds larger increases in the number of firm-product pairs in those same bound products, which is consistent with an adoption channel of TPU.

Handley et al. (2020) apply their model described in section 3.4 to Chinese firms' intermediate decisions. They ask if WTO accession increased the credibility of China's tariff liberalization that preceded it. They measure risk as the percent increase in a product's tariff if it reverted to its pre-1992 levels and find it depressed imported inputs before accession but significantly less so afterwards. This estimated commitment effect of the WTO on intermediates is larger than that of applied tariff reductions between 2000-2006. The reduced TPU also increases the elasticity of import values to tariffs. Moreover, post-accession, firms are more likely to adopt inputs with higher initial risk.

The input TPU framework has additional predictions that Handley et al. (2020) test; these are also useful in distinguishing input from export TPU theories. First, they find evidence of complementarity: imports of an input i are decreasing in the TPU of other inputs relevant for the firm. Second, the TPU effects are weaker for the least productive firms that are farther from adoption thresholds. Neither of these effects are present in standard models of export TPU and they indicate a novel TPU channel via import decisions. Future work should continue to distinguish between intermediate and final goods, focus on firm level data and firm-product risk measures if available.[34]

4.2.2 Sourcing mode and location

TPU can also affect how and where to source inputs. Carballo (2016) models a firm's choice of outsourcing vs. integrated production. Demand uncertainty lowers integration, which has higher sunk cost than outsourcing. At the same time trade between integrated firms is less sensitive to economic uncertainty shocks, as he finds for U.S. firms supplying related parties abroad after the 2008 crisis.[35]

How is the number and structure of international buyer-seller relationships affected by TPU? Pierce and Schott (2016) use U.S. import transactions and find an increase in the number of buyer-seller relationships with China after 2001 particularly in products with higher column 2 risk. Heise et al. (2019) use this data and experiment to test a model of firms' procurement mode. They consider "American" vs. "long-term Japanese" relationships—where the latter exhibits smaller, more frequent and higher priced shipments. The model predicts that Japanese relationships are more attractive if tariff increases are less likely and their evidence supports this for U.S. transactions with China after its WTO accession.

Uncertainty can also affect sourcing between firms in the same country, e.g. they could respond to TPU by switching to domestic suppliers. Charoenwong et al. (2020) examine if TPU leads to reshoring using U.S. firm-supplier data. They find that increases in U.S. TPU in 2003Q2-2018Q4 did not increase the share of

[34] One example is Shepotylo and Stuckatz (2021) who employ textual measures of TPU from 2003-2013 to estimate the effects of a potential FTA with the E.U. on Ukrainian firms.

[35] Kohler and Kukharskyy (2019) also study offshoring in the presence of uncertainty. Gervais (2021) incorporates a diversification motive for managers when input delivery is uncertain across countries.

domestic suppliers. In fact, the opposite occurs for U.S. firms with mostly foreign sales. Their approach uses a news index of TPU with variation over time as described in section 2; it would be interesting to explore variation across firms or industry characteristics.

The recent increases in TPU have the potential to reshape sourcing relationships. Future research can explore rich transaction data to estimate and quantify the impact of TPU on sourcing strategy and outcomes.

5 Broader Impacts

TPU can change prices and other incentives relevant for the decisions of firms, workers and consumers, hence we must go beyond its direct trade effects. We briefly discuss how TPU can be useful in empirically identifying broader impacts of trade shocks. We then summarize research on profits, investment, employment and other aggregate outcomes around key TPU episodes: China's WTO accession, Brexit and the 2018 trade war.

Trade shocks can impact a myriad of outcomes, but they are seldom exogenous. A standard approach to identify causal impacts of trade shocks is to seek reforms with quasi-experimental variation in applied trade policies. However, there are a limited number of such reforms.[36] TPU broadens the set of trade-related shocks beyond applied policy changes; and since some TPU shocks involve no government change in applied policy it eliminates at least one source of endogeneity.

Two basic factors determine the usefulness of TPU as an instrument to identify broader trade impacts. The first is relevance for trade, which is satisfied for several episodes described in section 4. The second is excludability from a second stage equation that determines the relevant outcome. Arguing for exclusion requires a well specified model to capture the relevant trade channels. A specific model is also important to construct the relevant measure of TPU instead of employing a proxy.[37]

Most research on the broader impacts of TPU thus far uses a reduced form approach. Interpreting a significant TPU coefficient on some outcome is then harder because it reflects a combination of different channels. Moreover, if those channels are individually significant but have offsetting effects, then the average TPU estimate may be zero. Nonetheless, reduced form studies can provide insight about alternative channels if they explore alternative controls and heterogeneity of impacts.

5.1 Firm profits, investment and innovation

The direct trade effects of TPU described in section 4 can change a firm's scale and thus profits and broader investments, as recent research shows.

Research on profit effects of TPU mostly focuses on stock returns. Bianconi et al. (2021) compute the returns of U.S. listed firms and estimate the differential between those in high vs. low risk industries based on the NTR gap. They find a positive differential in the 1990's and a negative one after WTO accession. One interpretation of this reduced form evidence is consistent with what we discussed before. Specifically, incumbent U.S. firms in higher gap industries faced less Chinese competition in the 1990's and thus had

[36] Endogenous policy changes may depend on the outcomes of interest and reflect confounding effects from anticipation or uncertainty effects that are heterogeneous across industries (Goldberg and Pavcnik, 2016).

[37] TPU can also be used as an additional instrument to provide evidence for exclusion restrictions in commonly used instruments, e.g. for Autor et al's (2013) use of China's exports to developed countries as an instrument for its U.S. exports.

higher profits, and the opposite occurred after accession.[38]

Similarly to profits, investment also fell for U.S. firms in industries with relatively higher NTR gaps after 2001. Pierce and Schott (2018) find this average effect by applying a difference-in-difference approach to U.S. manufacturing census investment data on structures and equipment. Autor et al. (2020) examine if import competition lowers profitability and the number of patents for U.S. firms; they find that is the case for firms in high gap industries after 2001. Both papers find the differential is smaller or even insignificant for firms with higher initial capital intensity or profits, we conjecture this is because those firms benefited from lower input uncertainty. Liu and Ma (2020) employ a similar estimation approach but focus on Chinese firms. They find relatively higher investment and patents for firms in high NTR gap industries after accession. The effects are larger for Chinese firms exporting to the U.S. and for new exporters.

Brexit uncertainty has reduced stock returns and investment of firms in the U.K. and abroad. Hassan et al. (2020) use quarterly investor calls to construct exposure to Brexit in firms headquartered in 81 countries. They use an event study and find that the stock returns in the 4 days after the 2016 referendum were lower for firms facing higher Brexit risk.[39] This risk measure is also negatively associated with firm yearly investment rates in 2011-19. The marginal impacts are similar for U.K. and foreign firms (for profits and investment) but foreign firms had lower risk exposure on average. The reduced form approach and broad measure used in Hassan et al. imply that their estimates reflect all sources of risk—output and input. In survey evidence of U.K. firms, those with larger sales or inputs originating in the E.U. report 'higher uncertainty affecting their business' after the referendum and Bloom et al. (2019) find this is associated with reductions in their investments and productivity. They also find higher costs from planning for Brexit. It would be interesting to examine if innovation fell.

How did uncertainty during Trump's trade war affected these broader outcomes? Benguria et al. (2020) construct TPU indices using reports of listed Chinese firms. They estimate that within-firm changes in TPU between 2017Q4 and 2018Q4 reduced contemporaneous investment and R&D expenditure and subsequent profits.[40] Amiti et al. (2020b) use event studies to estimate the impact of trade war announcements on daily stock returns for listed U.S. firms in 2018-19. The effect over all shocks is negative, and more so for firms with import or export exposure to China. They argue this reflects a lower return on capital and estimate that this dampened subsequent firm investment.[41]

In sum, there is growing evidence that TPU affects profits and can have persistent and dynamic effects by changing the incentives to invest and innovate. Future work can explore specific theoretical models to better identify and quantify specific mechanisms.

[38]The authors's interpretation is based on finance theory where the differential reflects a risk premium required by risk averse investors; they provide evidence that firm realized return volatility is higher in the high gap industries around MFN-renewal votes. Distinguishing between explanations is difficult in their reduced form approach but could be possible using theory to guide a more structural estimation. Filat and Garetto (2015) explicitly model how observed higher returns of exporters and multinationals (relative to domestic firms) can be generated by higher risk from sunk costs under global demand uncertainty, which can include TPU.

[39]Returns are also lower for firms with lower Brexit "sentiment", which measures if they believe Brexit will benefit them, which the authors argue captures a first moment effect.

[40]Interestingly, they find no significant effects for the applied tariffs. One reason is the increases were believed to be temporary, another is that firms take time to react and whereas tariffs just increase only in 2018 TPU was rising since Trump's election.

[41]Research on announcements that can isolate periods where actual policy is unchanged is a useful extension to better understand the impact of shocks to policy expectations. The interpretation of announcements by themselves as shocks to TPU is less straightforward though, particularly if we do not know what the priors were, e.g. the announcement can lower uncertainty about the timing, scope or level of tariffs. In fact, in Amiti et al. (2020) some events lead to higher returns.

5.2 Employment and Migration

What are the employment effects of TPU? The answer depends on how TPU affects firm decisions about hiring, wages, and investment. For U.S. manufacturing, Pierce and Schott (2016) use a reduced form approach and find that employment declines were higher after 2001 in industries with larger NTR gaps. Employment declined via plant exit and also in continuing plants. The authors pursue various specifications to better interpret the reduced form estimate. For example, the NTR gap impact is reduced after controlling for offshorability, capital intensity, and China's tariff reductions.

There is some evidence that Brexit uncertainty affected employment outcomes in the U.K. Javorcik et al. (2019) find that U.K. industries and regions more exposed to higher potential MFN protection posted fewer on-line jobs after the referendum vote. The survey evidence in Bloom et al. (2019) shows a negative but insignificant effect of firms' Brexit exposure on their employment.

Trade can also impact labor markets through migration (cf. Caliendo et al., 2019). Greenland et al. (2019b) find population growth is relatively lower in U.S. regions that are more exposed to import competition. They employ local labor market exposure to NTR gaps and find the adjustment occurs through out-migration concentrated in three groups: young, male, and less educated. Facchini et al. (2019) use a similar approach to explain migration patterns in China after 2000. They find strong evidence of migration from rural to urban areas where firms experienced larger exports from declines in TPU—an effect that is most pronounced for skilled labor.

The China shock has been applied to other worker outcomes. For example, Pierce and Schott (2020) find evidence that TPU reductions led to an increase in U.S. mortality. Khanna et al. (2020) show U.S. exports of education services increase because of new student enrollments from Chinese regions that gained after WTO accession. Further work using TPU shocks and other major reforms on a range of outcomes should remain a rich area of future research.

5.3 Aggregate outcomes: applications and implications

TPU shocks can have aggregate effects so it is important to go beyond partial equilibrium estimates. Alternative general equilibrium (GE) effects can dampen or amplify the TPU shocks depending on the specific model. There is no standard model in this context so we describe two approaches. The first approach places the minimum structure necessary to close a model that focuses on changes in the aggregate price index—a key channel in the trade literature. The second approach builds on quantitative macroeconomic models augmented with export entry decisions under TPU and reflects a combination of effects.

Some countries are large enough to influence aggregate outcomes in the export market. The model in Handley and Limão (2017) isolates a key GE effect of TPU: its impact on the aggregate ideal price index.[42] The aggregate price change relative to no uncertainty is described in section 3.3.3 and the authors calculate its cost for consumers is equivalent to 1/2 of the cost of going to trade autarky with China. Accession lowered the U.S. import and overall ideal price index for manufacturing, which also reduced profits for domestic firms and thus their sales and employment by around 1.3 log points.

Steinberg (2019) examines the economic effects of Brexit using a dynamic macro model. There are

[42] This requires assumptions on consumers, labor supply and an outside numeraire good that fix aggregate nominal expenditure on the differentiated goods.

heterogeneous firms and endogenous export participation subject to stochastic tariffs. His quantification of alternative Brexit scenarios on exports is broadly consistent with microeconometric estimates in Crowley et al. (2020) and Graziano et al. (2021a). However, he finds only modest welfare losses. We conjecture that this is at least partly driven by assumptions on timing and the uncertainty being modelled as temporary. One potential cost of more complex GE factors is that the farther the outcome is from the initial shock the more sensitive it is to modelling assumptions. Born et al. (2019) have a different approach that suggests substantial aggregate effects of Brexit. They find that expectations and policy uncertainty augmented VARs can explain much of the gap in quarterly economic performance between the U.K. and a synthetic control economy after 2016.

How did the U.S. trade war and resulting TPU affect the aggregate economy? Caldara et al. (2020) provide evidence that firm and aggregate outcomes were adversely affected by TPU shocks. They measure TPU using text analysis of investor conference calls and find a negative effect on firm investment even after controlling for applied policies in 2018. They also find negative effects of TPU on investment, consumption and exports using aggregate VARs and a calibrated macro model, which is augmented with a trade component based on Alessandria and Choi (2007).[43] Interestingly the mass of exporters increases with TPU in their baseline; this is the opposite of standard models, and the authors show it occurs because their model allows firms to re-allocate capital from exporting to other activities. This last point illustrates the importance of testing robustness in macro approaches to TPU, which these authors do.

Future research can better bridge microeconometric and quantitative macro approaches. Careful comparisons of firm or industry estimates with aggregate ones are a useful starting point. Macro approaches tend to explore time variation that may not be fully informative about the mechanism. For example, Caldara et al. (2020) use realized aggregate tariff volatility, which may underestimate potential TPU. Other studies use aggregate news TPU indices, which may be endogenous to economic conditions and lead to incorrect inferences if not used properly. It would be useful to incorporate the micro mechanism and identification in macro models.

Microeconometric estimates based on simple difference-in-difference approaches may also be misleading about the magnitude of impacts. When there are offsetting effects of a particular type of TPU there may be no differential across firms or industries but there could be aggregate effects, or there may be large differentials but a negligible aggregate effect. TPU can affect aggregate outcomes via different mechanisms so another potential approach is to ask if there are sufficient statistics that summarize the importance of these effects across models; we mention one in the next section.

6 Trade Agreements and Endogenous Uncertainty

We described the effects of TPU while assuming the policy regime is exogenous. One interesting feature of policy uncertainty is that it is endogenous and reflects the preferences of policymakers and the institutional constraints they face. There is extensive research on endogenous trade policy and recent reviews of how it reflects domestic motives (McLaren, 2016), international externalities (Grossman, 2016) and input-output linkages (Caliendo and Parro, 2021). We focus on the fewer studies where trade policy is not deterministic and have some insight into two broad questions. (1) How can uncertainty affect the incentives to set trade

[43] Earlier work by Sudsawasd and Moore (2006) also finds evidence that aggregate investment to GDP ratios decline relative to measures of trade policy volatility in a cross-country panel.

policies? (2) How can agreements affect TPU and when is doing so valuable? We conclude with open questions and suggestions for future research.

Uncertainty in endowments or term-of-trade can substantially change the optimal unilateral trade policy. For example, Fishelson and Flatters (1975) show tariffs and quotas are no longer equivalent for a country seeking to improve its terms-of-trade; subsequent work ranks price and quantity based policies under alternative objectives, sources of uncertainty, and mode of competition (cf. Young and Anderson, 1980; Cooper and Riezman, 1989). Newberry and Stiglitz (1984) show that free trade may become Pareto inferior when individuals are income risk averse and insurance markets are incomplete. These last two features are central in Eaton and Grossman (1985) who derive the optimal tariffs that insure individuals with heterogenous factors against terms-of-trade shocks in a small economy. The tariff uncertainty in Eaton and Grossman is increasing in the variability of terms-of-trade, the heterogeneity of incomes, and market incompleteness.[44] It would be useful to extend static political economy models of trade policy to derive other fundamental domestic determinants of TPU.[45]

How does uncertainty affect the design of trade agreements (TAs) and how do agreements change trade policy distributions? We have noted that TAs' aim to 'provide predictability' and how some of their features contribute to this aim. Negotiating maximum tariffs, is a way in which the WTO can affect TPU. Bindings allow tariffs below a maximum—providing valuable flexibility if there is uncertainty about future policy—but not above it. So bindings can work to limit externalities on other countries and as a domestic commitment device. WTO bindings are not state contingent, which is rationalized in models of TA design if there are contracting costs (Horn et al., 2010); private information (Amador and Bagwell, 2013); or costly state verification (Beshkar and Bond, 2017). Non-contingent bindings can be particularly useful in reducing applied tariff volatility, as Baccheta and Piermartini (2011) document for a large sample. Francois and Martin (2004) note that bindings can increase expected welfare for a small competitive economy by truncating the tariff distribution its exporters face and thus lower expected tariffs and improve terms-of-trade.[46]

When is there an uncertainty motive for a TA? The papers above address bindings—but other features may shape the policy distribution— and those papers do not examine if a TA is valuable even if it keeps mean protection unchanged. Limão and Maggi (2015) address this question by contrasting the endogenous trade policy distributions with and without cooperation. The importer government's objective, $G(\tau, \lambda_s)$, is concave in the tariff and maximized by a non-cooperative schedule, $\tau^N(\lambda_s)$. The optimal non-cooperative tariff is increasing in λ_s, e.g. some political or economic primitive, as is its variability.

Limão and Maggi (2015) show that exporter characteristics, such as income risk aversion, imply a role for TAs to reduce TPU. The tariff has an externality on the exporters' government, whose objective, $G^*(\tau, \lambda_s)$, is decreasing in τ. The agreement tariffs, $\tau^A(\lambda_s)$, maximize the expected value of $G + G^*$ while leaving the mean tariff fixed, so as to focus on the uncertainty motive. As a benchmark they consider an objective for the exporter that reflects a representative individual's welfare in a small competitive economy without frictions. They show that income risk aversion is necessary, and if it is high enough then there is an uncertainty reducing motive for a TA.[47] The main results also apply if capital can be efficiently allocated between the

[44] Uncertainty can also be useful in explaining why trade policy is used for redistribution and biased towards the status quo, as argued by Rodrik (1995).

[45] A recent example is Kost (2020).

[46] Bindings increase current exports in settings with sunk costs of exports as shown in Sala et al. (2010) and Handley (2014).

[47] The aversion is necessary to offset the standard convexity of the indirect utility and revenue functions in prices and thus tariffs, which reflect the ability of firms and consumers to make decisions after observing prices. The effect is magnified by the openness of the economy, so as other trade costs fall and countries become integrated the value of reducing TPU increases.

import and export sector after the TA (but before shocks are realized) and then immobile.

Carballo et al. (2018) also study a government's preference over TAs that change the distribution of foreign demand for its exports. Risk neutral firms incur sunk costs to export and face market conditions summarized by a_s, as in section 3, which depend on foreign tariffs and income. An unrestricted TA is one that changes potential tariffs and thus generates a distribution $H'(a)$ and if it SSD the original one, $H(a)$, then the TA reduces demand uncertainty. If the exporter government objective, $G^*(a_s, H')$, is higher than under H then it values an uncertainty-reducing TA, which is the basic condition identified by Limão and Maggi (2015) for a TA that maximizes the ex-ante joint objective of countries. The focus in Carballo et al. (2018) is on the implications of an uncertainty reducing TA. But they provide examples of government objectives implying G^* is consistent with uncertainty reduction.

TAs can also address domestic externalities, and these may be affected by TPU. Policy-makers often point to the importance of TAs in solving domestic commitment problems. If a government's value for a policy varies over time then it may benefit from tying the hands of future domestic governments. A TA that credibly limits policy changes can help governments implement time-consistent policies to improve social welfare (cf. Staiger and Tabellini, 1987) and/or political welfare (cf. Maggi and Rodriguez-Claire 2007).[48]

Future research should continue to explicitly model the domestic and foreign motives for TPU and the role of TAs. Doing so is important to illuminate the causes of TPU when it is endogenous and guide the estimation of its effects. For example, extensions of time-inconsistency models could explain why a government would have uncertain tariffs on inputs that hurt domestic firms, as in the case of China's liberalization in Handley et al.(2020).

Future research can also better quantify the TPU effects of TAs. The econometric estimates in section 4 identify partial equilibrium effects. These estimates are useful when derived from specific models to identify structural parameters relevant for conducting policy counterfactuals capturing changes in TAs.[49] Adding GE features to such analysis and multiple countries to study retaliation would be a valuable contribution to the interesting but static academic quantifications of TAs (cf. Ossa, 2014; Caliendo et al. 2015).[50]

7 Lessons and Open Questions

The long-standing importance of TPU has become obvious to policymakers and economists, particularly since 2016. The research shows that TPU has far-reaching impacts and we conclude by summarizing a few lessons and outstanding questions.

Identifying potential trade policy risks that are clearly measurable is essential in characterizing TPU and map its impacts from theory to estimation. The observability of tariff risks and their rich variation exceeds that available to study other sources of economic policy uncertainty that primarily rely on time variation

The authors also provide a sufficient statistic approach to determine ex-ante if the TA should reduce TPU and also use it to evaluate its gain relative to a TA that only changes the mean of the policy (for U.S.-Cuba 1934). That gain is proportional to the coefficient of variation of the non-cooperative policy.

[48]There is less evidence for the commitment motive of TA relative to other motives (Maggi, 2014). Tang and Wei (2009) provide evidence that WTO domestic accession commitments increased income.

[49]For example, Handley and Limão (2017) estimate the probability of the U.S. removing China's MFN status before 2002 and compute the effects of the U.S. adopting a similar behavior against all its trade partners at different applied tariffs (for consumers it is about one third of the cost they would face if the U.S. closed its borders to all trade).

[50]Government agencies also typically rely on static models to evaluate agreements. However, a recent prospective evaluation of the USMCA by the USITC incorporated a feature of TPU. <https://www.usitc.gov/publications/332/pub4889.pdf>.

of news indices. Prediction markets and detailed firm surveys are a valuable but underutilized source of probability shocks. These shocks can be partially proxied by events, e.g. agreements, or text-based indices; the latter are particularly useful when constructed at the firm-level and interacted with policy risks.

The trade investment under uncertainty approach is useful in terms of theoretical and empirical insights and should be enriched. This approach captures concerns of policy makers regarding 'the price to pay' for TPU in the form of delayed investments and losses to consumers. It produces insights for any partially irreversible trade investments and demand or cost uncertainty arising from import or export TPU sources. It can nest standard deterministic trade models and augment output and input demand equations with clear TPU measures, which if omitted will neglect an important channel and also bias the effects of applied tariffs. Interesting areas of future research using this approach include allowing for (i) the interaction of input and output TPU; (ii) richer general equilibrium channels; (iii) multiple policy-active countries with endogenous policies; and (iv) diversification decisions in sourcing and production. These extensions can provide significant theoretical and quantitative insights. Ideally, this research will shift standard trade models to incorporate expectations about trade policy and other shocks.

There is robust empirical evidence that TPU dampens trade. TAs reduce TPU and increase export values and entry by securing prior liberalization, reducing tariff bindings or lowering the probability of trade wars. Prices, sourcing, and input adoption are affected by TPU but more studies on these outcomes is needed. Tariff reductions are more effective when TPU is lower, which points to the value of credible commitments in TAs that reduce policy reversals. There is an extensive literature on average trade integration effects of TA accessions that can be revisited to quantify the role of TPU from tariffs and NTBs. Brexit shows the disintegration effects of threats to exit or restrict preferences. It would be interesting to examine if threats to exit NAFTA and the WTO had similar effects on the U.S.

Significant shocks to TPU can be useful to identify broader impacts of trade. Interesting research shows significant effects on profits, investment, employment and other aggregate outcomes in the context of China's WTO accession, Brexit and the 2018 trade war. The effects depend on whether TPU affects firms directly or via competition; in order to better identify channels more research should draw on specific models to guide the estimation and complement the mostly reduced form approach to broader impacts. Future research bridging microeconometric and macro approaches can offer important quantitative evaluations of trade reforms.

Trade policy is endogenous and so is its uncertainty. TPU can explain key features of policy and is also affected by TAs. Additional research incorporating TPU in TAs can (i) identify key features of agreements and (ii) improve the estimation and quantification of their impacts. Research on fundamental domestic determinants of TPU can build on the rich political economy models of static policy.

We anticipate TPU will remain a major item in the agenda of policy makers and researchers long after Brexit is implemented and the 2018 trade war ends. Looking ahead, recovering credibility will take time, particularly during a globalization backlash when trade wars are no longer a taboo and can be triggered by new economic shocks. Moreover, there are two new sources of TPU on the horizon, border adjustment taxes to harmonize heterogeneous country policies on corporate profits and carbon emissions.[51] The effectiveness of these border adjustments will depend crucially on their credibility. Research on TPU will remain vibrant as it addresses new and past events while exploring improved methods and data.

[51] A corporate border tax adjustment was proposed, but ultimately dropped in the U.S. Tax Cuts and Jobs Act of 2017. Both the E.U. and U.S. have proposed a carbon border adjustment mechanism, which could be difficult to implement within the WTO agreement.

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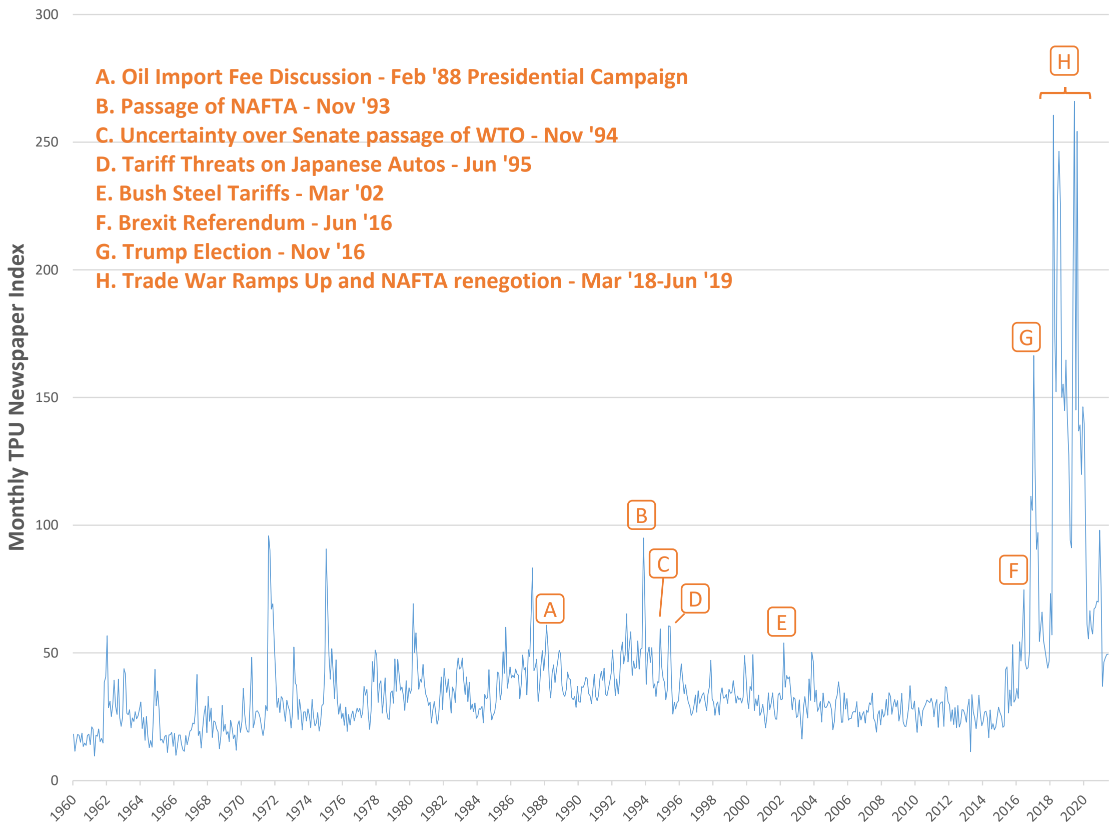
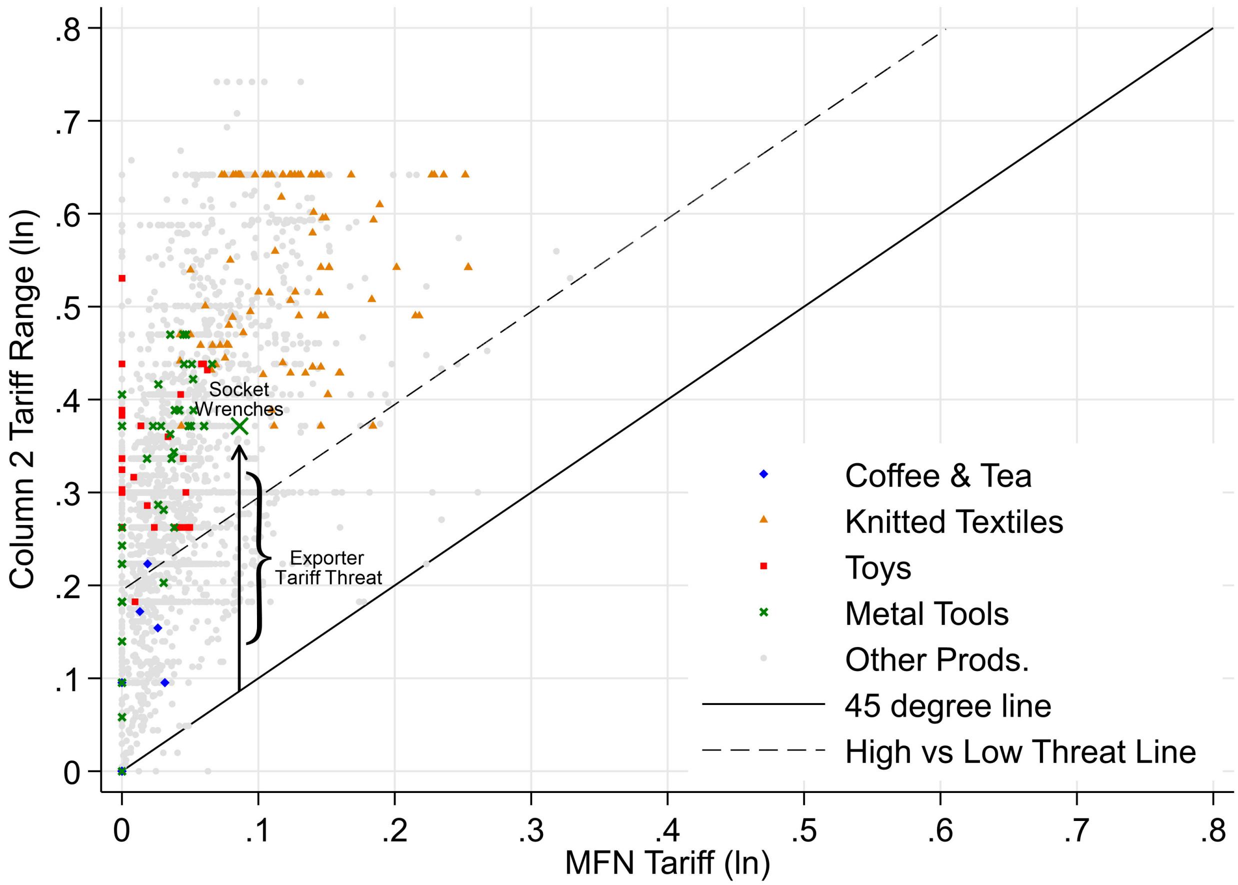
Figure 1: Trade Policy Uncertainty News Index, 1960-2021



Notes: Share of trade policy uncertainty articles in major newspapers relative to all articles about trade policy. Authors' calculations on data constructed by Caldara et al.(2020).

Figure 2: Measuring Threat vs. Applied Tariffs for US-China, 2000



Notes: Scatter plot of U.S. Column 2 log tariff rate vs U.S. MFN log tariff rate for year 2000. Only statutory ad valorem tariffs are plotted, 10 products with Column 2 rates above 0.75 are omitted. Solid line is 45 degree line. Magnitude of threat increases in vertical distance from line that measures gap between MFN and Column 2 threat. Dashed line delineates set of products in the top two terciles of threat distributions. Authors' calculations from replication data in Handley and Limão (2017).

Table 1: Applied vs Potential Threat Tariffs, Selected Countries

	Tariff Factors: 100×ln(1+tariff rate)				
	Multilateral			Non-Cooperative	
	MFN	Bound	Bound Share	Optimal Tariff	Historical Tariff
Australia	2.3	8.9	0.96	36.8	N.A.
	(2.4)	(10.9)		(57.2)	
Brazil	12.2	27.1	1.00	35.5	36.2
	(7.3)	(6.0)		(60.6)	(13.7)
Canada	2.0	4.7	1.00	40.1	N.A.
	(4.6)	(5.0)		(61.0)	
China	7.1	9.3	1.00	39.7	42.1
	(5.1)	(6.3)		(57.7)	(29.7)
European Union	4.2	4.0	1.00	50.7	N.A.
	(4.2)	(4.0)		(50.5)	
India	13.0	37.7	0.73	30.6	97
	(10.9)	(21.4)		(52.8)	(41.0)
Japan	2.9	2.9	0.99	42.0	N.A.
	(4.4)	(4.3)		(62.9)	
United States	3.2	3.3	1.00	66.1	28.8
	(5.9)	(6.0)		(63.7)	(16.5)

Notes: Means computed at HS 6-digit product level in log points of 100×ln(1+tariff rate) with standard deviations in parentheses. MFN, bound and historical rates are statutory, ad-valorem tariffs that exclude non-ad valorem rates and their equivalents. MFN rates are 2020 applied rates in HS2017 nomenclature. Bound rates and shares are author's calculations from WTO Consolidated Tariff Schedules in native HS nomenclature. MFN and Bound rates downloaded from tariffdata.wto.org. EU rates exceed bound here and in official WTO publications due to HS revisions. Non-cooperative trade war tariff rates are based on authors' calculations from Nicita et al. (2017). Brazilian historical threat tariffs are authors' calcuations from 1989 tariff schedule. China historical tariffs are authors' calcuations from 1992 schedules. U.S. column 2 threat are statutory ad valorem tariffs from year 2000. Historical output tariffs for India are 1989 average from Topalova and Khandelwal (2011).