# Regional Trade Policy Uncertainty*

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**Abstract**

Higher uncertainty about trade policy has recessionary effects on U.S. states. To show this, we first build a novel empirical measure of regional trade policy uncertainty, based on the volatility of national import tariffs at the sectoral level and the sectoral composition of imports in U.S. states. We find that a state which is more exposed to an unanticipated increase in the volatility of tariffs suffers from a larger drop in real output and employment, relative to the average U.S. state. We then build a two-region open-economy model and we find that the precautionary behavior acts as the main driver of the recession, although this effect is reinforced by a high exposure to import tariffs. The feedback effect resulting from trade connection with the Foreign country mostly affect the persistence of the dynamics.

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## 1 Introduction

Over the recent years, many countries have experienced economic and political disturbances initiated by the revision in some trade agreements and a general foster in trade protectionism. The most prominent events are the Brexit voted in 2016, the trade war launched by the Trump administration in 2018. More recently, the additional import tariffs pledged by Donald Trump for his second mandate are expected to fuel economic volatility. These events have led to an exceptional boost in uncertainty regarding the future market conditions, especially in the import-export market. The impact of higher trade policy uncertainty – which might source from unpredictable trade agreements negotiations or from a rising volatility in import tariffs – has been extensively analyzed in the literature (see Handley & Limão (2022) for a survey). Trade policy uncertainty has individual effects on firms' investment, employment or export decisions as well as aggregate effects on GDP at the country level. While tariffs on imports are decided at the national level, one might suspect that changes in tariffs and the uncertainty surrounding them have differentiated effects at the regional level, depending on the composition of imports of each region. In this paper, we tackle this question by analyzing the heterogeneous effects of uncertainty on trade policy at the regional level, focusing on the U.S. states level.

One contribution of this paper is to propose a novel empirical measure of trade policy uncertainty, at the U.S. state level. We capture trade policy uncertainty through the volatility of import tariffs. In a first step, we construct national series of tariffs at the sectoral level based on the share of duties (collected by U.S. customs) over imports for each sector. We then estimate the time-varying volatility of those sectoral tariffs series using a stochastic volatility model as previously done by Born & Pfeifer (2014) and Fernández-Villaverde et al. (2015) for (domestic) taxes. In a second step, we build the exposure to uncertainty at the state level by weighting the sector-based volatility by the share of sectoral imports in total imports within the state. We find for instance that the sectors "Stone and Glass" or "Textile" are those who suffer the most from tariff volatility and some states, like the New-York state for instance, are especially exposed to trade policy uncertainty since they intensively import those products. With our U.S. state-level measure of exposure to trade policy uncertainty in hands, we investigate the effects of uncertainty shocks on U.S. states' economic activity. Our estimation shows a significant and sizable negative effect of a higher exposure to trade policy uncertainty on the economic activity whether this is measured by employment or GDP cumulative growth at the regional level.

We then develop an open two-region model to investigate the mechanisms by which trade policy uncertainty affects the activity of U.S. states. In our model, both regions make up the Home country – illustrating the United States – and each region trades within the country and with the rest of the world. Both regions tax their imports through a common tariff set nationally while they differ in their exposure to international trade. We investigate the dynamics of a representative trade-exposed U.S. state which features a high import share (i.e. the ratio import-to-GDP) as well as a high degree of export intensity that we define as the value of exports relative to total value of exports in the country. The model is calibrated using the empirical evidence emphasized in the empirical part. We simulate the model with trade policy uncertainty shocks so as to extract model-based series of output. This strategy allows us to confront the model to the data. We find that our stylized model, when it is submitted to the same data-generating process than the empirical data, is able to reproduce the empirical finding that higher exposure to trade policy uncertainty deteriorates the economic activity. The fact that our model is regional allows us to further analyze how exposure to trade affects the transmission channels of shocks on trade policy uncertainty.

We find that the exposed region, when it is hit by volatility shocks on national import tariffs, experiences a recession. This result is explained by two main drivers that we decompose in the paper. First, it is well accepted that uncertainty shocks affect the economy through the so-called "traditional" transmission channels of uncertainty shocks. More precisely, since firms in the region are strongly exposed to import tariffs, they are more uncertain about their future marginal cost while households are more willing to adopt a precautionary saving behavior. As a result, aggregate demand in the Home country drops when trade policy uncertainty rises. Due to the presence of nominal rigidities in the Home country, prices do not adjust as quickly as they should, leading to a strong recession and a large increase in markups. We show that "traditional" transmission channels are related to the absence of the negative wealth effect in the labor supply combined with nominal rigidities. As already mentioned by Basu & Bundick (2017), shutting down the wealth effect in the labor supply allows us to disconnect the precautionary-saving behavior from labor supply decisions, which therefore dampens the rise in labor supply that results from reduced consumption. This preference-related channel interacts with the presence of nominal rigidities since price stickiness leads to a rise in markups which depresses economic activity. These mechanisms are well known as they relies to a closed-economy structure of the model.

Second, in the context of open economy, the fall in aggregate demand has international consequences since it reduces the demand for Foreign goods, which affects the region, especially when it is highly exposed to trade. Indeed, as the Foreign country also imports less, the region needs to produce less, generating an international trade feedback effect. We perform a counterfactual analysis to better understand these international trade channels. Unsurprisingly, a lower degree of trade openness makes the demand function for imported goods less sensitive to tariffs volatility, which dampen the recession. On the opposite, when the Foreign country features a stronger bias toward goods of representative the region (relative to the other region), this region is more exposed to the Foreign recession, which in turn amplify its recession. Interestingly, we find that the international feedback effect – that we can shut down by setting a large home bias in the Foreign country – affects mostly the persistence of the dynamics, notably by making a long-lasting drop in output to the negative trade policy uncertainty shock.

## Contributions to the literature

There is a large literature that measures trade policy uncertainty based on various data sources and concepts of uncertainty. Handley & Limão (2022) provides an extensive survey of the tools to measure trade policy uncertainty and its economic effects. For instance, uncertainty can be measured through a change in trade agreements (Handley (2014); Handley & Limão (2015, 2017)), or textual analysis methods on newspapers, country reports or on earnings conference calls by firms ((Baker et al. (2016)), Caldara et al. (2020) and Ahir et al. (2022) ). Our contribution to this literature is to provide a measure of uncertainty at the regional level based on the volatility of import tariffs. It is a common practice in macroeconomics to use tax volatility as a measure of uncertainty in the tradition of Born & Pfeifer (2014) and Fernández-Villaverde et al. (2015). These authors resort to a stochastic volatility model to estimate the time-varying volatility of taxes and exogenous shocks to this volatility. Caldara et al. (2020) apply this process to measure tariff uncertainty at the national level for the U.S. economy. We show in the paper how this methodology can be enriched to deliver measure of tariff uncertainty at the U.S. state level which we refer to as regional trade policy uncertainty.

In this way, we are also joining the important branch of the literature devoted to the disaggregation of uncertainty, below the national level. Baker et al. (2022) provide historical series economic policy uncertainty at the U.S. State level.[1] We differ from them in the methodology since they resort to textual analysis on local newspapers, which allows them to distinguish whether uncertainty comes from local events or national/international events. On top of this, we contribute to the literature by providing a U.S. state-level measure of uncertainty that is specific to trade policy.

Our second contribution is to extend the literature on regional macroeconomic models. To our best knowledge, the analysis of trade policy uncertainty in a regional perspective has not yet been studied in this literature. There is an increasing interest in macroeconomics for regional/state data to understand global phenomenon – see Chodorow-Reich (2020) for a discussion on the use of regional data in macroeconomics. The interest for regional data is to improve the identification of causal relationships compared to macroeconomic data which generally aggregate several simultaneous events. The literature on regional local fiscal multipliers is reviewed in Chodorow-Reich (2019), notably the leading contribution by Chodorow-Reich et al. (2012), Nakamura & Steinsson (2014) and Dupor & Guerrero (2017). Theoretical models with a special focus on

[1] Elkamhi et al. (2023) provide a similar index, using a different set of newspapers and removing the nationwide information. Shoag & Veuger (2016) adopt a similar approach focusing in the Great Recession.

regional economies are developed for instance in Beraja et al. (2018), Beraja et al. (2019), House et al. (2018) and House et al. (2021). The local effects of trade policy have also been extensively studied in this literature to better understand the consequences of China's integration into international trade by Autor et al. (2013) and of the protectionist measures put in place by the USA in 2018 by Fajgelbaum et al. (2020). However, this literature on local effects of trade policy is almost silent when it comes the uncertainty about this policy, partly because of the lack of data. Since we develop a measure of this type of uncertainty at regional level, we can supplement this literature by considering the role of uncertainty shocks using regional data in a structural open economy model.

The paper is organized as follows. Section 2 builds an empirical measure of regional trade policy uncertainty and it investigates the effects on the U.S. state economies. Section 3 describes the theoretical model while Section 4 explains its parametrization. Section 5 analyzes the transmission channels of trade policy uncertainty shocks and Section 6 concludes.

## 2 Empirical Analysis

In this section, we lay out the methodology to build a novel measure of trade policy uncertainty (TPU, henceforth) based on sector-specific volatility of import tariffs and we highlight the effects of TPU shocks on the economic activity at the U.S. state level. We proceed in three steps. First, we construct a measure of tariff uncertainty by extracting the time-varying volatility of (national) import tariff series at the sectoral level. Second, we use these series to measure the exposure to tariffs uncertainty of U.S. states, taking into account the sectoral composition of imports by state. Third, we resort to a panel estimation to quantify the effects of TPU on U.S. states economic indicators.[2]

### 2.1 A Measure of Tariff Volatility

We construct sector-specific series of tariff rate by using data from the Census Bureau Foreign Trade Database (USA Trade Online). We extract the U.S. monthly data on imports by type of commodity.[3] Using the Harmonized System Codes of the World Customs Organization of 2017,

[2] All data sources are detailed in the online appendix.

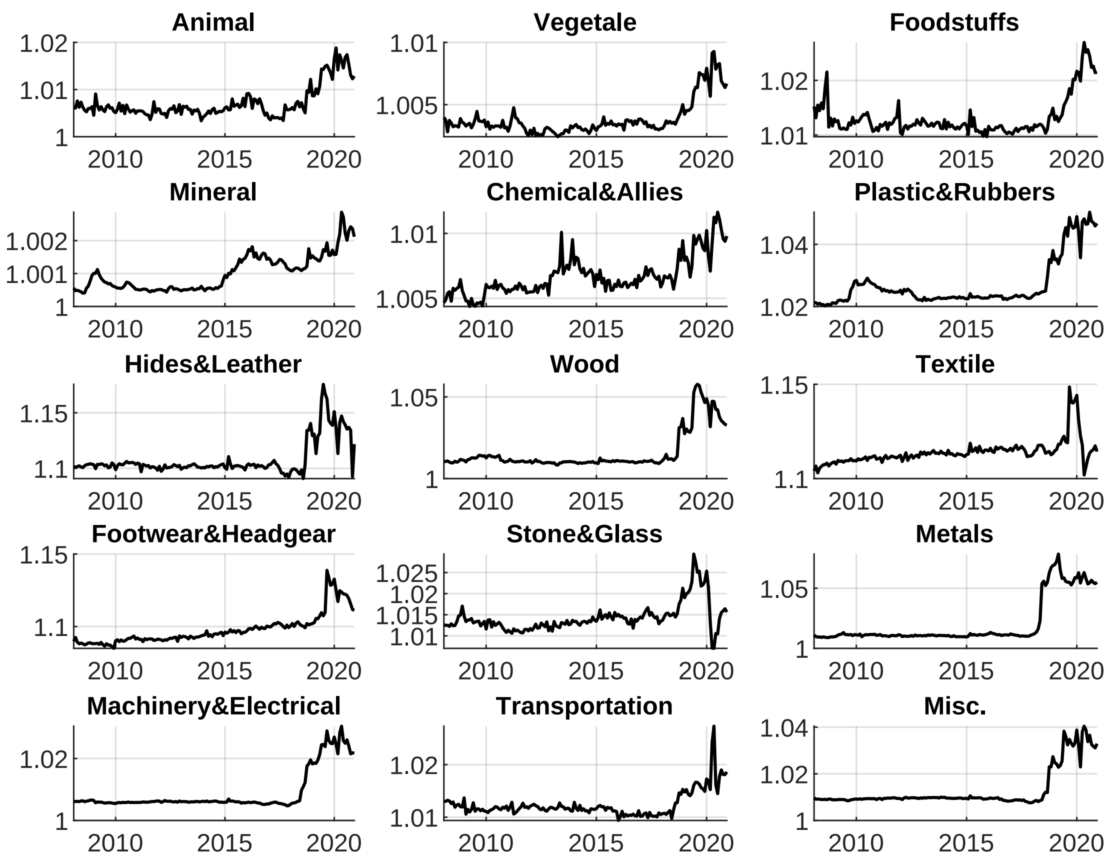
[3] Notice that the database covers trade in the manufacturing and the agricultural sectors, excluding therefore trade in services. We use imports for consumption, i.e. "Measures the total of merchandise that has physically cleared through Customs either entering consumption channels immediately or entering after withdrawal for consumption from bonded warehouses or Foreign Trade Zones under U.S. Customs and Border Protection (CBP) custody" (source: Census).

we convert commodity types into 15 sectors.[4] The data sample goes from 2008m2 to 2020m12. Let $p = 1, ..., P$, denote the sector index with $P = 15$ and $t = 1, ..., T$, the time index. Let $M_{p,t}$ denote the total real value of imports in sector $p$ at time $t$, and $CD_{p,t}$, the estimates of calculated duty.[5] We define the gross rate of the national effective tariff at the sectoral level, $\tau_{p,t}$, as

$$\tau_{p,t} = 1 + \frac{CD_{p,t}}{M_{p,t}}. \tag{1}$$

Figure 1 displays the gross import tariff rate, $\tau_{p,t}$, for the 15 sectors over our sample.

Figure 1: Sector-specific gross tariff rate




Note: The sector-specific gross tariff rate, $\tau_{p,t}$, is defined in Equation (1).

[4]The 15 sectors are classified using the 2-digit HS code list: "01-05 Animal & Animal Products", "06-15 Vegetable Products", "16-24 Foodstuffs", "25-27 Mineral Products", "28-38 Chemicals & Allied Industries", "39-40 Plastics / Rubbers", "41-43 Raw Hides, Skins, Leather, & Furs", "44-49 Wood & Wood Products", "50-63 Textiles", "64-67 Footwear / Headgear", "68-71 Stone / Glass", "72-83 Metals", "84-85 Machinery / Electrical", "86-89 Transportation", "90-97 Miscellaneous". The Harmonized System Codes of the World Customs Organization of 2017 is a natural candidate since our raw data are classified using the Harmonized System. Santacreu et al. (2023) also construct a sectoral classification, which in their case aggregates their raw data classified with the NAICS (2012) classification. In total, we share more than 70% of their 16 sectors.

[5]The value of imports and custom duties at the sectoral level are computed by summing all types of commodity holding to a sector. All series are seasonally adjusted.

Unsurprisingly, most of the sectors experienced a surge in their import tariffs during the U.S. Trade War initiated in 2018 by President D. Trump mostly against China, but also against other countries. The first wave of tariffs increase started in Spring 2018 as the Federal government started to impose tariffs on steel and aluminum imports against several countries – including China but also Canada –, which led to an average tariff rate in the metal sector of 1.2% in February 2018 and 7.8% in March 2019. In September 2019, supplementary tariffs has been imposed on imports, targeting textile products from China, leading to an average tariff rate in the textile sector of 11.9% in August 2019 and 14.9% in September 2019. Despite this exceptional period of high volatility, Figure 1 also shows some heterogeneity in tariffs across sectors over the full sample. For example, in September 2009, the Obama administration signed China-specific safeguard actions against imports of tires for three years by imposing tariffs of 35% in the first year, 30% in the second year and 25% in the third year.[6] The Figure 1 reports this protective trade policy through an average tariff rate in the sector "Plastic and Rubbers" changed from 2.1% in August 2009 to 2.8% in December 2009.

The stochastic volatility model is an attractive setup to disentangle level shocks from volatility shocks and therefore to extract time-varying uncertainty (see Fernández-Villaverde & Guerrón-Quintana (2020) for a discussion). On top of this, this statistical process is in line with typical way of modeling time-varying volatility shocks in the DSGE-type of models (see Section 3). Fernández-Villaverde et al. (2011) applied this methodology to extract time-varying volatility on the real interest rates, Fernández-Villaverde et al. (2015) on fiscal instruments, and closer to us, Caldara et al. (2020) estimated a stochastic-volatility process on import tariffs. In this spirit, we assume that $\Delta\tau_{p,t}$ – the monthly growth rate of $\tau_{p,t}$ – follows an AR(1) process with time-varying volatility[7]

$$\Delta\tau_{p,t} = \rho_p^\tau \Delta\tau_{p,t-1} + \alpha_p \Delta\tau_{-p,t} + \exp(\sigma_{p,t}^\tau)\varepsilon_{p,t}^\tau, \tag{2}$$

with

$$\sigma_{p,t}^\tau = (1-\rho_p^\sigma)\bar{\sigma}_p^\tau + \rho_p^\sigma \sigma_{p,t-1}^\tau + \eta_p \varepsilon_{p,t}^\sigma, \tag{3}$$

where $\varepsilon_{p,t}^\tau \sim \mathcal{N}(0,1)$ and $\varepsilon_{p,t}^\sigma \sim \mathcal{N}(0,1)$ for $p = 1, ..., P$. Let $\sigma_{p,t}^\tau$ denote the measure of trade policy uncertainty in sector $p$. Following Fernández-Villaverde et al. (2011), $\sigma_{p,t}^\tau$ is expressed in exponential in Equation (2) to ensure that trade policy uncertainty remains positive. Level (first-order) shocks, $\varepsilon_{p,t}^\tau$, correspond to unexpected variations in the sector-$p$ tariff growth rate and volatility (second-order) shocks, $\varepsilon_{p,t}^\sigma$, correspond to unexpected variations in its standard deviation. Parameter $\rho_p^\tau$ drives the persistence of level shocks and $\rho_p^\sigma$ drives the persistence of

[6]These tariffs applied to products 4011.10.10, 4011.10.50, 4011.20.10, and 4011.20.50 of the Harmonized Tariff Schedule of the United States. See Bown & Kolb (2023) for a discussion about the reform.

[7]Notice that $\Delta\tau_{p,t}$ is demeaned in the estimation of Equation (2).

volatility shocks. $\bar{\sigma}^{\tau}_{p}$ gives the average standard deviation of innovations $\varepsilon^{\tau}_{p,t}$ and $\eta_p$ governs the magnitude of tariff volatility shocks. The process (2)-(3) is estimated sector by sector. Because we are interested in sector-specific volatility, we control for the common variations in tariffs coming from others sectors than $p$. Precisely, we sum the gross effective tax rates over all sectors but $p$ and we compute the associated variation, denoted $\Delta\tau_{-p,t}$. Thus, parameter $\alpha_p$ captures variations in $\Delta\tau_{p,t}$ which are explained by the aggregate dynamics of all other sectors.

Regressions (2)-(3) capture the dynamics of sectoral growth rate tariffs as well as their time-varying standard deviation. Caldara et al. (2020) estimate a similar stochastic volatility process on U.S. aggregated series of tariffs while we consider herein sector-$p$ specific tariff uncertainty. Using the algorithm provided by Born & Pfeifer (2014), Equations (2)-(3) are estimated jointly with Bayesian methods using sequential Monte Carlo Methods. We obtain priors directly from the data using simple least-squares regressions. The historical series of the unobserved volatility shock are extracted using a non-linear particle filter from the posterior distribution computed using the MCMC algorithm. The posterior distributions of parameters are computed from 20 000 draws where the first 5 000 are discarded. The Metropolis-Hastings parameter is adjusted to get an acceptance rate of roughly 25%.

Figure 2 plots the historical series of tariffs uncertainty as estimated in Equation (3).[8] The solid line is the median historical smoothed estimate of $\sigma^{\tau}_{p,t}$, expressed in exponential and multiplied by 100. The grey area displays the first and last deciles, respectively. The figure confirms that if tariff volatility is sector specific, all sectors have experienced a peak in volatility starting in 2018. As mentioned above, "Footwear and Headgear", "Foodstuffs"and "Textile"display a high volatility in average. However, some sectors concentrate high volatility in tariffs during the 2018 trade war peak, as for instance "Stone and Glass" or "Metals". We now exploit this heterogeneity across sectors to capture U.S. states exposure to trade policy uncertainty.[9]

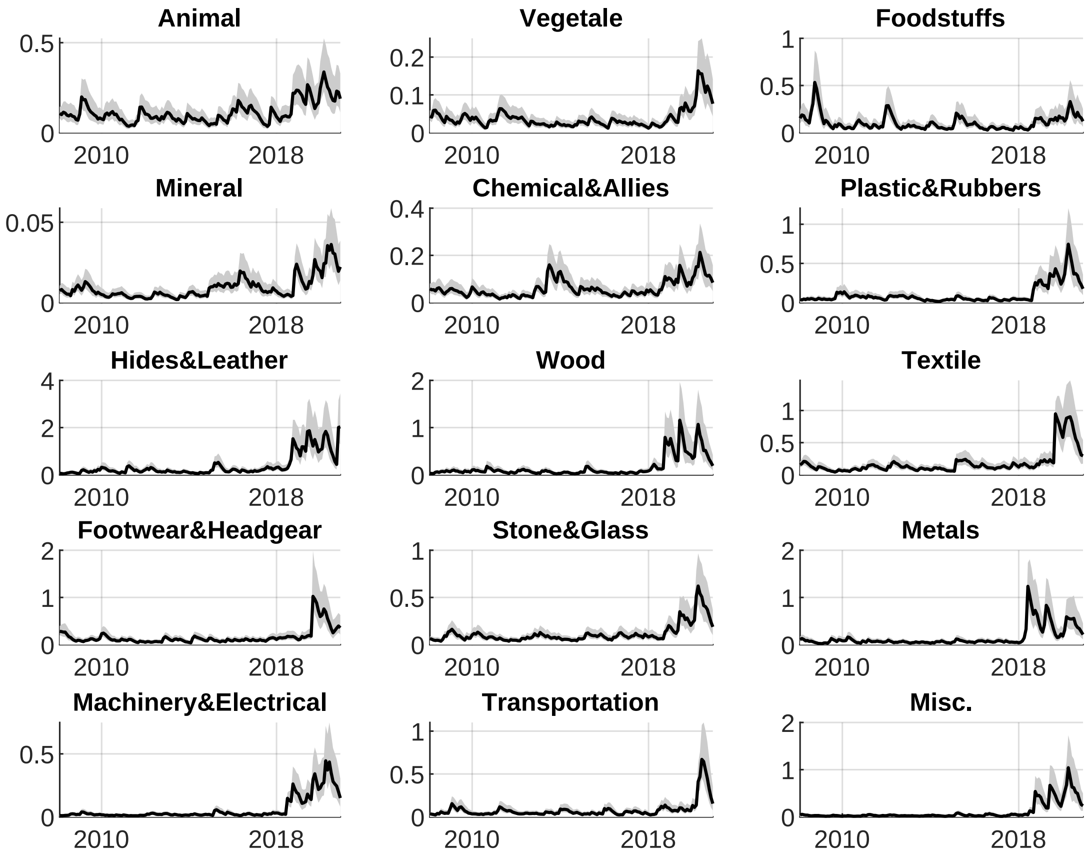
## 2.2 State-Level Exposure to Uncertainty

In the spirit of the shift-share design, we assess the effects of trade policy uncertainty on the U.S. states by using the weighted average of the sectoral shocks as a regressor, the weight being the state-exposure share (see Adão et al. (2019) and Goldsmith-Pinkham et al. (2020) for recent discussion of shift-share settings). This strategy allows us to proxy state-level TPU shocks by assigning volatility shocks to the sectoral composition of imports. In practice, we build a series of

[8]The posterior estimates are reported in the online appendix.

[9]In the online appendix, we compare each sector-specific tariff volatility series with the newspaper-based index of TPU for the U.S. provided by Caldara et al. (2020). In average, the correlation coefficient is 0.33, it varies between $-0.03$ and 0.68 depending on the sector. These correlation coefficients are significantly different from zero for most sectors (except for the sector Foodstuffs). Each peak in the news-based TPU index can be associated with an increases in stochastic volatilities specific to some sectors. Our sectoral series on TPU then allow us to decompose much of the information contained in this aggregate TPU indicator according to the sectors concerned.

Figure 2: Sector-specific tariff volatility series




Note: The tariff volatility $\sigma^{\tau}_{p,t}$ is defined in Equation (3). The displayed series are $(100\times\exp(\sigma^{\tau}_{p,t}))$ based on the posterior estimation results reported in the online appendix. The solid line is the median historical smoothed series and the grey area displays the $[10^{th}, 90^{th}]$ percentile probability interval.

exposure to TPU shocks in state-$s$ ($TPU_{s,t}$), weighting volatility shocks ($\varepsilon^{\sigma}_{p,t}$) by the state-specific sectoral composition of imports ($\mu_{p,s,t}$) defined as

$$\mu_{p,s,t} \equiv \frac{M_{p,s,t}}{M_{s,t}}. \tag{4}$$

$M_{p,s,t}$ corresponds to the sector-$p$ custom values collected from imports in state $s$ at time $t$ and $\mu_{p,s,t}$ is therefore the share of sector-$p$ imports in total imports for state $s$ at time $t$. Series of imports at the state level, $M_{p,s,t}$, are here again extracted from the Census Bureau Foreign Trade Database and are also available at a monthly frequency. In addition, we seek to take into account the overall import share of the state, so as to not only capture the sectoral composition of the imports but also the state's degree of openness. Therefore, we define $\omega_{s,t} \equiv M_{s,t}/Y_{s,t}$ as the state-level share of imports in GDP computed at a yearly frequency.[10] Finally, in order to mitigate

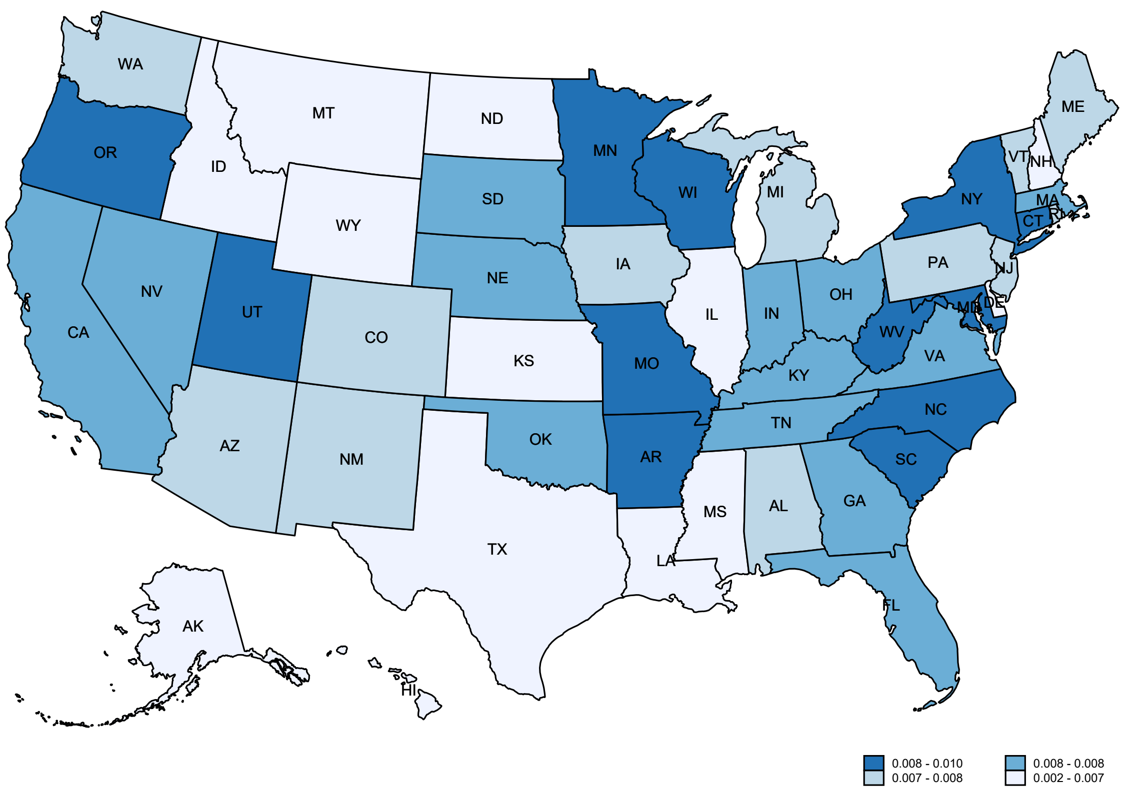
[10]Notice that the sectoral composition of the imports, $\mu_{p,s,t}$ is computed at a monthly frequency. Therefore, we cannot directly use state's GDP in the measure of $\mu_{p,s,t}$.

endogeneity issues, we use the constant share $\bar{\mu}_{p,s} \times \bar{\omega}_s$ equal to the average value of the import share over the first three years of the sample (2009m1-2011m12) for each state. The series of exposure to TPU shocks in state-$s$ ($TPU_{s,t}$) is then

$$TPU_{s,t} = \sum_{p=1}^{P} (\bar{\mu}_{p,s}\bar{\omega}_s) \times \varepsilon^{\sigma}_{p,t}, \tag{5}$$

where $s = 1, ..., 50$, $\bar{\mu}_{p,s} = (1/36) \times \sum_{t=1}^{36} \mu_{p,s,t}$ using the definition of $\mu_{p,s,t}$ given by Equation (4), $\bar{\omega}_s = (1/3) \sum_{t=1}^{3} \omega_{s,t}$ and $\varepsilon^{\sigma}_{p,t}$ is estimated from Equation (3).

Figure 3: Tariff-volatility exposure across the U.S. states




Note: Colors illustrate states' exposure to tariff volatility, which are computed from Equation (5) using $\sigma^{\tau}_{p}$, averaged over the sample 2008m2-2020m12. Darker colors represent states which are the most exposed to tariff volatility.

Figure 3 plots the average degree of exposure to trade policy uncertainty of each state. Darker colors correspond to the states which are the most exposed to sectors displaying high volatility in import tariffs. The most exposed state is the state of New York (NY) which is also in the top 5 of the largest importers in the U.S. Note that 28% of imports reaching NY comes from the sector "Stone and Glass " and 11% from the sector "Textile". As mentioned above, these two sectors feature a quite high volatility (see Figure 2). They also explain the high degree of exposure of Utah (UT) – 39 % of its import are "Stone and Glass "– and North Carolina (NC) since 16 % of its imports are “Textile”. The sector “Metal ”also explains the high exposure to tariff volatility. For example, Connecticut (CT) and Maryland (MD) are the two largest importers in this sector (16 % and 15 % of their imports, respectively). As shown in Figure 2, “Metal” has been extensively affected by the 2018 trade war as its volatility of tariffs has jumped.

## 2.3 Regional Effects of Trade Policy Uncertainty

Armed with a state-level measure of exposure to tariff volatility, we now turn to investigate the economic effects of TPU shocks.

### 2.3.1 Baseline Estimation

We estimate a cross-sectional regression in the spirit of the “local multipliers” literature (see Chodorow-Reich (2019) and Canova (2024) for instance), which allows us to use the heterogeneity across states to assess the dynamic effects of a policy change. We estimate the following baseline regression

$$y_{s,t+h} - y_{s,t-1} = \delta_{s,h} + \delta_{t,h} + \beta_h TPU_{s,t} + \gamma_h X_{s,t} + v_{s,t+h}, \tag{6}$$

where $\beta_h$ corresponds to the cumulative response of the outcome variable $y_{s,t+h}$, $h \geq 0$ periods after the realization of the TPU exposure shock in state $s$ as of time $t$.[11] We consider two measures of economic activity $y$, namely the real GDP and employment. The former consists in state-level GDP in private industries and it is available from the Bureau of Economic Analysis. Employment is the total number of employees in the private sector, reported by the Bureau of Labor Statistics. Both measures are expressed in log and Equation (6) is estimated weighting observations by the population share of states in 2008 as in Dupor & Guerrero (2017). Since the real state-level GDP is available at a quarterly frequency, we convert our series of volatility exposure, $TPU_{s,t}$, from monthly to quarterly by an averaging transformation. We include time fixed effects, $\delta_{t,h}$, to absorb all the common shocks in the U.S., as well as state fixed effects, $\delta_{s,h}$, to control for unobservable state-specific factors which might affect the outcome variable. In order to mitigate a potential omitted variable bias, we also include $X_{s,t}$, a vector of state-level control variables. We include as a first control variable the exposure to level shocks, which corresponds to the state exposure to the sectoral tariff shocks as built in Equation (5) where we replace $\varepsilon^{\sigma}_{p,t}$ by $\varepsilon^{\tau}_{p,t}$. By doing so, we seek to isolate the pure effects of a rise in volatility exposure by removing all variations that would come from a level shock, even through the stochastic process (2)-(3) disentangles volatility and level shocks, which are supposed to be uncorrelated. Second, we control for the business cycle

[11]Notice that $\beta_h$ cannot be interpreted as the aggregate response at the U.S. level. Indeed, it measures the relative change in the outcome variable between two states in response to an increase in TPU exposure in a treated (or shocked) region relative to an untreated one. By resorting to state-level estimation, we therefore depart from Caldara et al. (2020) who estimate a bivariate SVAR model on U.S. data and show that that positive shocks on tariff volatility are recessionary at the national level.

by using the growth rate of the Coincident Economic Activity Index provided by the Federal Reserve Bank of Philadelphia (ΔCI). The sample goes from 2008q1 to 2020q4. Equation (6) is estimated for horizons $h = 0, 4, 8$ by pooling the 50 states over the 64 quarters.[12]

Table 1 reports the estimation results.[13] The first three columns provide the relative effect of an exogenous rise in the exposure to TPU on state-level real GPD at impact ($h = 0$), after a year ($h = 4$) and after two years ($h = 8$). [14]

Table 1: Effects of TPU shocks on the economic activity

| | Real GDP | | | Employment | | |
|---|---|---|---|---|---|---|
| | (I) | (II) | (III) | (IV) | (V) | (VI) |
| | $h = 0$ | $h = 4$ | $h = 8$ | $h = 0$ | $h = 4$ | $h = 8$ |
| Volatility exposure | -0.042 | -0.322* | -0.548*** | -0.022 | -0.277*** | -0.292** |
| (TPU) | (0.059) | (0.173) | (0.203) | (0.051) | (0.092) | (0.110) |
| Level exposure | 0.030 | 0.074 | 0.074 | 0.015 | 0.018 | 0.025 |
| | (0.024) | (0.045) | (0.084) | (0.014) | (0.043) | (0.069) |
| Δ CI | 0.151*** | 0.896*** | 0.792** | 0.334*** | 0.666*** | 0.739*** |
| | (0.032) | (0.211) | (0.331) | (0.042) | (0.169) | (0.252) |
| Obs. | 2,550 | 2,350 | 2,150 | 2,550 | 2,350 | 2,150 |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| State FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Note:* Table reports the effects of TPU shocks on real GDP in Columns (I)-(III) and employment in Columns (IV)-(VI). Each column reports the results from regression (6) for the horizon $h = 0, 4, 8$ quarters. The coefficient of interest $\beta_h$ associated to $TPU_{s,t}$ is reported in the first line. All regressions include state- and time-FE. Robust standard errors are clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

We find that a higher exposure to trade policy uncertainty have recessionary effects, although it takes one year to materialize. The maximum impact is reached after two years, with the estimate $\beta_h = -0.548$, significant at 1%. If we consider a high shock of 0.017 (corresponding to the 90 percentile of the shock distribution), this means a 0.93 percent cumulated drop in output over two years. When it comes to employment, we also find that a higher exposure to uncertainty significantly reduces employment after a year. The value of the estimates indicates that a shock to exposure of 0.017 reduces employment by 0.49 percent after 8 quarters and it is highly significant.

Uncertainty about trade policy thus has persistent and high magnitude effects on the economic activity of U.S. states. The magnitude of these effects is assessed by controlling for the state's

[12] Canova (2024) highlights potential bias in cross-sectional estimation of average dynamic effect when data are pooled. We then run a state-by-state estimation of Equation (6) where the coefficient of TPU becomes state-specific, denoted by $\beta_{s,h}$. As shown in the online appendix, the relatively low dispersion between estimated coefficients suggests that our baseline estimates are not affected by a bias associated with the heterogeneity between states' responses to trade policy uncertainty.

[13] Section 2.3.2 and the online appendix report robustness results with alternative outcome and control variables.

[14] We report in the online appendix figures of the point estimates for all horizons $h$ between 0 and 8.

cyclical situation at the time of the shock, measured by the change in the coincident index ΔCI, which is naturally highly correlated with the future evolution of output and employment in states. In the online appendix, we show the state-level National Economic Policy Uncertainty index from Baker et al. (2022) is not significantly related to economic activity in our estimation. This indicates that trade policy uncertainty, measured by states' exposure to tariff volatility, contains distinct information from the EPU uncertainty variable, which concerns all aspects of economic policy, not just tariff policy. The last interesting result from Table 1 is that a higher exposure to tariffs (in level) does not significantly impact economic activity for the considered horizons $h$. However, we find that there is a positive and significant impact on output, at quarter-1 only. This leads us to conclude that a rise in protectionism might have some beneficial effects on the regional economies, but they are very short in time.[15]

### 2.3.2 Robustness Checks

We now explore the robustness of our findings. Table 2 reports the estimation results for GDP for several alternative specifications. For the sake of space, we focus here on the effects of TPU shocks on real GDP after two years ($h = 8$). In the online appendix, we report the estimation results for all horizons and for both GDP and employment.

**(I). Spillover Effects** The cross-sectional dimension of our analysis helps us to assess the extent to which a stronger exposure of a state to TPU shocks alters its own economic activity, relative to the average state's exposure. Therefore, it fails to capture the spillover effects across units – U.S. states, here – that might emerge because these units are interconnected (see Auerbach et al. (2020), for instance). We check the robustness of our results when we take into account the geographical and the trade spillover effects across states. One state can be affected by its own idiosyncratic TPU shocks but also indirectly by TPU shocks hitting its neighboring states. In this case, our estimation would not fully estimate the economic impact of TPU shocks since these indirect effects are not taken into account. First, we enrich the baseline regression (6) by adding a new variable that corresponds to the sum of all TPU exposure indexes ($TPU_{s,t}$) of the neighboring states. Column (Ia) of Table 2 shows that TPU shocks in the neighboring states do not significantly impact the economic activity of a specific state. This finding suggests that geographical spillovers are small. Interestingly, when we assume that TPU shocks do not come from the neighboring states but from the main economic partner of one state, as defined by Dupor & Guerrero (2017), one find a strong positive effect (see Column (Ib) of Table 2). However, our main estimates is not altered and still significant. This positive spillover effect suggests that

[15]In the online appendix, we show that the point estimates is larger (although still positive) when we re-estimate Equation (2) with $\sigma^{\tau}_{p,t}$ being constant. This confirms that our estimation based on the stochastic volatility model identifies a sequence of volatility shocks whose economic effects are different from level shocks.

the total effect of trade policy uncertainty could be somehow smaller than in our benchmark.

Table 2: Robustness checks

| | (Ia) | (Ib) | (II) | (III) | (IV) | (V) | (VI) |
|---|---|---|---|---|---|---|---|
| Volatility exposure | -0.548** | -0.543** | -0.264* | -0.523** | -0.062** | -0.428* | |
| (TPU) | (0.205) | (0.208) | (0.142) | (0.231) | (0.025) | (0.237) | |
| Level exposure | 0.077 | 0.064 | -0.004 | 0.073 | 0.002 | -0.007 | 0.038 |
| | (0.084) | (0.086) | (0.102) | (0.084) | (0.010) | (0.083) | (0.094) |
| Δ CI | 0.788** | 0.775** | 0.797*** | 0.791** | 0.745** | 0.836** | 0.799** |
| | (0.329) | (0.328) | (0.257) | (0.333) | (0.251) | (0.336) | (0.332) |
| Geographical spillovers | -0.008 | | | | | | |
| | (0.007) | | | | | | |
| Trade spillovers | | 0.032*** | | | | | |
| | | (0.011) | | | | | |
| Retaliation effect | | | -2.819 | | | | |
| | | | (2.757) | | | | |
| Swing-state interaction | | | | -0.092 | | | |
| | | | | (0.267) | | | |
| Volatility exposure | | | | | | | -0.004 |
| (TPU placebo) | | | | | | | (0.008) |
| Obs. | 2,150 | 2,150 | 1,200 | 2,150 | 2,150 | 1,950 | 2,150 |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| State FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

*Note:* Table reports the effects of TPU shocks on real GDP. Each column reports the results from regression (6) for the horizon $h = 8$ quarters. The coefficient of interest $\beta_h$ associated to $TPU_{s,t}$ is reported in the first line. Columns (Ia)-(Ib)-(II)-(III) extend the benchmark regression reported in Column (III) of Table 1 (namely, $h = 8$ for Real GDP) by sequentially adding the variables associated to geographic spillovers, trade spillovers, retaliation effect, and swing-state interaction (see text for definitions and sources). Column (IV) reports the results when the exposure to uncertainty is weighted using the intermediate goods intensity to import. Column (V) corresponds to the pre-2017 sample estimation of the benchmark regression reported in Column (III) of Table 1. Column (VI) is the placebo regression of the benchmark regression reported in Column (III) of Table 1. All regressions include state- and time-FE. Robust standard errors are clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

**(II). Retaliation Effects** Any change in the level and the volatility of import tariffs might lead trade partners to retaliate. In order to control for the reaction of foreign countries, we re-run the benchmark regression by including the increase in retaliation tariff as provided by Fajgelbaum et al. (2020), which is sector specific. More precisely, we aggregate their measure of retaliation tax increase over the 15 sectors presented in Section 2.1 and we build a state-specific retaliation exposure index using as a weight the state's export share to total U.S. exports. Due to data availability, we re-run the estimation over a shorter sample, i.e. 2013q1-2019q2. Column (II) in Table 2 shows that state's GDP reacts negatively but not significantly to retaliation tax at quarter 8. More importantly, a stronger exposure to TPU still significantly reduces GDP while the less pronounced effect is mostly explained by the shorter sample.

**(III). Swing-states Effects** The last alternative control variable that we consider is related to political considerations. In order to check the exogeneity of our measure of tariff volatility exposure, we investigate the role of swing states in our baseline regression. We use data from the MIT Election Data and Science Lab (MEDSL) which provides the state-level returns for elections to the U.S. presidency from 1976 to 2020. We create a dummy equals to one when a state is considered as a swing state, i.e. the election returns have shifted from Democrat to Republican (or vice-versa) at least once over our period 2008-2020. The swing states are Arizona (AZ), Florida (FL), Georgia (GA), Indiana (IN), Iowa (IA), Michigan (MI), North Carolina (NC), Ohio (OH), Pennsylvania (PA), Wisconsin (WI). We then create an interaction term between the tariff volatility exposure series and the swing-states dummy. This interaction term is negative and significantly different from the zero at the impact (reported in the online appendix), but not at longer horizons, as in shown in Column (III) of Table 2. The estimation of economic effects of TPU shocks are close to those reported in our benchmark regression.

**(IV). Intermediate Goods Share** The series of exposure to TPU shocks – build from Equation (5) – is based on the sectoral composition of total imports at the state level, abstracting from whether goods are final or intermediate goods. We investigate whether our results still hold when we take into account the share of intermediate goods in imports, using the Input-Ouput database provided by WIOT, in 2008.[16] We then compute the share of intermediates goods imported in the US, relative to the total number of imported goods and weight the state-based exposure to uncertainty by the intermediate goods intensity to imports by state. Column (IV) of Table 2 shows that the effects of volatility exposure on GDP are still significant. Notice that the magnitude can not be directly compared since the scales of shocks differs between this specification and our benchmark.

**(V). Sample Without Trade War** We estimate the baseline regression over the sample 2008q1-2017q4 to abstract from the 2018 trade war. As shown in Column (V) of Table 2, estimated coefficients are slightly lower and significantly different from zero only at 10%-level for real GDP, against 5% for the benchmark, but remains significant at the 1% level for employment (reported in the online appendix). It is remarkable that even if we discard from the sample the trade war episode, we identify significant economic effects of shocks to TPU that occurred before

[16]We thank our discussant, Joseph Steinberg, for this suggestion.

this period suggesting that the recessionary effects of trade policy uncertainty is not only driven by this exceptional jump in tariff volatility.

**(VI). Placebo Shocks** The degree of exposure to trade policy uncertainty is built based on the state-specific sectoral composition of imports, as explained in Equation (4). In order to check that our results capture exogenous variations in tariff volatility, instead of being driven by the heterogeneous composition of imports, we run a placebo test by randomly resampling the vector of sectoral tariffs volatility and then building a counterfeit measure of exposure to TPU. Column (VI) in Table 2 shows the results. We find that when the baseline regression is estimated using this placebo series, there is no longer significant effects of volatility exposure shocks on the state economic activity.

### 2.3.3 Effects of TPU Shocks on Inflation

Our previous findings have shown that higher exposure to trade policy uncertainty significantly depresses state-level economic activity. However, a full picture of the effects of state-based TPU requires to assess how prices react to higher uncertainty, all the more so because higher volatility on import taxes is likely to alter expected firm's marginal cost and therefore price dynamics. To conduct this analysis, we use the state-specific quarterly inflation rates for the Consumer Price Index (CPI) provided by Hazell et al. (2022). Due to limited data availability, the sample covers the period 2008q1-2017q4. However, we showed in Section 2.3.2 that our results are not entirely driven by the 2018 trade war episode. In addition, CPI inflation series are provided for 32 states, which altogether represent 86% of total GDP in the U.S.

Table 3 presents the results when we estimate regression (6) by setting the outcome variable, $y_{s,t}$ as the price index built from the CPI inflation measure provided by Hazell et al. (2022). The effect of the level tariff shock on trade policy is positive and very close to be significant at 10%. This positive sign in line with the transmission of tariff shocks to prices e.g. Fajgelbaum et al. (2020). When it comes to the effects of uncertainty shocks about trade policy, we find that cumulative inflation becomes significantly negative after two years. This positive co-movement between output and prices suggests that (import tariffs) uncertainty shocks look like demand shocks, as argued by Leduc & Liu (2016) and Basu & Bundick (2017) for instance. In the next section, we develop a regional open-economy model consistent with these negative effects of TPU shocks on output and inflation.

Table 3: Effects of TPU shocks on inflation

| | (I)<br>$h = 0$ | (II)<br>$h = 4$ | (III)<br>$h = 8$ |
|---|---|---|---|
| Volatility exposure | -0.013 | -0.643* | -0.916** |
| (TPU) | (0.110) | (0.337) | (0.363) |
| Level exposure | 0.030 | 0.026 | -0.030 |
| | (0.018) | (0.077) | (0.111) |
| $\Delta$ CI | 0.103 | -0.242 | -1.142*** |
| | (0.070) | (0.325) | (0.414) |
| Obs. | 1,287 | 1,155 | 1,023 |
| Year FE | Yes | Yes | Yes |
| State FE | Yes | Yes | Yes |

*Note:* Table reports the effects of TPU shocks on inflation in Columns (I)-(III). Each column reports the results from regression (6) for the horizon $h = 0, 4, 8$ quarters. The coefficient of interest $\beta_h$ associated to $TPU_{s,t}$ is reported in the first line. All regressions include state-level EPU, state- and time-FE. Robust standard errors are clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

# 3 Theoretical Model

We now describe the theoretical model which allows us to go further in the understanding of the transmission channels of TPU shocks at the regional level.[17] The economy is made up of two countries, Home and Foreign. The Home country is split into two groups of regions of size $\eta_j$ where $j = \{1, 2\}$ is the region-specific index. The Foreign country is considered as a whole, his size being $\eta^*$, such that we normalize $\eta_1 + \eta_2 + \eta^* = 1$. The two Home regions belong to a monetary union. We assume that individual goods are tradable at the interstate and the international level with the Foreign country. For international trade, we assume that the Home country impose national import taxes on imported intermediate goods. We abstract from labor and capital mobility.

## 3.1 Production Sector

In each region $j$ of the Home country, at time $t$, a representative firm produces a non-tradable final good ($Y_{j,t}$) by aggregating differentiated intermediate goods. Intermediate goods are produced by monopolistic competitors who combine domestic and imported individual goods through a CES production function. They face price adjustment costs *à la* Calvo (1983) and

[17] The online appendix provides details of the computations.

we consider a producer currency pricing setting implying that the law of one price holds. Finally, the individual goods are produced in each region by a representative wholesaler who uses labor and capital. In the Foreign country, the production structure is the same, the representative final good producer uses a combination of domestic and imported individual goods, imported from both regions. Foreign variables are denoted with a star $^*$. For notation convenience of trade-related variables, the lower index of these variables corresponds to the country/region of origin (for the production of goods) and the upper index corresponds to the country/region of destination. Also, when we describe the production sector in Region $j$, we refer to the other region using index $j^-$. We start describing in details the production in the Home country and then we present briefly the Foreign country when it differs.

### 3.1.1 Final Good Production

In Region $j$ of the Home country, a representative firm produces a final good $Y_{j,t}$, by combining type-$i$ differentiated intermediate goods, $Y_{j,t}(i)$ using a Dixit-Stiglitz production function

$$Y_{j,t} = \left[ \int_0^1 Y_{j,t}(i)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \, \mathrm{d}i \right]^{\frac{\varepsilon_p}{\varepsilon_p - 1}}, \tag{7}$$

where $\varepsilon_p > 1$ is the elasticity of substitution between intermediate goods. Let $P_{j,t}$ denote the aggregate price index of the Home Region-$j$ final good $Y_{j,t}$ and $P_{j,t}(i)$ denote the price of type-$i$ region-$j$ intermediate good, $Y_{j,t}(i)$. The profit maximization yields the typical demand function for intermediate goods $Y_{j,t}(i)$

$$Y_{j,t}(i) = \rho_t^j (i)^{-\varepsilon_p} Y_{j,t}, \tag{8}$$

where $\rho_{j,t}(i) \equiv P_{j,t}(i) / P_{j,t}$ is the relative price of differentiated goods.

### 3.1.2 Intermediate Good Production

In Region $j$ of the Home country, we assume a continuum of monopolistic competitive firms, indexed by $i \in [0,1]$. Type-$i$ monopolistic competitive firm produces a non-tradable intermediate goods $Y_{j,t}(i)$ by combining domestic and imported individual goods ($\tilde{Y}_{H,t}^j$ and $Y_{F,t}^j$, respectively) through a CES production function

$$Y_{j,t}(i) = \left[ (1-\omega_j)^{\frac{1}{\theta}} (\tilde{Y}_{H,t}^j)^{\frac{\theta-1}{\theta}} + (\omega_j)^{\frac{1}{\theta}} (Y_{F,t}^j)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{9}$$

where $\theta > 1$ is the trade elasticity of substitution between domestic and foreign goods and parameter $\omega_j \in [0,1]$ is the degree of openness, i.e. it drives the magnitude of the home bias in Region $j$. Domestic goods correspond to a bunddle of goods, $\tilde{Y}_{H,t}^j$, coming from its own location

$(Y^j_{Hj,t})$ and from the other region $(Y^j_{Hj,t})$, such that

$$\tilde{Y}^j_{Ht} = \left[ (\hat{\omega}_j)^{\frac{1}{\theta}} \left( Y^j_{Hj,t} \right)^{\frac{\theta-1}{\theta}} + (1-\hat{\omega}_j)^{\frac{1}{\theta}} \left( Y^j_{Hj^-,t} \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}},$$

where $\hat{\omega}_j$ mesures the degree of trade openess of each region relative to the other region.

In a first step, the type-$i$ monopolistic producer from Region $j$ chooses the amount of domestic and imported individual goods, $Y^j_{Hj,t}$, $Y^j_{Hj^-,t}$ and $Y^j_{F,t}$ resp., so as to minimize its real cost, denoted by $S^j_t(i)$, taking into account the production function (9), with

$$S^j_t(i) \equiv \frac{P_{Hj,t}}{P^j_t(i)} Y^j_{Hj,t} + \frac{P_{Hj^-,t}}{P^{j^-}_t(i)} \frac{P^{j^-}_t(i)}{P^j_t(i)} Y^j_{Hj^-,t} + (1+\tau_t) \frac{P_{F,t}}{P^j_t(i)} Y^j_{F,t}, \tag{10}$$

where $P_{Hj,t}$ and $P_{Hj^-,t}$ is the price index of the good produced in Region $j$ and $j^-$ respectively, and $P_{Ft}$ denote the price index of the individual goods produced by the Foreign good.[18] Since the tariff policy at Home is national, this rate is identical in both regions. The minimization program yields the demand for domestic individual goods, expressed at the symmetric equilibrium,

$$Y^j_{Hj,t} = (1-\omega_j)\,\hat{\omega}_j \left( \frac{\rho_{Hj,t}}{\Lambda^j_t} \right)^{-\theta} Y^j_t, \qquad \text{and} \qquad Y^j_{Hj^-,t} = (1-\omega_j)\,(1-\hat{\omega}_j) \left( \frac{\rho_{Hj^-,t} Q_{j,t}}{Q_{j^-,t}} \frac{1}{\Lambda^j_t} \right)^{-\theta} Y^j_t, \tag{11}$$

as well as the demand for imported individual goods, expressed at the symmetric equilibrium,

$$Y^j_{F,t} = \omega_j \left( \frac{(1+\tau_t)\,\rho^j_{F,t}}{\Lambda^j_t} \right)^{-\theta} Y^j_t, \tag{12}$$

where $\Lambda_{j,t}$ denotes the real marginal cost of the intermediate good producer in Region $j$, $\rho_{Hj,t} \equiv P_{Hj,t}/P^j_t$ and $Q_{j,t}$ is the state-based real exchange rate defined below.

In a second stage, the type-$i$ monopolistic competitor in Region $j$ chooses the price of its good, $P_{j,t}(i)$, by maximizing its profits $d_{j,t}(i)$. We assume that price setting is modeled through a Calvo price setting. Precisely, a type-$i$ intermediate good producer keeps its previous price with probability $\alpha_p$ and resets its price with probability $1-\alpha_p$. This gives the standard non-linear New-Keynesian Phillips Curve (NKPC)

$$\pi^\star_{j,t} = \pi_{j,t} \left( \frac{\varepsilon_p}{\varepsilon_p - 1} \right) \frac{A_{j,t}}{B_{j,t}}, \tag{13}$$

[18] The imported quantity of good $Y^j_{Ft}$ may differ according to the region $j$, but the price $P_{Ft}$ is identical for the two regions. Similarly, the price of goods produced in Region $j$ is the same however its location of consumption, $P^j_{Hj,t} = P^{-j}_{Hj,t} = P_{Hj,t}$.

where $\pi^{\star}_{j,t} \equiv P^{\star}_{j,t}/P_{j,t-1}$ and $P^{\star}_{j,t}$ denotes the optimal reset price, all expressed at the symmetric equilibrium. In addition, $A_{j,t}$ and $B_{j,t}$ are defined recursively as

$$A_{j,t} = \Lambda_{j,t} Y_{j,t} + \alpha_p \mathrm{E}_t \left\{ \beta_{j,t,t+1} (\pi_{j,t+1})^{\varepsilon_p} A_{j,t+1} \right\}, \tag{14}$$

$$B_{j,t} = Y_{j,t} + \alpha_p \mathrm{E}_t \left\{ \beta_{j,t,t+1} (\pi_{j,t+1})^{\varepsilon_p - 1} B_{j,t+1} \right\}, \tag{15}$$

where $\beta_{j,t,t+1}$ is the stochastic discount factor of the household and $\mathrm{E}_t$ is the expectation operator conditional to the information available in period $t$. Expressing the aggregate price index in terms of inflation rate yields

$$\pi_{j,t}^{1-\varepsilon_p} = \left(1 - \alpha_p\right) \left(\pi^{\star}_{j,t}\right)^{1-\alpha_p} + \alpha_p. \tag{16}$$

Notice that we assume zero inflation at the steady-state. The real marginal cost $\Lambda_{j,t}$ in Region $j$ is increasing with import tariff, $\tau_t$, with

$$\Lambda_{j,t} = \rho_{Hj,t} \frac{Y^j_{H,t}}{Y_{j,t}} + (1 + \tau_t)\, \rho^j_{F,t} \frac{Y^j_{F,t}}{Y_{j,t}}. \tag{17}$$

As standard in the literature, the NKPC given by Equation (13) tells us that monopolistic competitive firms set their price taking into account the future expected real marginal cost. In our regional open-economy model, a region which is more open ($\omega_j$ large) will have its real marginal cost more sensitive to the import tax $\tau_t$ (see Equations (11) and (17)).

#### 3.1.3 Wholesaler

In Region $j$ of the Home country, we assume perfectly competitive wholesale producers who produce the good $X_{j,t}$ by using capital services, $k_{j,t}$, and labor $\ell_{j,t}$. The wholesale good is then split into intermediate goods used domestically, denoted $Y^j_{H,t}$, and abroad, denoted $Y^*_{Hj,t}$, such that

$$X_{j,t} = Y^j_{H,t} + Y^*_{Hj,t}. \tag{18}$$

The supply of intermediate goods used domestically is equal to the demand by monopolistic producers: $Y^j_{H,t} = \int_0^1 Y^j_{H,t}(i)\,\mathrm{d}i$. The wholesale good $X_{j,t}$ is produced with a Cobb-Douglas production function

$$X_{j,t} = a_t \eta_j k^{\alpha}_{j,t} \left(\ell_{j,t}\right)^{1-\alpha}, \tag{19}$$

where $a_t$ corresponds to a total factor productivity (TFP) shock, defined below. The Region-$j$ size, $\eta_j$, intervenes since the input quantities, $k_{j,t}$ and labor $\ell_{j,t}$, are per household of Region $j$.

The representative wholesaler chooses the amount of capital and labor services, as well as the supply of intermediate goods, so as to maximize its real profits denoted by $\tilde{d}_{j,t}$, subject to the production function (19) and definition (18). The real profits write

$$\tilde{d}_{j,t} = \rho_{Hj,t} Y^{j}_{H,t} + Q_{j,t} \rho^{*}_{Hj,t} Y^{*}_{Hj,t} - w_{j,t} \eta_j \ell_{j,t} - z_{j,t} \eta_j k_{j,t}, \tag{20}$$

where $\rho^{*}_{Hj,t} \equiv P^{*}_{Hj,t}/P^{*}_{t}$, $w_{j,t}$ and $z_{j,t}$ denote the Region-$j$ real wage and rental rate of capital, respectively. The real exchange rate in Region $j$ is defined as the price of Foreign consumption goods basket relative to the price of Region-$j$ consumption goods basket, such that $Q_{j,t} \equiv e_t P^{*}_{t}/P_{j,t}$, where $e_t$ is the nominal exchange rate. The law of one price holds, such that

$$\rho_{Hj,t} = Q_{j,t} \rho^{*}_{Hj,t}. \tag{21}$$

Therefore, intermediate good producers charge the same price for both their domestic and their import markets. Profit maximization yields the labor-demand and capital-demand equations

$$w_{j,t} = (1-\alpha)\, \rho_{Hj,t} \frac{X_{j,t}}{\eta_j \ell_{j,t}}, \quad \text{and} \quad z_{j,t} = \alpha \rho_{Hj,t} \frac{X_{j,t}}{\eta_j k_{j,t}}. \tag{22}$$

#### 3.1.4 Foreign Country

We now turn to describe the production sector in the Foreign country. For the sake of simplicity, we keep the Foreign country as stylized as possible, abstracting for instance from nominal rigidities. The Foreign market creates an additional trade connection between the two regions of the Home country since the Foreign final good, $Y^{*}_{t}$, is produced by using both domestic, $Y^{*}_{F,t}$, and imported individual goods, $\tilde{Y}^{*}_{H,t}$, using the following production function

$$Y^{*}_{t} = \left[ (1-\omega^{*})^{\frac{1}{\theta}} (Y^{*}_{F,t})^{\frac{\theta-1}{\theta}} + (\omega^{*})^{\frac{1}{\theta}} (\tilde{Y}^{*}_{H,t})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{23}$$

where $\omega^{*} \in [0,1]$ is the Foreign degree of trade openness. We assume that the imported individual good, $\tilde{Y}^{*}_{H,t}$, is a bundle of imported goods from each Home region

$$\tilde{Y}^{*}_{H,t} = \left[ (\tilde{\omega})^{\frac{1}{\theta}} (Y^{*}_{Hj,t})^{\frac{\theta-1}{\theta}} + (1-\tilde{\omega})^{\frac{1}{\theta}} (Y^{*}_{Hj^{-},t})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}. \tag{24}$$

Parameter $\tilde{\omega} \in [0,1]$ drives the degree of preference of Foreign producers for Region 1's individual goods. Let $P^{*}_{t}$ denotes the price of the final good $Y^{*}_{t}$, $P^{*}_{Ft}$ the price of domestic individual goods $Y^{*}_{F,t}$, and $P^{*}_{Hj,t}$ the price of individual goods imported from Region $j$. The profit maximization of the final good producer gives the demand equation for domestic goods as

$$Y^{*}_{F,t} = (1-\omega^{*}) \left( \rho^{*}_{F,t} \right)^{-\theta} Y^{*}_{t}, \tag{25}$$

with $\rho^*_{F,t} \equiv P^*_{Ft}/P^*_t$, the relative price of domestically produced individual goods, and the demand equation for imported goods as

$$Y^*_{Hj,t} = \omega^* \tilde{\omega} (\rho^*_{Hj,t})^{-\theta} Y^*_t, \quad \text{and} \quad Y^*_{Hj^-,t} = \omega^* \left(1 - \tilde{\omega}\right) (\rho^*_{Hj^-,t})^{-\theta} Y^*_t, \tag{26}$$

with $\rho^*_{Hj,t} \equiv P^*_{Hj,t}/P^*_t$, the relative price of the imported goods from region $j$. A stronger preference for Region $j$ ($\tilde{\omega}$) increases the imports of goods coming from this region.

Similarly to the Home country, we assume that a representative wholesaler produces an individual good which is sent domestically ($Y^*_{F,t}$) or exported in each region of the Home country ($Y^1_{Ft}$ and $Y^2_{Ft}$), such that

$$X^*_t = Y^*_{F,t} + Y^1_{Ft} + Y^2_{Ft}. \tag{27}$$

The good $X^*_t$ is produced using capital, $k^*_t$, and labor, $\ell^*_t$, through the following Cobb-Douglas production function

$$X^*_t = \eta^* \left(k^*_t\right)^{\alpha} \left(\ell^*_t\right)^{1-\alpha}. \tag{28}$$

The demand for labor and capital are therefore given by

$$w^*_t = (1-\alpha)\, \rho^*_{Ft} \frac{X^*_t}{\eta^* \ell^*_t}, \quad \text{and} \quad z^*_t = \alpha \rho^*_{Ft} \frac{X^*_t}{\eta^* k^*_t}. \tag{29}$$

while the law of one price implies that

$$\rho^*_{Ft} = \frac{\rho^1_{Ft}}{Q_{1,t}}, \quad \text{and} \quad \rho^1_{Ft} = \frac{Q_{1,t}}{Q_{2,t}} \rho^2_{Ft}. \tag{30}$$

The zero profit condition gives

$$\rho^*_{Ft} Y^*_{Ft} + \frac{\rho^1_{Ft}}{Q_{1,t}} Y^1_{Ft} + \frac{\rho^2_{Ft}}{Q_{2,t}} Y^2_{Ft} = w^*_t \ell^*_t + z^*_t k^*_t. \tag{31}$$

### 3.2 Household

We assume that households make their saving decisions under financial autarky, implying that they do not have access to international lending or borrowing and thus there is no opportunity to share financial risks across borders. For the sake of brevity, we focus here only on the Home country.

The Home country is populated by a continuum of identical households. In each region, they choose a sequence of consumption ($c_{j,t}$) and regional bonds ($b_{j,t}$), and they supply labor ($\ell_{j,t}$) and capital services ($k_{j,t}$) to maximize the discounted lifetime utility. The objective of the representative household is thus to maximize

$$\mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\sigma} \left[ \left( c_{j,t} - \psi \ell_{j,t}^{\omega_w} \mathcal{X}_{j,t} \right)^{1-\sigma} - 1 \right] \right\}, \tag{32}$$

where the term $\mathcal{X}_{j,t}$ is defined by

$$\mathcal{X}_{j,t} = c_{j,t}^{\sigma_X} \mathcal{X}_{j,t-1}^{1-\sigma_X}, \tag{33}$$

with $\beta \in (0,1)$ is the subjective discount factor, $\sigma_X \in (0,1)$ drives the strength of the wealth effect on labor supply, $\omega_w^{-1}$ is the Frisch elasticity of labor supply, $\psi$ is a normalizing constant (which governs the relative disutility of labor effort) and $\sigma$ is the inverse of the risk aversion coefficient. We assume financial autarky such that the representative household has access in $t-1$ to a one-period regional bond ($B_{j,t-1}$), which pays off a gross riskless interest rate $R_t$. She can also save by investing in physical capital by the amount $i_{j,t}$ and she receives labor income, with the real wage denoted $w_{j,t}$, and capital services revenue, with the real return denoted $z_{j,t}$. Last, the household perceives dividend income from differentiated goods producers and lump-sum transfers from the government. Accordingly, the budget constraint writes down as

$$c_{j,t} + b_{j,t} + i_{j,t} = \frac{R_{t-1}}{\pi_{j,t}} b_{j,t-1} + w_{j,t} \ell_{j,t} + z_{j,t} k_{j,t} + T_{j,t} + T_{j,t}^f, \tag{34}$$

where $b_{j,t} = B_{j,t}/P_{j,t}$ denotes the amount of bonds held in real terms, $T_{j,t}$ and $T_{j,t}^f$ are lump-sum transfers of profits from differentiated firms and of the international bond adjustment, respectively. We assume that the law of motion of capital is given by

$$k_{j,t+1} = (1-\delta) k_{j,t} + \left[ 1 - \frac{\varkappa}{2} \left( \frac{i_{j,t}}{i_{j,t-1}} - 1 \right)^2 \right] i_{j,t}, \tag{35}$$

where $\varkappa$ drives the strength of investment adjustment costs. For the sake of space, first-order conditions, which are standard, are reported in Appendix A.

### 3.3 Fiscal and Monetary Policy

State-specific government in each country runs a balanced budget

$$\eta_j T_{j,t}^f = \eta_j b_{j,t} - \frac{R_{t-1}}{\pi_{j,t}} \eta_j b_{j,t-1} + \tau \rho_{Ft}^j Y_{Ft}^j - g_t, \tag{36}$$

where $g_t$ corresponds to public spending, which follows an exogenous process as defined below. In addition, all regions in the Home country are part of a monetary union. The Home central bank sets the nominal interest rate rule according to the following Taylor Rule

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho_r} \left(\frac{\pi_t}{\bar{\pi}}\right)^{(1-\rho_r)\rho_\pi} m_t, \tag{37}$$

where $\rho_r$ drives the degree of interest rate inertia and $\rho_\pi$ is the weight on CPI national inflation, defined as $\pi_t = \frac{\eta_1}{\eta_1+\eta_2}\pi_{1,t} + \frac{\eta_2}{\eta_1+\eta_2}\pi_{2,t}$ and $m_t$ is a monetary policy shock defined below. The real exchange rate at the national level is given by

$$Q_t = (Q_{1,t})^{\frac{\eta_1}{\eta_1+\eta_2}} (Q_{2,t})^{\frac{\eta_2}{\eta_1+\eta_2}}. \tag{38}$$

#### 3.3.1 Equilibrium and Shocks

The market clearing equation in Region $j$ on the final goods market

$$Y_{j,t} = \eta_j c_{j,t} + \eta_j i_{j,t} + \eta_j g_t, \tag{39}$$

while the zero trade balance between Home and Foreign and at the regional level implies

$$\rho^*_{Hj^-,t} Y^*_{Hj^-,t} + \rho^*_{Hj,t} Y^*_{Hj,t} = \frac{1}{Q_{j^-,t}} \rho^{j^-}_{F,t} Y^{j^-}_{F,t} + \frac{1}{Q_{j,t}} \rho^{j}_{F,t} Y^{j}_{F,t}, \tag{40}$$

$$\rho_{Hj,t} Q_{j^-,t} Y^{j^-}_{Hj,t} = \rho_{Hj^-,t} Q_{j,t} Y^{j}_{Hj^-,t}. \tag{41}$$

We assume that import tariffs follow an AR(1) process with stochastic volatility such that

$$\begin{aligned} (1+\tau_t) &= (1-\rho_\tau)(1+\bar{\tau}) + \rho_\tau(1+\tau_{t-1}) + \exp(\sigma^\tau_t)\varepsilon^\tau_t, & (42)\\ \sigma^\tau_t &= (1-\rho_\sigma)\bar{\sigma}^\tau + \rho_\sigma \sigma_{t-1} + \gamma \varepsilon^\sigma_t, & (43) \end{aligned}$$

where $\rho_\tau$ and $\rho_\sigma$ are persistence parameters of level and volatility tariff shocks, respectively, $\gamma$ drives the magnitude of tariff uncertainty shocks and $\bar{\sigma}^\tau$ is the steady-state standard deviation. The three other level shocks, namely the supply-driven TFP and the demand-driven public spending and monetary policy shocks follow an AR(1) process[19]

$$x_t = (1-\rho_x)\bar{x} + \rho_x x_{t-1} + \exp(\sigma^x)\varepsilon^x_t, \tag{44}$$

where $\rho_x$ and $\sigma^x$ are the persistence and standard-deviation parameters with $x = \{a, g, m\}$. All innovations $\varepsilon^z_t \sim \mathcal{N}(0,1)$ for $z = \{\tau, \sigma, a, g, m\}$.

[19] Although we are primarily interested in the effect of the uncertainty shock, the quantitative fit of our model requires to incorporate all standard sources of fluctuations, i.e. demand and supply shocks.

# 4 Parametrization

We now calibrate the set of parameters following standard values in the literature and some empirical targets. A period in our regional model is a quarter. We assume that the two regions of the Home country as well as the Foreign country are perfectly symmetric, except regarding their size and some trade parameters, as explained below. Tables 4 reports our parametrization. Only parameters which are specific to a given region or a country are subscripted by an index.

**Common Parameters** We start with parameters which are common to all location. As standard in the literature, the discount factor, $\beta$ is set to 0.99 which fits an annual interest rate of 4%. The capital share, $\alpha$, is equal to 0.33 so as to fit a labor income share of 0.67 and the capital depreciation rate $\delta = 0.025$ implying an annual depreciation rate of 10%. We set the elasticity of substitution between intermediate goods, $\varepsilon_p$, to 11, implying a markup of 10%. The trade elasticity equals $\theta = 1.5$, which is in line with the literature (see Caldara et al. (2020) for instance). The Calvo parameter is set to $\alpha_p = 0.75$ which corresponds to a price frequency change of one year. Household's preference parameters are standard in the literature. We set the degree of risk aversion $\sigma = 2$ and we calibrate the strength of the wealth effect ($\sigma_X = 0.001$) following Born & Pfeifer (2014), as for the Frisch elasticity ($\omega_w = 1$). The scale parameter $\psi$ is set to ensure that steady-state hours worked correspond to $\bar{\ell} = 0.33$ of total hours. The investment adjustment cost is set to $\kappa = 6$. When it comes to the Taylor rule, we choose the standard value by assuming that inflation reaction parameter to the nominal interest rate is $\rho_\pi = 1.5$ and the interest rate inertia parameter is $\rho_r = 0.8$. We set the share of public spending-to-GDP on our sample mean and we get $\bar{g}/\bar{y} = 0.18$. Finally, we set the steady-state value of import tax to $\bar{\tau} = 5\%$ in both Home regions, which corresponds to our sample mean. We abstract from any retaliatory taxation.

**Region-specific Parameters** We now turn to the calibration of parameters which are region-specific, in particular those which determine trade openness of the two Home regions as well as the Foreign country ($\omega_1$, $\omega_2$, $\hat{\omega}_1$, $\hat{\omega}_2$, $\omega^*$, $\tilde{\omega}$). It is worth noticing that both regions face a common national import tariff, $\tau_t$, and so they differ in their exposure to international trade only, captured through these parameters. We are not the first to parametrize a two-region model. For instance, Nakamura & Steinsson (2014) or Chodorow-Reich & Wieland (2020) assume that both regions are symmetric but the region of interest corresponds to a "representative" average U.S. state while the other region represents the rest of the country. We follow an alternative road by parametrizing our representative region (Region 1) as a set of typical regions that are exposed to international trade while Region 2 can be interpreted as the rest of the country. Therefore, on contrary to these authors, we seek to exploit in the calibration the heterogeneity across regions and notably the degree of exposure to trade. Precisely, we pick the values of $\omega_1$, $\omega_2$, $\omega^*$ and $\tilde{\omega}$

Table 4. Parametrization

| | | | |
|---|---|---|---|
| Common Parameters | | | |
| $\beta$ | Discount factor | 0.99 | Annual interest rate (4%) |
| $\alpha$ | Capital share | 0.33 | Labor income share (0.67) |
| $\delta$ | Capital depreciation rate | 0.025 | Annual depreciation rate (10%) |
| $\varepsilon_p$ | Elasticity of substitution btw intermediate goods | 11 | Markup (10%) |
| $\theta$ | Trade elasticity | 1.5 | Caldara et al. (2020) |
| $\alpha_p$ | Calvo parameter | 0.75 | Price adj. of one year |
| $\sigma$ | Degree of risk aversion | 2 | Born & Pfeifer (2014) |
| $\omega_w^{-1}$ | Frisch elasticity of labor supply | 1 | Born & Pfeifer (2014) |
| $\sigma_X$ | Wealth effect | 0.001 | Born & Pfeifer (2014) |
| $\bar{\ell}$ | Steady state labor | 0.33 | Standard calibration |
| $\kappa$ | Investment adjustment cost | 6 | Standard calibration |
| $\rho_\pi$ | Taylor rule parameter wrt inflation | 1.5 | Standard calibration |
| $\rho_r$ | Interest rate inertia | 0.8 | Standard calibration |
| $g/y$ | Share of government expenditure in output | 0.18 | Bureau of Economic Analysis |
| Region-specific Parameters | | | |
| $\tilde{\omega}$ | Region-1 export intensity | 0.84 | Highest export intensity (0.68) |
| $\omega_1$ | Region-1 degree of trade openess | 0.14 | Import share (0.13) |
| $\omega_2$ | Region-2 degree of trade openess | 0.08 | Import share (0.08) |
| $\hat{\omega}_1$ | Region-1 interstate degree of trade openess | 0.62 | model's steady state |
| $\hat{\omega}_2$ | Region-2 interstate degree of trade openess | 0.62 | model's steady state |
| $\omega^*$ | Foreign degree of trade openess | 0.25 | Foreign import share (0.10) |
| $\eta^*$ | Size of Foreign | 0.5 | U.S. population share (0.5) |
| $\eta_1$ | Size of Region-1 | 0.315 | Population share (0.63) |
| $\eta_2$ | Size of Region-2 | 0.185 | Population share (0.37) |
| $\bar{\tau}$ | U.S. import tax | 0.05 | Foreign Trade Database |

so as to fit four targets from the empirical analysis presented in Section 2, while $\hat{\omega}_1$ and $\hat{\omega}_2$ are deduced from the model's steady-state. We split the sample of 50 U.S. states into two groups of a same size and we assume that the representative exposed region is the one which have a degree of export intensity in 2008 above the median.[20] The degree of export intensity gives us a target to calibrate $\tilde{\omega}$. Targeting the sum of export intensity leads us to $\tilde{\omega} = 0.78$. We then pick the values for $\omega_1$ and $\omega_2$ so as to target the 2008 average import-to-GDP share of each group, i.e. 0.13 and 0.08, respectively. These empirical targets lead to $\omega_1 = 0.14$ and $\omega_2 = 0.09$. Notice that model's steady state leads to $\hat{\omega}_1 = \hat{\omega}_2 = 0.62$. Finally, we assume that the import-to-GDP share in the Foreign country is 10%, which implies $\omega^* = 0.25$. We also target the population share in the two group of U.S. states, based on the empirical finding that our region of interest corresponds to 63% of the total U.S. population share in 2008 (and thus 0.37% for the other region). Assuming that the Foreign country consists in 50% of the world economy ($\eta^* = 0.5$), we obtain $\eta_2 = 0.315$ and $\eta_1 = 0.185$.

**Shocks parameters** We finally parametrize the exogenous driving process outside the model by using available aggregate U.S. series and estimating an AR(1) over the sample 1980q1-2020q4. Results are reported in Table 5. First, we build the quarterly series of U.S. tariffs rate as in Caldara et al. (2020), with $\tau_t = CD_t/(M_t - CD_t)$ where $CD_t$ is the taxes on production and imports received by the Federal government and $M_t$ is the real value of total imports.[21] We then estimate a stochastic volatility process as in Equations (42)-(43), here again using the algorithm of Born & Pfeifer (2014) and select the mean values of the posterior distribution of the parameters. This parametrization strategy gives us $\rho_\tau = 0.99$ and $\rho_\sigma = 0.99$ as well as $\gamma = 0.29$ and $\bar{\sigma}^\tau = -5.90$, which is in line with the results by Caldara et al. (2020). When it comes to the level shocks, TFP, public spending and monetary policy, we estimate an AR(1) as in Equation (44). The TFP series is borrowed to Fernald (2012) and corresponds to the utilization-adjusted measure. Public spending series is the real government consumption expenditures and gross investment provided from the U.S. Bureau of Economic Analysis. Both series are expressed in log and HP-filtered. We obtain $\rho_a = 0.76$ and $\sigma_a = \log(0.008)$ for TFP shocks as well as $\rho_g = 0.90$ and $\sigma_g = \log(0.014)$ for public spending shocks. The monetary policy shock is recovered by estimating a typical Taylor rule on the Federal Funds Effective Rate (provided by the Board of Governors of the Federal Reserve

[20] The degree of export intensity in a state $s \in [0, 50]$, denoted $\mathcal{D}_s$, is computed as $\mathcal{D}_s = \frac{X_{s,2008}}{\sum_{s=1}^{S} X_{s,2008}}$, where $X_{s,2008}$ is the value of real exports per capita in state $s$ in 2008, which corresponds to the beginning of the sample. We compute the median value in 2008 for all states and we partition the states which have a value above the median (high intensity) or below the median (low intensity). The degree of export intensity would be $1/50$ for each state if they would be uniformly distributed. States which feature a degree of export intensity larger than the median are "AK"; "CA"; "CT"; "DE"; "IL"; "IN"; "IA"; "KS"; "KY"; "LA"; "MA"; "MI"; "MN"; "NJ"; "NY"; "ND"; "OH"; "OR"; "SC"; "TN"; "TX"; "UT"; "VT"; "WA"; "WI".

[21] Since our theoretical model is not a multi-sector model, it does not aim at capturing the sectoral heterogeneity in tariffs highlighted in Section 2. Therefore, we calibrate the tariff shocks – level and volatility shocks – by using U.S. aggregate data.

System), the growth rate of the implicit price deflator and the GDP growth (both provided by the U.S. Bureau of Economic Analysis). We then estimate an AR(1) on the residuals and we obtain $\rho_m = 0.93$ and $\sigma_m = \log(0.0085)$. Finally, we assume that the Foreign country is not directly hit by any shock.

Table 5. Parametrization

| Shocks Parameters | | |
|---|---|---|
| $\rho_\tau$ | Tariff level shock: persistence | 0.99 |
| $\bar{\sigma_\tau}$ | Tariff level shock: s.d, $\exp(\bar{\sigma_\tau})$ | $\exp(-5.83)$ |
| $\rho_\sigma$ | Tariff volatility shock: persistence | 0.99 |
| $\eta$ | Tariff volatility shock: magnitude | 0.28 |
| $\rho_a$ | TFP shock: persistence | 0.76 |
| $\sigma_a$ | TFP level shock: s.d | log(0.008) |
| $\rho_g$ | Public spending shock: persistence | 0.90 |
| $\sigma_g$ | Public spending shock: s.d | log(0.014) |
| $\rho_m$ | Monetary policy shock: persistence | 0.93 |
| $\sigma_m$ | Monetary policy shock: s.d | log(0.0085) |

*Note:* All estimates are obtained by estimating Equation (44) from aggregated U.S. data.

# 5 Transmission Channels of Regional TPU

In this section, we investigate the regional effects of trade policy uncertainty shocks resorting to the theoretical model developed in Section 3. First, we solve and simulate the theoretical model to check its quantitative validity. Then, we analyze the Impulse Response Functions (IRFs) to trade policy uncertainty shocks and we perform a set of counterfactual exercise.

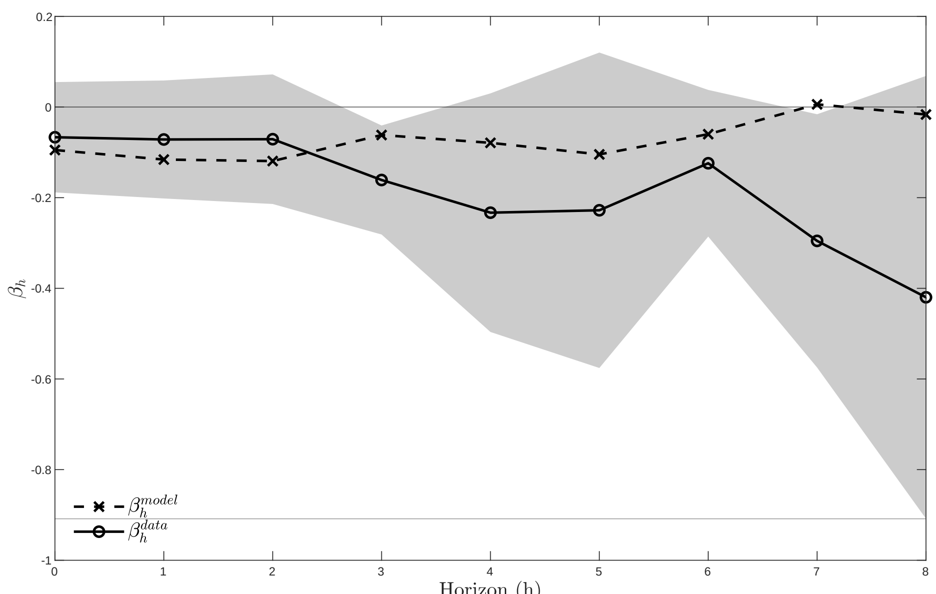
## 5.1 Solution Methods and Simulation

We solve the model using third-order pruned perturbation methods in order to track the effects of tariff volatility shocks on the economy. We first check the ability of our theoretical model to replicate the empirical evidence emphasized in Section 2.3. As explained in Section 4, we parametrized the regional model so as to reproduce the main empirical moments related to international trade exposure which have been extracted from our empirical dataset. We then simulate the theoretical model after a long enough burn-in period that allows us to start from the stochastic steady state. We extract the simulated series of output, $Y_{j,t}$ for $j = \{1,2\}$, as defined in Equation (7) that we express in log. The panel structure of the theoretical model allows us to estimate the following regression

$$\log(Y_{j,t+h}) - \log(Y_{j,t-1}) = \delta_{j,h} + \delta_{t,h} + \beta_h^{model} TPU_{j,t} + v_{j,t+1}, \text{ for } h >= 0 \quad (45)$$

for each $j = \{1, 2\}$, where $TPU_{j,t}$ corresponds to the simulated volatility shocks, $\delta_{j,h}$ and $\delta_{t,h}$ are region- and time-fixed effects. Since our empirical dataset set is made up of 50 states while our theoretical one corresponds to two average states, we re-estimate Equation (6) by imposing region-fixed effects in the empirical regression. This simulation-based estimation strategy has the advantage that we apply a similar data-generating process than in the empirical part.

Figure 4: Effects of regional TPU shocks on output: Data versus model




Note: Each marker point corresponds to point estimates $\beta_h$ estimated from Equation (6) for the data (solid line) and from Equation (45) for the model (dashed line). The grey area displays the $[10^{th}, 90^{th}]$ confidence interval of the empirical estimates.

Figure 4 reports the results. Each marker corresponds to the point estimates from the data ($\beta_h$) and the model ($\beta_h^{model}$).[22] The Figure shows that, despite its stylized dimension, the theoretical regional model does a good job in reproducing the magnitude of effects of tariff volatility shocks on output at several horizons. In particular, the model generates an impact elasticity of $\beta_0^{model} = -0.09$ while it is $\beta_0^{data} = -0.06$ in the data. It fails to replicate the stronger magnitude of the effects over longer horizons but it remains inside confidence intervals over the two years following the shock. In the following subsection, we investigate the transmission channels of tariff volatility shocks in the model.

[22]Therefore, the data-based markers for horizon $h = 0, 4, 8$ correspond to the counterpart of the values reported in Table 1 when we include region-fixed effect instead of state-fixed effect. The region dummy is defined in Footnote 19.

## 5.2 IRFs Analysis

We now investigate the transmission channels of a pure TPU shock in a regional model by computing the IRFs to a national volatility tariff shock and by carrying out a set of counterfactual exercises. We compute the response of variables to the volatility shock in deviation from the EMAS, all shocks being shut down.[23] From now, we display the responses in the representative region, namely the typical most-exposed region to international trade and we investigate the main drivers of the effects.[24]

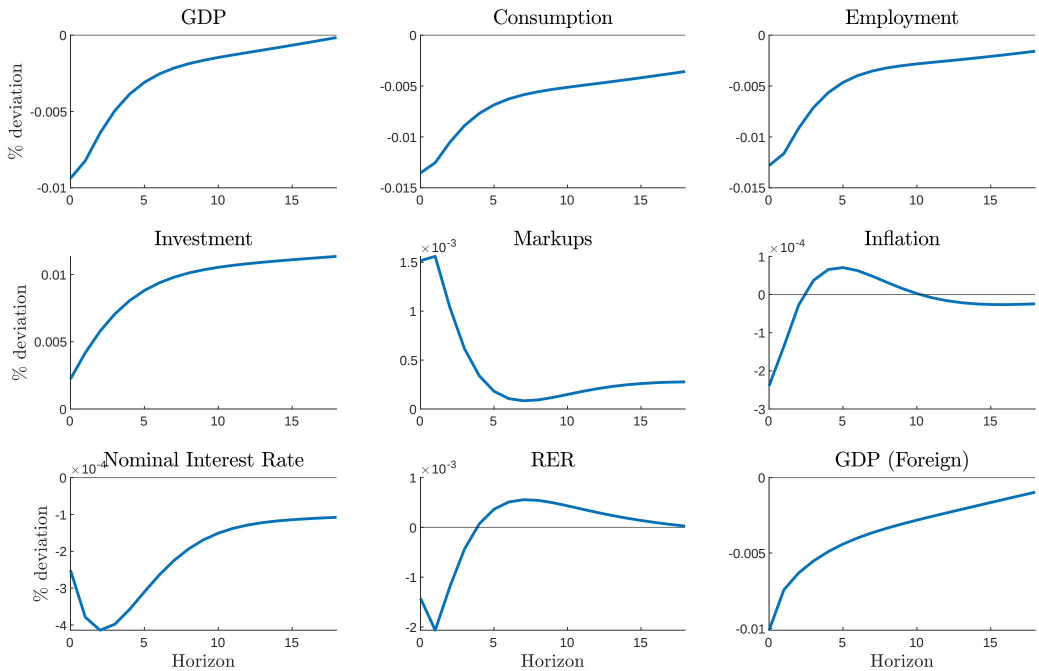
### 5.2.1 Baseline Calibration

Figure 5 shows the IRFs in the representative exposed region to a national TPU shock that hits the Home economy. We find that that a rise in import tariffs volatility generates a drop in consumption as well as a recession, while there is a surge in investment. In Keynesian models where production is determined by demand, a fall in consumption leads to a fall in production. The reaction of investment depends on the relative magnitude of these two falls. Here, the fall in consumption is so large relative to realized output that unconsumed output available for investment increases. Note that this property results from the high persistence of the trade policy shock. For a lower value of this persistence, we find the usual comovement between consumption, investment and production in response to uncertainty shocks, without affecting our results. Higher uncertainty about tariffs in the Home economy leads to a collapse of its imports, which means for the Foreign economy a contraction in demand for its own production. As a result, the Foreign country also enters a recession, which generates a feedback effect through a reduction in Home exports. In total, the reduction in aggregate demand generates a rise in markups and a drop in inflation. Unlike Caldara et al. (2020), our model does not incorporate the firms' export participation decision. Even without this mechanism, our model captures the main expected effects of an uncertainty shock on tariffs, as the authors show that the extensive margin of exports mostly affect the magnitude of the responses rather than the transmission channels.

[23]Technically, we simulate the model starting from the deterministic steady state with all shocks imposed to be zero and burn in the 10 000 first observations to get the ergodic mean without shock (EMAS). We simulate once again the model, impulsing the volatility innovation $\varepsilon_t^{\sigma}$ after the burn-in period. The IRFs are then expressed in deviation from the EMAS.

[24]Although the model is parametrized to capture heterogeneity in terms of trade exposure across both regions, their responses follow a very similar pattern and magnitude. House et al. (2021) show that interstate trade generates stronger reaction of the economic activity to shocks. We complement their results by finding that it reduces heterogeneity, the reason being that the effects of shocks are propagated among regions through trade (see online appendix).

Figure 5: IRFs to a TPU shock: Baseline



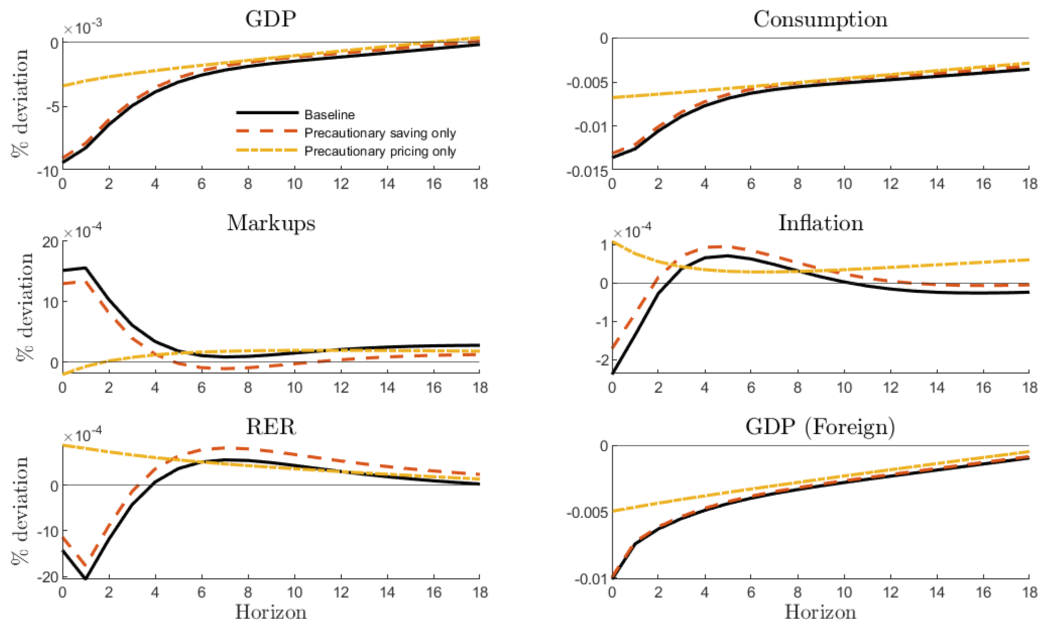

Note: IRFs are computed in deviation from the ergodic mean and multiplied by 100. The grey area highlights the gap between the two regions.

### 5.2.2 Precautionary behavior

It is well documented in the literature that the recessionary effects of uncertainty shocks are explained by the precautionary behavior of agents – in particular the precautionary-saving motive and the precautionary-pricing behavior of firms, see Bianchi et al. (2023) for details. First, the convex marginal utility of consumption implies that households who face uncertainty about the future economic prospective postpone their current consumption and increase their savings to smooth consumption over time. As a consequence of this precautionary-saving channel, a higher volatility of import tariffs generates second-order effects which lead to a reduction in private consumption. In addition, the rise in labor supply arising from "precautionary labor supply" (Basu & Bundick (2017)) is attenuated through our parametrization of zero wealth effect on labor supply ($\sigma_X$ small) combined with the presence of nominal rigidities. Second, trade policy uncertainty makes also firms more uncertain about their expected real marginal cost since import tariffs have a direct impact on the real marginal cost, as shown in Equation (17), and as emphasized by Caldara et al. (2020). Therefore, the variance of future desired price is higher, which in turn makes firms more "prudent" in their pricing decisions, by setting a price higher than that they normally would do in the absence of uncertainty. This precautionary-pricing behavior of firms leads them to increase markups which reduces output since firms are demandconstrained.

Our model allows us to disentangle the contribution of these two second-order-moments channels in explaining the recession. Figure 6 displays the IRFs of output, consumption, markups and inflation in the baseline model (solid lines), when we shut down the precautionary-pricing channel (by linearizing the New-Keynesian Phillips Curve (13), dashed orange lines) and the precautionary-saving channel (by imposing a constant stochastic discount factor in Euler equations (46), dotted-dashed yellow lines) in the region.[25]

Figure 6: IRFs to a TPU shock: Precautionary motives




Note: IRFs are computed in deviation from the ergodic mean and multiplied by 100. The solid lines correspond to our baseline model. The dashed orange lines corresponds to a model with linearized pricing equation (13). The dotted-dashed yellow lines display the the case with constant stochastic discount factor.

Figure 6 makes clear that the precautionary-pricing behavior explains a very small amount of the recession while most of the magnitude of output and consumption is explained by the precautionary-saving motive. When the precautionary-pricing behavior only is active, we indeed find that markups increases (after one period) but in a small amount, that goes with a moderate increase in inflation. The reduction in inflation that we observe in the baseline is mostly explained by the negative effect on aggregate demand that precautionary saving generates. The real

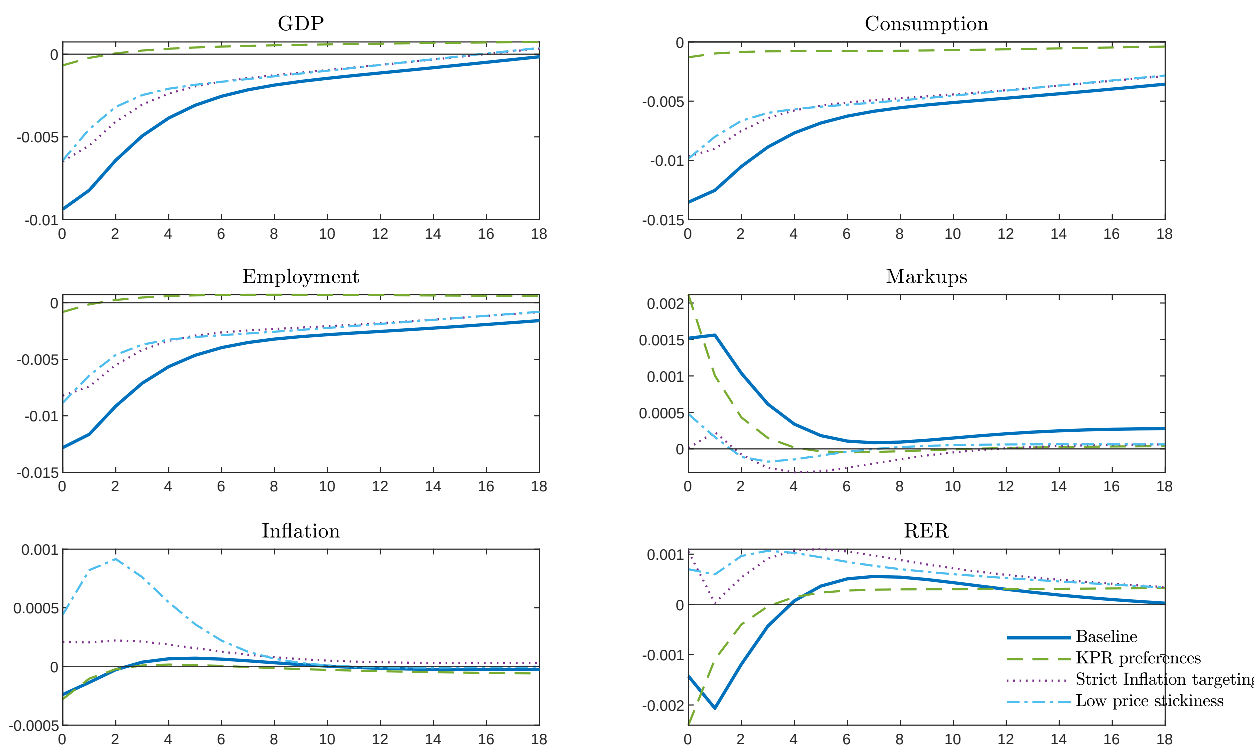
[25]Regarding the last counterfactual, it means that we assume a linear utility function for households. On top of ignoring the precautionary saving motive, we therefore assume that households are no longer risk averse. In order to focus on the precautionary saving behavior, we impose a constant stochastic discount factor on the Euler equation only, keeping it endogenous and time-varying in the other equations.

exchange appreciation that comes from a reduction in Home export is also driven by the drop in aggregate demand.

#### 5.2.3 Dissecting the Transmission Channels

The precautionary behavior of agents – and more particularly the precautionary-saving motive – can be seen as the main driver of the recession observed after a peak in tariffs volatility. In this experiment, we investigate to which extent key model's features alter the transmission channels of uncertainty shocks. Figure 7 reports the responses of a set of key variables in the baseline calibration (solid black lines) and under a set of counterfactual exercises.

Figure 7: IRFs to a TPU shock: Transmission channels




Note: IRFs are computed in deviation from the ergodic mean and multiplied by 100. The solid black line corresponds to the benchmark calibration. The dashed green line corresponds to King et al. (1988) preferences. The dotted purple line corresponds to a strict inflation targeting rule. The dashed-dotted blue line corresponds to a model with low price stickiness.

In our baseline calibration, parameter $\sigma_x$ is set to a small value, implying that the wealth effect on the labor supply is limited, corresponding to Greenwood et al. (1988)'s preferences. The dashed green lines Figure 7 displays the responses when we set $\sigma_x = 1$ in Equation (33), i.e. the utility function (32) in Region $j$ takes the form $U_{j,t} = (c_{j,t} - \psi \ell_{j,t}^{\omega_w})^{1-\sigma}$, as in King et al. (1988). We find that the wealth effect on the labor supply has a substantial dampening effect of the recession since output slightly drops and only for two quarters. The reason is that uncertainty leads households to supply more labor, at least in the medium run. This excess of labor supply boosts the economic activity which limits the size of the recession. The dotted purple line shows the IRFs when we impose a strict inflation targeting ($\rho_\pi = 5$). In this case, because inflation is stabilized by the central bank, markups are less responsive to higher uncertainty and the real exchange rate depreciates, which corresponds to some extra demand for the region that mechanically reduces the magnitude of the collapse. Finally, we assume a lower degree of price stickiness by setting $\alpha_p = 0.4$ (see dotted-dashed blue lines). As explained by Basu & Bundick (2017) or Born & Pfeifer (2021), nominal rigidities act as an amplification mechanism of uncertainty shocks, notably by making markups countercyclical. To complement their results, we find that in a regional open-economy model, nominal rigidities drive the real exchange rate appreciation, which magnifies the drop in output.[26]

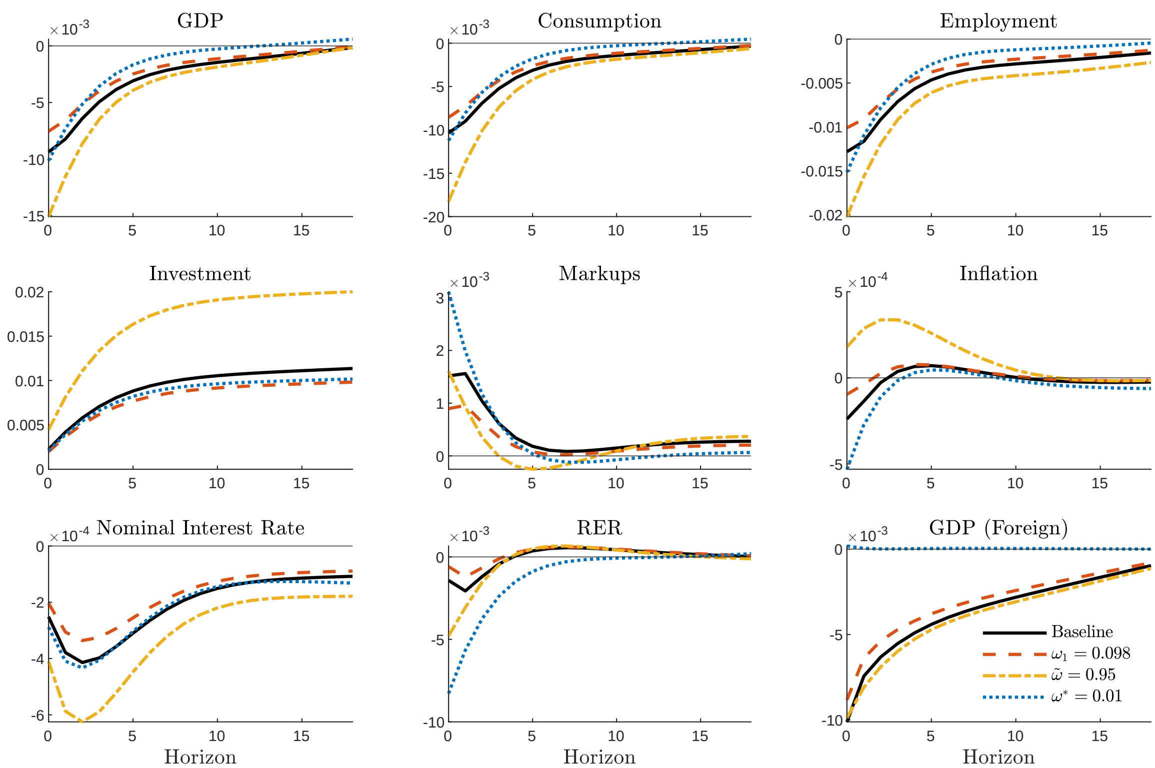
#### 5.2.4 Assessing the Role of Trade Exposure

Our previous analysis allowed us to emphasize the transmission channels of uncertainty shock that relies on the closed-economy structure of the model. However, the regional effects of TPU shocks are also conditional to the regional degree of exposure to trade. We assess more in details the open-economy structure of the model by plotting in Figure 8 the IRFs of a set of variables to a national TPU shock when we alternately modify parameters $\omega_j$, $\tilde{\omega}$ and $\omega^*$. The solid line corresponds to the response for the baseline calibration. The dashed orange line represents the IRFs under a lower import share, i.e. $\omega_1$ is set to the alternative region's value. The production technology in the region is less dependent on imported goods which in turn results in a demand function of imported good less sensitive to a tariffs volatility. Therefore, the transmission channels of uncertainty shocks are attenuated that materialized through a dampened appreciation of the real exchange rate and a slightly more limited recession. We also consider the case where the region features a high degree of export intensity ($\tilde{\omega}$), see dotted-dashed yellow line, that generates an amplified recession. The reason is that the Foreign country features a stronger preference bias towards the good of the region, which makes this region more exposed to the Foreign recession. This acts as an additional recessionary force, on top of the traditional transmission channels of uncertainty. Finally, we assess the role of the feedback effect by assuming that the Foreign country has a large home bias ($\omega^*$ small), as displayed by the dotted blue lines. Since the Foreign country consume domestic goods only, Foreign output becomes insensitive to the Home uncertainty shock. Nevertheless, the region in

[26] In the online appendix, we report the IRFs of both regions. We also consider a worldwide uncertainty shock on trade policy in the model, i.e. both Home and Foreign countries impose import tariffs and they are hit by an exogenous volatility shock in order to capture the effects on the export side. We find that a global uncertainty shock mostly raises the magnitude of the recession.

the Home country experiences a recession that comes from for the precautionary behaviors of agents, as explained above. Looking at the dynamics of output, consumption or employment, the impact response in the no-feedback effect case is similar to the baseline model. However, the feedback effect makes these variables more persistent since the drop in Foreign output generates a long-lasting reduction in the demand for Home goods emanating from foreigners.

Figure 8: IRFs to a TPU shock: International trade channels




Note: IRFs are computed in deviation from the ergodic mean and multiplied by 100. The solid line displays the response for the baseline calibration. The dashed orange line shows the IRFs for a lower import share. The dotted-dashed yellow line represents the IRFs for a larger degree of export intensity. The dotted blue line represents the IRFs when we shut down the feedback effect from the Foreign country.

## 6 Conclusion

This paper studies the effects of trade policy uncertainty shocks – both empirically and theoretically – using a regional approach. We build a measure of U.S. states' exposure to trade policy uncertainty and we estimate the effect of a related shock on GDP and employment. We show that a positive shock on regional TPU exposure is recessionary. We rationalize this result using a two-region open-economy model. We find that the precautionary behavior of agents – and most precisely the precautionary-saving behavior – acts as the main driver of the recessionary effect of TPU shock, this effect being reinforced by a high exposure to tariffs. On the opposite, the feedback effect resulting from trade connections with the Foreign country mostly affect the persistence of the responses to TPU shocks. Our findings complement the results already obtained in the literature at different levels of aggregation, such as at Caldara et al. (2020), which are at the level of the United States as a whole or of American firms. This analysis could be pursued in the analysis of local policies which could be useful to mitigate the effects of tariffs that are decided at national level.

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# Appendix

## A. Households First-Order Conditions

Maximizing the discounted lifetime utility measure (32) subject to the definition 33), the budget constraint (34), the law of capital accumulation (35) yields the following first-order conditions

$$1 = \beta \mathrm{E}_t \left\{ \frac{\lambda_{j,t+1}}{\lambda_{j,t}} \frac{R_{j,t}}{\pi_{j,t+1}} \right\}, \tag{46}$$

$$\left(c_{j,t} - \psi \mathcal{X}_{j,t} \left(\ell_{j,t}\right)^{\omega_w}\right)^{-\sigma} + \sigma_X v_{j,t} c_{j,t}^{\sigma_X - 1} \mathcal{X}_{j,t-1}^{1-\sigma_X} = \lambda_{j,t}, \tag{47}$$

$$v_{j,t} + \psi \left(\ell_{j,t}\right)^{\omega_w} \left(c_{j,t} - \psi \left(\ell_{j,t}\right)^{\omega_w} \mathcal{X}_{j,t}\right)^{-\sigma} = \beta \left(1 - \sigma_X\right) \mathrm{E}_t \left\{ v_{j,t+1} c_{j,t+1}^{\sigma_X} \mathcal{X}_{j,t}^{-\sigma_X} \right\}, \tag{48}$$

$$\psi \omega_w \left(\ell_{j,t}\right)^{\omega_w - 1} \mathcal{X}_{j,t} \left(c_{j,t} - \psi \mathcal{X}_{j,t} \left(\ell_{j,t}\right)^{\omega_w}\right)^{-\sigma} = \lambda_{j,t} w_{j,t}, \tag{49}$$

$$\varsigma_{j,t} = \left[1 - \Phi\left(\frac{i_{j,t}}{i_{j,t-1}}\right) - \Phi'\left(\frac{i_{j,t}}{i_{j,t-1}}\right) \frac{i_{j,t}}{i_{j,t-1}} + \beta \mathrm{E}_t \left\{ \frac{\lambda_{j,t+1} \varsigma_{j,t+1}}{\lambda_{j,t} \varsigma_{j,t}} \left(\frac{i_{j,t+1}}{i_{j,t}}\right)^2 \Phi'\left(\frac{i_{j,t+1}}{i_{j,t}}\right) \right\} \right]^{-1}, \tag{50}$$

$$1 = \beta \mathrm{E}_t \left\{ \frac{\lambda_{j,t+1}}{\lambda_{j,t}} \left[ \frac{z_{j,t+1} + (1-\delta)\, \varsigma_{j,t+1}}{\varsigma_{j,t}} \right] \right\}, \tag{51}$$

with $\varsigma_{j,t} \equiv \breve{\zeta}_{j,t} / \lambda_{j,t}$, the relative price of capital and with $\Phi\left(\frac{i_{j,t}}{i_{j,t-1}}\right) = \frac{\varkappa}{2}\left(\frac{i_{j,t}}{i_{j,t-1}} - 1\right)^2$ and $\Phi'\left(\frac{i_{j,t}}{i_{j,t-1}}\right) = \varkappa \frac{i_{j,t}}{i_{j,t-1}}\left(\frac{i_{j,t}}{i_{j,t-1}} - 1\right)$, and where $\lambda_t$, $v_t$ and $\breve{\zeta}_t$ denote the Lagrangian multipliers associated to the budget constraint (34), the definition (33), and the law of motion of capital (35), respectively.