To What Extent Are Tariffs Offset By Exchange Rates?*

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Abstract

In theory, we should expect tariffs to be partially offset by a currency appreciation in the tariff-imposing country or by a depreciation in the country on which the tariff is imposed. We find, based on a calibrated model, that the tariffs imposed by the US in 2018-19 should not have had a large impact on the dollar but may have significantly depreciated the renminbi. This prediction is consistent with a high-frequency event analysis looking at the impact of tariff-related news on the dollar and the renminbi. We find that tariffs explained at most one fifth of the dollar effective appreciation but around two thirds of the renminbi effective depreciation observed in 2018-19.

Keywords: exchange rates, tariffs, dollar, renminbi.

JEL Codes: F31, F41

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1 Introduction

In 2018-19 the US imposed new tariffs of 15.1 percent on average on its imports from China[1] but the renminbi depreciated by 7.0 percent against the dollar (see Figure 1). Indeed, a common argument against tariffs is that their effect is likely to be mitigated by endogenous offsetting movements in exchange rates (Stiglitz, 2016). Of course, the appreciation of the dollar and the weakness of the renminbi could have resulted from factors other than tariffs, such as the lift-off of the Fed policy rate in the US and slowing growth in China.

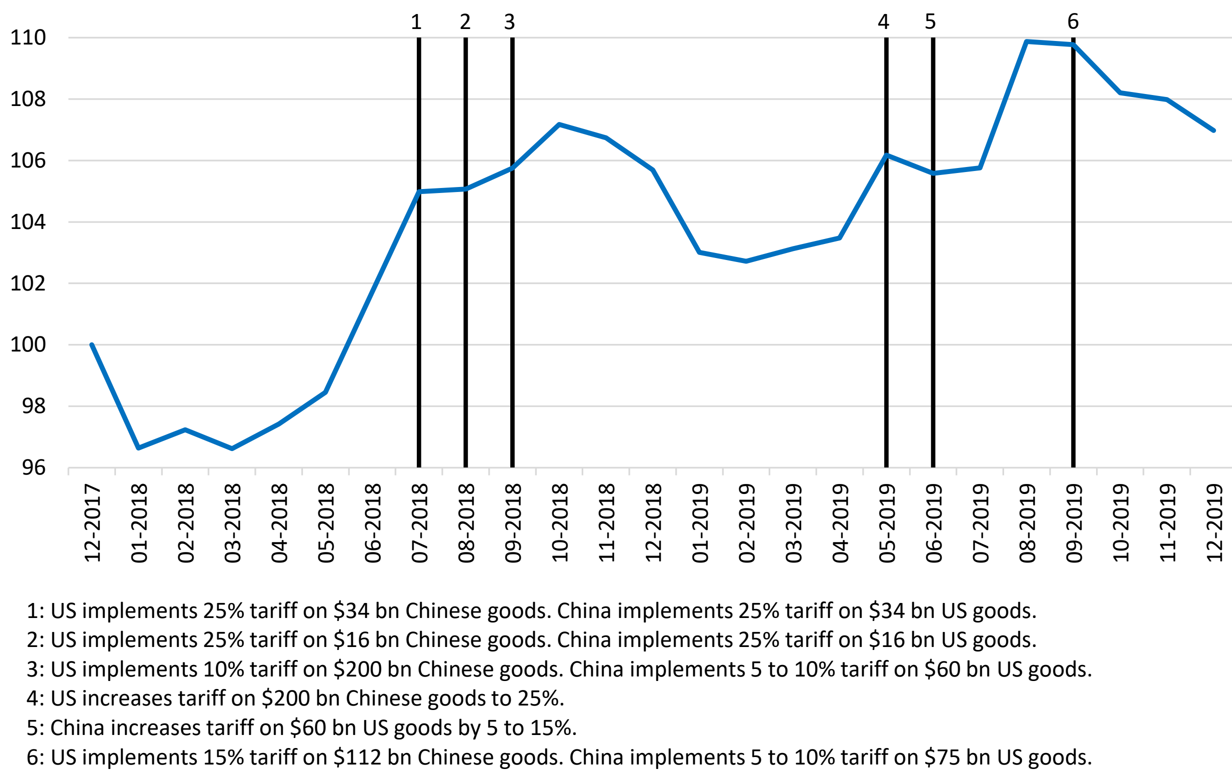

Figure 1: End-of-month CNY/USD exchange rate and main tariff events (Dec. 2017=100, Source: BIS)

The question in this paper is the extent to which tariffs are offset by countervailing movements in exchange rates. We look at this question from a general theoretical perspective and in the context of the US-China tariff war.

We first present a simple model of an open economy applying a tariff on its imports or being imposed a tariff on its exports. The authorities have a domestic objective in terms of inflation and pursue this objective through a Taylor rule.

[1] The data underlying the estimate of the average tariff can be found in Appendix B.

In general the tariffs change both the supply of and demand for the home good. Domestic producers respond by raising or lowering the home currency price of the home good, and the home monetary authorities in turn respond to the change in inflation by adjusting the nominal interest rate. Importantly, the change in the exchange rate results from the fact that the central bank pursues a domestic objective in terms of inflation and not that it tries to offset the tariffs per se (the central bank does not target the exchange rate or the trade balance). We call the fraction of the tariff that is offset by a change in the exchange rate the "exchange rate offset."

We derive closed-form expressions for the exchange rate offsets in our model in the special case where permanent tariffs are introduced in a steady state. In this case, the exchange rate jumps to a new steady state level and there are no transition dynamics. We also study the implications of alternative assumptions, such as replacing the assumption of Producer Currency Pricing (PCP) with Dominant Currency Pricing (DCP) or looking at temporary or expected tariffs. These cases give rise to transition dynamics, which we characterize and quantify in a calibrated version of the model. We find that in all cases, the exchange rate moves in a way that offsets the impact of the tariff (a tariff on imports appreciates the home currency and a tariff on exports depreciates it). The exchange-rate offset tends to be larger for a tariff on exports than for a tariff on imports, and to be larger under DCP than PCP because of exchange rate overshooting.

The second part of the paper attempts to quantify the impact of the 2018-19 US-China trade war on the US dollar and Chinese renminbi effective exchange rates. We do this following two methodologically independent approaches. First, we estimate the quantitative implications of the model when calibrated to the tariffs on the exports and imports of the US and China that were introduced in 2018 and 2019. Average tariff rates increased for both exports and imports of the U.S. and China so that it is unclear a priori whether their currencies should have appreciated or depreciated. We find that the tariffs introduced in 2018-19 should have left the effective exchange rate of the dollar broadly unchanged, but should have depreciated the renminbi by more than 3 percent. This difference reflects that the average tariff increased more for exports than for imports in China whereas the opposite is true for the US.

We then present the results of a high-frequency event study. We look at how the dollar and the renminbi responded to tariff-related news in 2018-19.[2] We construct nominal effective exchange rates (NEERs) for the US dollar and the renminbi at the ten-minute frequency and measure the impact of tariff news on these effective exchange rates at time horizons of a few hours. This exercise is model-free and provides an independent estimation of the impact of tariffs on the dollar and renminbi exchange rates.

We find that the impact of tariff news depends on whether the news were about US tariffs or Chinese tariffs. On the one hand, the estimated impact of US tariffs is quite consistent with our theoretical framework. We find that news about US tariffs appreciated the dollar and depreciated the renminbi and that their impact was larger on the renminbi than on the dollar by a factor of more than two. On the other hand, news about Chinese tariffs did not have a statistically significant impact on the dollar or the renminbi effective exchange rates.

[2] Our benchmark news sample was constructed using Bloomberg News. We also use another sample of news constructed by Bown and Kolb (2020) for robustness analysis.

Finally, we estimate the cumulative impact of tariff news on the dollar and renminbi effective exchange rates implied by our regression results. For this exercise we consider only news about US tariffs since news about Chinese tariffs were found to be statistically insignificant. We estimate that the tariff news that occurred in 2018-19 appreciated the dollar by about one percent and depreciated the renminbi by two percent. This represents more than one fifth of the dollar effective appreciation, and around two thirds of the renminbi effective depreciation observed during that period.

Literature. The paper is related to several lines of literature. On the theoretical side, Mundell (1961) made the point that tariffs could worsen the trade balance and employment because of a currency appreciation. A literature dating back to the 1980s examined the macroeconomic impact of tariffs in the context of open-economy Keynesian models (Eichengreen,1981; Krugman, 1982; Dornbusch, 1987). Ostry (1991) and Van Wijnbergen (1987) later studied the macroeconomic impact of tariffs in the context of two-period intertemporal models of the current account.

More recent papers have followed the resurgence of interest in the macroeconomic impact of tariffs (see e.g. Erceg et al, 2018, Lindé and Pescatori, 2019, or Barattieri et al, 2021).[3] Like those papers we use a New-Keynesian open-economy framework. Our main contribution relative to that literature is that we focus on the exchange rate impact of tariffs and compare the results under different assumptions about pricing (PCP and DCP).

On the empirical side, some recent papers have compared the impact of exchange rates and of tariffs on trade flows. There is evidence that trade flows are more responsive to tariffs than to exchange rate movements (see e.g. Fontagné et al, 2018, for France). Benassy-Quéré et al (2018) find that exports are more responsive to a tariff cut in the destination country than to a real depreciation of the same amount in the source country. Using impulse response functions estimated over a large sample of countries, Furceri et al (2018) find that tariffs result in real exchange rate appreciations. Barattieri et al (2021) find that the Canadian dollar appreciates in response to a temporary increase in Canadian trade barriers. There is evidence that the United States experienced complete passthrough of the recent tariffs into domestic prices of imported goods (Amiti et al, 2019 and Fajgelbaum et al, 2020). As a result Chinese exporters were significantly affected by the US tariffs (Jiao et al, 2020).

Finally, our paper contributes to a large literature on the impact of news on exchange rates (see for example Faust et al, 2006, Andersen et al, 2007, or Rogers et al, 2014). Matveev and Ruge-Murcia (2021) find that tweets by the U.S. President regarding possible tariff increases on Canadian and Mexican goods appreciated the US dollar. Blanchard and Collins (2019) measured the joint response of the Chinese and US stock markets to President Trump's China-trade-related tweets. In a closely related study, Li (2019) finds evidence that the offshore yuan depreciated relative to the dollar when the U.S. imposed or announced tariffs and appreciated when trade talks resulted in the delay of tariffs.

The paper is structured as follows. Section 2 presents the model and some calibration exercises. Section 3 quantifies the effect of tariffs on the dollar and renminbi exchange rates using two independent but complementary methods: a calibration of the model and a

[3] See Eichengreen (2019) for a review.

high-frequency event study. Section 4 concludes.

2 Theory

This section presents a model to study how the exchange rate responds to tariffs on exports and imports. The model features a generic small open economy and does not try to represent specific countries such as the US or China. Section 2.1 presents the assumptions and main equilibrium conditions. We look at the impact of permanent tariffs on imports and exports on the exchange rate in section 2.2. Section 2.3 discusses alternative assumptions.

2.1 Model

The model features a small open economy that consumes goods that are produced at home and abroad like in Gali and Monacelli (2005). The model is in continuous time and perfect foresight, and we look at the impact of unexpected tariffs introduced in a steady state. There is nominal stickiness because domestic firms must pay a cost to change their prices like in Rotemberg (1982). For the baseline model we assume that prices are set in the currency of the producer (the PCP assumption). This assumption is relaxed in section 2.3.

Households. The economy is populated by atomistic identical infinitely-lived households. The representative household has preferences represented by the utility function

$$U = \int_0^{+\infty} \left(\frac{C_t^{1-1/\epsilon_i} - 1}{1 - 1/\epsilon_i} - \frac{N_t^{1+1/\epsilon_\ell}}{1 + 1/\epsilon_\ell} \right) e^{-rt} dt, \tag{1}$$

where C_t is the level of consumption, N_t is labor, ϵ_i is the elasticity of intertemporal substitution and ϵ_ℓ is the Frisch elasticity of labor supply. Consumption is a CES index of the consumption of home good (H) and imported foreign good (F),

$$C_t = \left(\omega_H^{1/\epsilon_m} C_{Ht}^{(\epsilon_m - 1)/\epsilon_m} + \omega_F^{1/\epsilon_m} C_{Ft}^{(\epsilon_m - 1)/\epsilon_m} \right)^{\epsilon_m/(\epsilon_m - 1)}, \tag{2}$$

where $\omega_H + \omega_F = 1$. We call ϵ_m the import elasticity because it determines how the level of imports responds to change in the terms of trade.

The country is integrated to a global financial market where real bonds denominated in the foreign good and yielding a fixed return r are traded. The foreign currency price of the foreign good is exogenous and denoted by P_t^*. The home currency price of the bonds, thus, is given by $E_t P_t^*$, where E_t is the nominal exchange rate. The exchange rate is defined as the price of foreign currency in terms of home currency, so that an increase in the exchange rate means a depreciation of the home currency.

The home country applies a tariff τ_t on imports, implying that the home-currency price of the foreign good is

$$P_{Ft} = (1 + \tau_t) E_t P_t^*. \tag{3}$$

The representative household's budget constraint can be written in terms of the foreign good as

$$\dot{B}_t + \frac{P_{Ht}}{E_t P_t^*} C_{Ht} + (1 + \tau_t) C_{Ft} = \frac{W_t N_t}{E_t P_t^*} + Z_t + D_t + r B_t, \tag{4}$$

where B_t is the household's holding of real bonds, W_t is the home currency nominal wage, D_t is the profit of home firms, and Z_t is the lump-sum rebate of taxes.

Firms. The home good is a CES index of a continuum of differentiated goods indexed by $j \in [0, 1]$. Each differentiated good is produced by a monopolistic firm using a linear production function, $Y_{Hjt} = N_{jt}$. We assume an employment subsidy to correct for monopolistic distortion in production. We denote by $\pi_t = \dot{P}_{Ht}/P_{Ht}$ the rate of inflation in the price of the home good and assume that firms must pay a quadratic adjustment cost à la Rotemberg (1982) from deviating from an inflation target $\hat{\pi}$.

Under these assumptions the rate of inflation satisfies the New Keynesian Phillips curve,

$$\dot{\pi}_t = r\left(\pi_t - \hat{\pi}\right) - \alpha \left(\frac{W_t}{P_{Ht}} - 1\right) \tag{5}$$

(see Appendix A1 for the derivation). Integrating forward, the Phillips curve can be rewritten as

$$\pi_t = \hat{\pi} + \alpha \int_t^{+\infty} \left(\frac{W_{t'}}{P_{Ht'}} - 1\right) e^{-r(t'-t)} dt'. \tag{6}$$

Home producers raise their prices at a faster rate than the inflation target if their markup is expected to be lower than desired.

Demand for Home Good. The home terms of trade are equal to the price of the home good in terms of foreign good,

$$S_t = \frac{P_{Ht}}{E_t P_t^*}. \tag{7}$$

The total demand for the home good is equal to the sum of home and foreign demands for the home good

$$Y_{Ht} = C_{Ht} + \left[(1 + \tau_t^*) S_t\right]^{-\epsilon_x} M_t^*, \tag{8}$$

where M_t^* is foreign imports, τ_t^* is the tariff imposed by foreign countries on home exports, and ϵ_x is the elasticity of substitution between the home good and foreign goods in foreign markets (the export elasticity). We assume that the export elasticity is larger than 1,

$$\epsilon_x > 1. \tag{9}$$

Monetary Policy. The domestic monetary authorities implement a Taylor rule to achieve the inflation target $\hat{\pi}$,

$$i_t = r + (1 - \phi)\, \hat{\pi} + \phi \pi_t, \quad \phi > 1. \tag{10}$$

By arbitrage domestic currency bonds must yield the same return as foreign bonds. The nominal interest rate i_t must be equal to the real interest rate in terms of foreign good, r, plus the rate of inflation in the home currency price of the foreign good, $E_t P_t^* = P_{Ht}/S_t$. Hence

$$i_t = r + \pi_t - \frac{\dot{S}_t}{S_t}. \tag{11}$$

Using the Taylor rule to substitute out i_t from this equation gives,

$$\frac{\dot{S}_t}{S_t} = -\left(\phi - 1\right)\left(\pi_t - \hat{\pi}\right). \tag{12}$$

The home central bank raises the interest rate if inflation is higher than the target. Like in the Dornbusch model, this appreciates the currency and implies that it depreciates over time.

Linearized model. We derive the equilibrium conditions and linearize the model in Appendices A2 and A3. The linearized model (with first-order deviations from the steady state denoted in lower case) is as follows,

$$\begin{aligned}
c_t &= \gamma - \epsilon_i \left(\omega_H s_t + \omega_F \tau_t\right), && (13)\\
y_{Ht} &= \omega_H c_t - \omega_F \left[\omega_H \epsilon_m (s_t - \tau_t) + \epsilon_x (s_t + \tau_t^*)\right], && (14)\\
\dot{\pi}_t &= r\left(\pi_t - \hat{\pi}\right) - \alpha \left[\frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} - \omega_F \left(s_t - \tau_t\right)\right] \Bigg(&& (15)\\
\dot{s}_t &= -\left(\phi - 1\right)\left(\pi_t - \hat{\pi}\right). && (16)
\end{aligned}$$

Equation (13) characterizes the intertemporal allocation of home consumption. Consumption is lower when the terms of trade or the tariff on imports are higher. Variable γ is endogenous and must be chosen so as to satisfy the country's intertemporal budget constraint (see Appendix A3).

Equation (14) gives global demand for the home good. The demand for the home good increases with home consumption (c_t) and decreases with the relative price of the home good in home markets ($s_t - \tau_t$) and foreign markets ($s_t + \tau_t^*$).

Equation (15) is the linearized Phillips curve. The markup decreases with home production, home consumption and the price of home consumption in terms of home good. Equation (16) is the linearized version of (12).

For exogenous tariff paths $(\tau_t, \tau_t^*)_{t \geq 0}$, one can solve for the endogenous paths $(c_t, y_{Ht}, \pi_t, s_t)_{t \geq 0}$ using the system of equations (13)-(16). The question of interest is how the exchange rate responds to the introduction of tariffs. In the next section we study the case where the tariffs are permanent, and then proceed to discuss different circumstances in section 2.3.

2.2 Permanent tariffs

In this section we study the impact of permanent tariffs on imports or exports that are unexpectedly introduced in a steady-state equilibrium. Other things equal, the tariffs affect demand and supply in the market for the home good, which generates inflationary or deflationary pressures. The monetary authorities would respond to the change in inflation, if it materialized, by raising or lowering the interest rate. With constant tariffs, however, the interest rate does not need to change in equilibrium: the exchange rate immediately jumps to a level such that the economy stays in a steady state where inflation remains equal to the target. The lack of transition dynamics simplifies the model and allows us to derive closed-form expressions for the exchange rate offset.

We define the exchange-rate offset for a tariff on imports as the amount by which the home currency appreciates following the unexpected but permanent imposition of a 1 percent uniform tariff on all imports. For example, an offset of 1 means that the exchange rate appreciates one-for-one in response to the tariff, so that the net price of imports does not change at home. A tariff on imports makes them less competitive at home if and only if the exchange-rate offset is lower than one.

Setting $\pi_t = \hat{\pi}$ in the Phillips curve (15) gives

$$\frac{y_H}{\epsilon_\ell} + \frac{c}{\epsilon_i} = \omega_F \left(s - \tau \right). \tag{17}$$

In steady state the intertemporal budget constraint (A10) with $b_0 = 0$ implies

$$c = y_H + \omega_F s. \tag{18}$$

Using this expression to substitute out c in (14) and (17) gives the following two expressions for home output,

$$y_H = -\left[\epsilon_x - \omega_H (1 - \epsilon_m)\right] s + \omega_H \epsilon_m \tau - \epsilon_x \tau^*, \tag{19}$$

$$y_H = \omega_F \frac{\left(\epsilon_i - 1\right) s - \epsilon_i \tau}{1 + \epsilon_i / \epsilon_\ell}. \tag{20}$$

Equation (19) is the steady state demand for the home good. Demand is lowered by an increase in the terms of trade s, which makes the home good less competitive abroad and at home. Although this effect is partially offset by the fact that higher terms of trade raises home income and consumption, the expenditure-switching effect dominates the income effect because $\epsilon_x > 1$. Demand for the home good increases with the tariff on imports but decreases with the tariff on exports because of expenditure-switching in the home and foreign markets.

Equation (20) gives the steady state supply of home good. On the one hand, a stronger currency raises the purchasing power of the wage in terms of imports, which increases the supply of labor. On the other hand, it raises consumption, which decreases the supply of labor. The first effect dominates if and only if $\epsilon_i > 1$. Supply unambiguously decreases with the tariff on imports, which lowers the purchasing power of the wage.

Solving for s by equating demand to supply gives

$$s = \left[1 + \frac{\epsilon_x - \omega_H - \omega_F / \left(1 + \epsilon_i / \epsilon_\ell\right)}{\omega_H \epsilon_m + \omega_F \epsilon_i / \left(1 + \epsilon_i / \epsilon_\ell\right)} \right]^{-1} \tau - \left[1 + \omega_H \frac{\epsilon_m - 1}{\epsilon_x} + \omega_F \frac{\epsilon_i - 1}{\left(1 + \epsilon_i / \epsilon_\ell\right) \epsilon_x} \right]^{-1} \tau^*. \tag{21}$$

Equation (21) gives the change in the terms of trade that is caused by the unexpected introduction of tariffs τ and τ^* in a steady state. The terms of trade jump to this permanent level when the tariffs are introduced. The nominal prices of the home and foreign goods being sticky, the adjustment in the terms of trade comes from a jump in the nominal exchange rate. Denoting the log value of the exchange rate by e, it follows from equation (7) that

$$\frac{de}{d\tau} = -\frac{ds}{d\tau} \tag{22}$$

with a similar equation for τ^*. There is a negative sign because a currency appreciation corresponds to an increase in s but a decrease in e. It then follows from (21) that the exchange-rate offset for a permanent tariff on imports is

$$\frac{de}{d\tau} = -\left[1 + \frac{\epsilon_x - \omega_H - \omega_F / \left(1 + \epsilon_i/\epsilon_\ell\right)}{\omega_H \epsilon_m + \omega_F \epsilon_i / \left(1 + \epsilon_i/\epsilon_\ell\right)}\right]^{-1}. \tag{23}$$

A tariff on imports leads to an appreciation of the home currency. The tariff increases demand for the home good as it shifts home demand away from the foreign good, and reduces supply because it lowers the purchasing power of the wage in terms of imports. The currency must appreciate so as to bring demand back in line with supply.

Equation (23) implies that the magnitude of the exchange-rate offset increases with the import elasticity and decreases with the export elasticity. A larger import elasticity magnifies the impact of the tariff on home demand for the home good and requires a larger offsetting appreciation. Conversely, a larger export elasticity means that a smaller currency appreciation is required to offset the increase in demand for the home good induced by the tariff.

Similarly, one can look at the endogenous response of the exchange rate to a permanent tariff imposed on the country's exports. Because the tariff reduces foreign demand for the home good, it is offset by a depreciation (rather than an appreciation) of the home currency. Using (21) the offset coefficient is now given by,

$$\frac{de}{d\tau^*} = \left[1 + \omega_H \frac{\epsilon_m - 1}{\epsilon_x} + \omega_F \frac{\epsilon_i - 1}{\left(1 + \epsilon_i/\epsilon_\ell\right) \epsilon_x}\right]^{-1}. \tag{24}$$

If $\epsilon_m = \epsilon_i = 1$ (the Cole-Obstfeld case) the exchange-rate offset is equal to 1, i.e., the exchange rate depreciates one-for-one with a tariff on exports. This is because in this case the exchange rate affects neither home demand for the home good nor its supply.[4] The only thing that the exchange rate needs to do is to offset the impact of the tariff on *foreign* demand for the home good. This is achieved by a depreciation of the same size as the tariff. If $\epsilon_m > 1$ and/or $\epsilon_i > 1$ a depreciation increases home demand for the home good and/or reduces its supply. The depreciation then does not need to be as large as when $\epsilon_m = \epsilon_i = 1$ to bring back demand in line with supply.

[4]The impact of the exchange rate on the home demand for the home good is captured by the term in $\omega_H(1 - \epsilon_m)$ in equation (19). The impact of the exchange rate on the supply of home good is captured by the term in $(\epsilon_i - 1)$ in equation (20).

Calibration. We conclude this section by exploring the quantitative implications of equations (23) and (24) under a standard calibration of the parameters. The baseline calibration is given in Table 1. The parameters that determine the exchange rate offsets are the weight of the home good in home consumption, ω_H, and the elasticities ϵ_i, ϵ_m, ϵ_x and ϵ_ℓ.

We assume $\omega_H = 0.85$, which is approximately equal to one minus the share of imports in GDP in the US. We assume a logarithmic utility ($\epsilon_i = 1$). The elasticities for imports and exports are taken from Feenstra et al (2018).[5] We adopt a Frisch elasticity of labor supply of $\frac{1}{3}$.

With these values, the exchange-rate offset implied by equation (23) for a uniform tariff on all imports is 0.296, i.e., a ten percent tariff on imports appreciates the currency by about 3 percent. Since $\epsilon_i = \epsilon_m = 1$ the exchange-rate offset for a tariff on exports is 1. The exchange rate impact of a tariff, thus, is more than three times larger if the tariff is on exports than if it is on imports.

The last three columns of the Table 1 report the values of the real interest rate, the coefficient on inflation in the Taylor rule and the markup coefficient in the Phillips curve. These parameters do not appear in equations (23) and (24) but they are necessary to compute the transition dynamics of the model, which play a role in the extensions of the model presented in the next section. We assume a real interest rate of 5 percent. The Taylor rule puts a weight of 1.5 on inflation. The value for α ensures that the Phillips curve has the same slope as in the Calvo model where firms can change their price every year on average.[6]

Table 1: Calibration

ω_H	ϵ_i	ϵ_ℓ	ϵ_m	ϵ_x	r	ϕ	α
0.85	1	1/3	1	3	0.05	1.5	1.05

2.3 Alternative assumptions

We discuss the sensitivity of our results to changes in the assumptions.

Transitory or expected tariffs. What is the impact of transitory or expected tariffs? In Appendix A4 we analyze the case where the tariffs τ and τ^* are applied during a limited period T, or are announced at time 0 but implemented at a future time T. In both cases the economy settles in a steady state at time T. Before time T there are transition dynamics in which the country accumulates foreign assets or liabilities.

The tariff on imports acts as an intertemporal tax that decreases home consumption when it is applied. If $\epsilon_m = \epsilon_i$ (which is true under our benchmark calibration) the intertemporal

[5] These authors find that the price elasticity between the goods exported by different countries is significantly higher than the elasticity between home goods and imports in a given country. Their estimates for the import elasticity are close to 1 whereas those for the export elasticity are close to 3.

[6] In the continuous time Calvo model the Phillips curve is given by (5) with $\alpha = \phi(r + \phi)$ where ϕ is the flow probability that a firm can change its price. If the average duration of sticky prices is one year, then $\phi = 1$, which gives $\alpha = 1.05$.

effect and the expenditure switching effect exactly offset each other so that demand for home goods is constant over time. In this case, there are no transition dynamics in inflation or the nominal interest rate and the exchange rate jumps to a constant level in period 0.

Transitory or expected tariffs on exports always give rise to transition dynamics. The central bank responds to inflation deviating from the target by changing the interest rate, which leads the exchange rate to overshoot or undershoot the long-run adjustment. With a transitory tariff on exports, home producers respond to lower demand by adjusting their prices downward. The home central bank lowers the interest rate which depreciates the currency more in the short run than in the long run (overshooting). By contrast an expected tariff on exports stimulates the demand for the home good before the tariff is introduced. The central bank raises the interest rate to tackle inflation, which mitigates the exchange rate depreciation (undershooting).

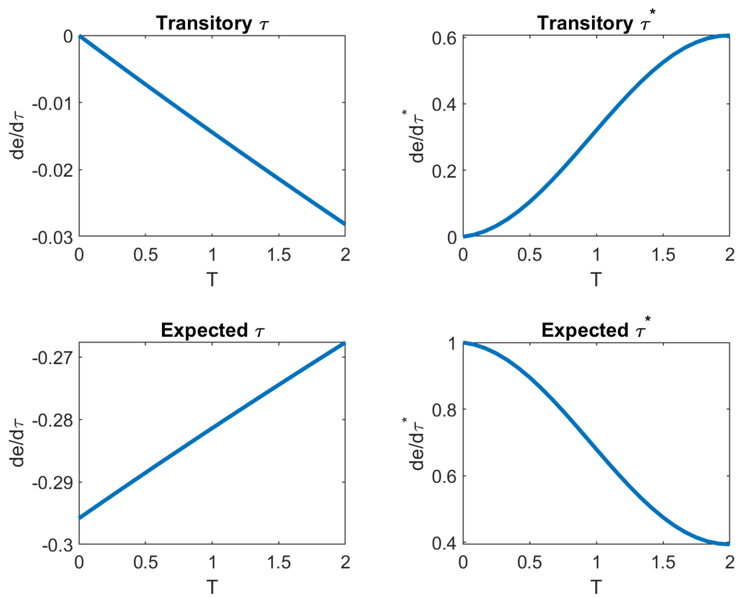

Figure 2: Variation of exchange rate offset with T

Figure 2 shows how the exchange rate offset varies with T.[7] The upper panels show the case of transitory tariffs on imports (left-hand-side panel) and on exports (right-hand side panel). As expected, transitory tariffs have a smaller impact than permanent tariffs. The exchange rate impact of tariffs on imports is reduced by a factor of ten if they are expected to last two years instead of being permanent. By contrast, the exchange rate impact of a tariff on exports is reduced by a factor of less than two. This difference is explained by overshooting in the case of a tariff on exports.

The lower panels of Figure 2 report our results for expected tariffs. They show how the exchange-rate offset varies with the lag between the announcement and the imposition of the tariff. The case $T = 0$ corresponds to the permanent tariffs analyzed in the previous

[7] A range of 2 years was used for T because the empirical exercises presented in Section 3 uses 2 years of data.

section. We observe that the impact of an expected tariff on imports does not decrease very fast with the lag. A tariff on exports, by contrast, loses more of its impact if it is delayed because of undershooting.

Dominant Currency Pricing (DCP). The baseline model assumes producer currency pricing (PCP). Gopinath (2016) argues that a more realistic assumption for many countries is that the prices of imports and exports are fixed in terms of foreign currency (mostly the US dollar).

How does DCP change our results about the exchange rate offset? With DCP there are different Phillips curves for the home and foreign markets for the home good. Even with permanent tariffs, it is no longer possible to have producers achieve their desired markups in both markets simultaneously by letting the exchange rate adjust to a new constant level when constant tariffs are introduced. We characterize the transition dynamics in Appendix A5 and summarize the main results here.

A permanent tariff on imports raises the demand for the home good at home. Home producers raise their prices both in home currency in the home market and in dollar in exports markets. The increase in home inflation leads the monetary authorities to raise the local currency interest rate. As a result, the home currency appreciates by more under DCP than under PCP. This is because the increase in the home interest rate leads the exchange rate to overshoot in the short run. Under our benchmark calibration this increases the exchange rate offset for a tariff on imports to 0.35 (instead of 0.30 under PCP).

The exchange rate offset for a permanent tariff on exports is also higher under DCP than under PCP, and for similar reasons. The tariff on exports reduces foreign demand for the home good, leading home producers to decrease their prices at home and abroad and to a relaxation of home monetary policy. The home currency now overshoots in the direction of depreciation. Under our benchmark calibration the exchange rate offset is 1.22 for a tariff on exports (instead of 1.0 under PCP).

The results that we have just described apply to a small open economy that does not use the dollar as its own currency. The impact of tariffs under DCP is different, and more complicated to analyze, in the case of the US. One can no longer maintain the small open economy assumption in this case because changes in the dollar exchange rate affects trade flows and consumption in the rest of the world.[8] We summarize the analysis of the US case under DCP in Appendix A5 and give further details in Appendix C. The upshot is that the exchange rate offsets are also larger than under PCP and about the same as when the home economy is not the US (0.35 for a tariff on imports and 1.19 for a tariff on exports).

To summarize the analysis so far, the imposition of a tariff on imports leads to an appreciation of the home currency and a tariff on exports has the opposite effect. Under PCP the exchange-rate offset is 30 percent for a permanent tariff on imports and 100 percent for a permanent tariff on exports for our benchmark calibration. The exchange rate offsets are

[8]The issue is not that the US is a large economy, it is that the dollar is used to invoice trade between all countries. A multilateral dollar appreciation reduces trade flows and consumption in the rest of the world. Hence, global imports and the global real interest rate cannot be taken as exogenous to the dollar effective exchange rate.

lower for temporary or expected tariffs and somewhat higher under DCP than under PCP.

3 Tariffs, the Dollar and the Renminbi

This section quantifies the impact of the US-China trade war on the dollar and renminbi. The renminbi depreciated against the dollar by 7.0 percent in 2018-19. As shown by Figure 3, this reflected both a 4.2 percent effective appreciation of the dollar and a 3.1 percent effective depreciation of the renminbi. To which extent can these developments be explained by the tariffs introduced by the US, China and their trading partners in 2018-19?

We answer this question following two complementary but independent approaches. First, in section 3.1 we calibrate the model presented in the previous section to the tariffs imposed by and on the US and China. This exercise has obvious limitations as the model was not constructed to fit the US or Chinese economy but as we argue below, it is nevertheless useful to think about the impact of tariffs on those countries' economies. We then study the exchange rate impact of tariffs using high-frequency news about tariffs during the period 2018-19 in section 3.2. Our findings confirm that the trade war significantly depreciated the renminbi but had little impact on the dollar.

3.1 Calibration

In this section we estimate the average tariffs on imports and exports for the US and China, and then use equations (23) and (24) to derive their impact on the dollar and the renminbi predicted by the model under the calibration of Table 1. This exercise should be viewed as illustrative since the model was meant to represent a generic small open economy rather than the US or Chinese economy.

There are several discrepancies between the model and reality that one might be concerned about. First, the small open economy assumption is objectionable when applied to the US and Chinese economies.[9] Second, our model assumes that the entirety of international trade is in final goods. This is not true in the data, although most of US and Chinese exports are indeed composed of final goods.[10] A tariff is likely to have a larger impact on the exporting country if that country has a smaller share of domestic value added in gross exports. This is likely to amplify the exchange rate impact of tariffs for China relative to the US. Finally, the assumption that the central bank uses a Taylor rule in an environment of free capital mobility is another simplification, especially for China. However, we would observe that it is closer to reality now that China has relaxed the restrictions on its capital account and made

[9] Taken together, the US and Chinese economies amount to about one third of global GDP (34.1% in 2020 according to the PPP-adjusted data in the October 2020 World Economic Outlook database). This is large but not to the extent that a two-country model would be more realistic than a small open economy model.

[10] The share of final goods (total goods net of intermediate goods) in exports are 82.6% and 78.2% respectively for the US and China in 2018 according to the World Integrated Trade Solution (WITS) database. The share is lower in China because of its involvement in the global value chain but it has been steadily increasing over time.

its exchange rate more flexible.

We calibrate the model using the tariffs implemented by and on the US and China in 2018-19. Tables B1 to B4 in Appendix B report the list of the US and Chinese tariffs that we use in the calibration.

Since the beginning of 2018, the US administration has imposed tariffs on various goods such as solar panels, washing machines, steel and aluminum, and on various grounds such as safeguarding domestic industries, national security threats, and unfair trade practices. Most of the US tariffs, however, were imposed in the context of the trade war with China, based on alleged Chinese unfair trade practices for technology and intellectual property. As reported in Table B1, the tariffs introduced by the US in 2018-19 amounted to 3.7 percent of the value of US imports of goods on average. Most of the tariffs (3.3 percent) were imposed on goods from China. This number is much smaller than the headline tariff rates (which varied between 15 and 25 percent, as reported in Table B1) because it is an average taken over all US imports. The share of China in US imports was 21.9 percent in 2017 and one third of this amount was not subjected to new US tariffs in 2018-19.

The rest of the world imposed countervailing tariffs on the US. For example, the EU imposed an average tariff of 25 percent on \$3.2 billion of US goods in retaliation to the steel and aluminium tariffs. Turkey and India also retaliated, imposing an average tariff of 13 percent and 10 percent on \$1.6 billion and \$1.3 billion of US goods respectively (see Table B2 in Appendix B). Like for imports, however, most of the tariffs on US exports came from the trade war with China. We find that the average tariff on US exports amounted to 1.3 percent, almost entirely due to the Chinese tariffs. Although the headline tariff rates imposed by China on US exports were high, the average tariff on US exports was much lower because the US sends only 10 percent of its exports to China.

In summary, we estimate the average tariff rates to be $\tau = 3.7\%$ and $\tau^* = 1.3\%$ for the US. The implications of these values for the dollar are reported in the second row of Table 2. The third column reports the multilateral appreciation of the dollar caused by the tariff on imports, as predicted by the model under the calibration of Table 1. The fifth column reports the dollar depreciation caused by the tariffs on US exports and the last column reports the net impact. These estimates are calculated by multiplying the exchange rate offsets from equations (23) and (24) by the average tariffs reported in the second and fourth columns. Under the benchmark calibration, the dollar should appreciate by 0.3 percent for each percent of tariff on imports and depreciate by 1 percent for each percent of tariff on exports.

Table 2 shows that according to the model, the tariffs introduced in 2018-19 had virtually no impact on the dollar because the tariffs on imports and the tariffs on exports offset each other. The tariffs on US exports were about three times smaller than the tariffs on US imports but the exchange rate is about three times more sensitive to a tariff on exports than a tariff on imports, according to the model.

The third row of Table 2 reports the results of the same exercise conducted for the renminbi.[11]

[11] For China we set the value of ω_H to 0.81, which is approximately equal to one minus the share of imports in Chinese GDP.

The average tariffs on Chinese imports and exports were computed in the same way as for the US (details can be found in Appendix B). The Chinese average tariff rates are the mirror image of the US tariffs, in the sense that the tariffs on Chinese exports are more than three times larger than the tariffs on Chinese imports. The exchange rate being more sensitive to tariffs on exports than to tariffs on imports, the model unambiguously predicts an effective depreciation of the renminbi, to the tune of 3.2 percent.

Remark. Let us conclude this section with a remark about how the tariffs are averaged. In the context of the US-China trade war the US administration imposed tariffs on predetermined dollar amounts of imports from China. For example, in the summer of 2018 it decided to impose a 25 percent tariff on \$50bn of Chinese goods. This was achieved by imposing the tariff on a list of goods whose import from China had amounted to \$50bn in the previous year (2017). Thus, in Tables B1 to B4 we compute the average tariff on US imports by taking the average of the tariffs weighted by the 2017 import values.

Because the tariff is averaged over import values that were observed before the tariff was imposed, it does not take into account the fact that US importers substituted away from the goods that were subjected to the tariffs. We estimate the resulting bias in Appendix A6, and find that the effective tariff rates are between one fourth and one third lower than the simple averages that we have used for Table 2. The exchange rate impact of tariffs should accordingly be reduced by one fourth to one third if one takes that effect into account.[12]

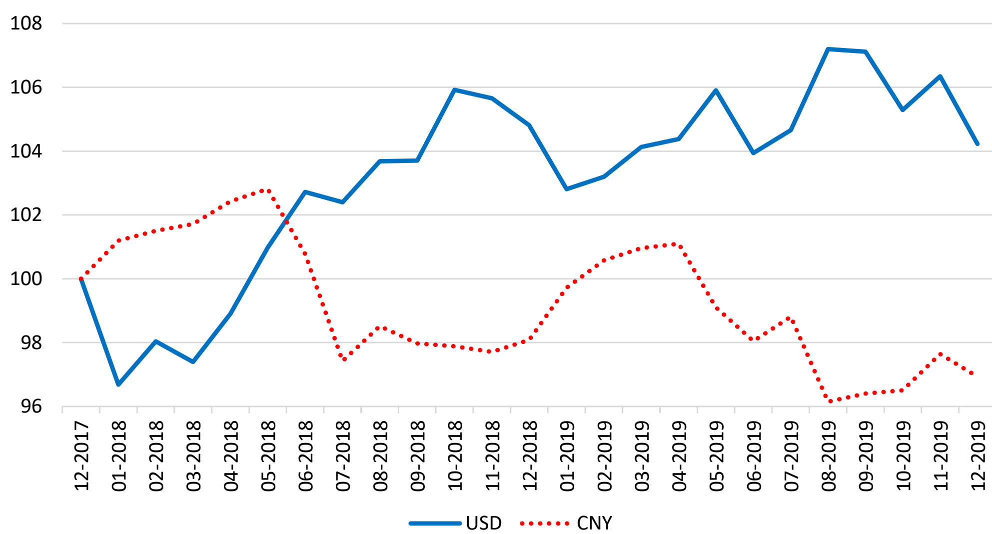

Figure 3: End-of-month USD and CNY effective exchange rates (Dec. 2017=100, Source: BIS). An increase in the index means an effective appreciation of the currency.

[12]Assuming DCP would lead to an adjustment in the opposite direction. If we assume both substitution effects and DCP, the model-predicted impact of tariffs on the dollar and reminbi effective exchange rates are -0.1 and -3.0 percent respectively, almost the same as the estimates reported in Table 2.

Table 2: **Impact of tariffs on dollar and renminbi effective exchange rates**

	Tariff on imports, τ	Appreciation due to τ	Tariff on exports, τ^*	Depreciation due to τ^*	Net appreciation
Dollar	3.7%	1.1%	1.3%	1.3%	-0.2%
Renminbi	1.0%	0.3%	3.5%	3.5%	-3.2%

3.2 News

This section investigates the impact of news about US and Chinese tariffs on the dollar and renminbi effective exchange rates. As usual in the news literature, we use high frequency data to identify the causal impact of the news on the exchange rate. Our main sample of tariff news was constructed using Bloomberg News. Bloomberg News Search was used to identify news related to the tariff war between the US and China and record the exact time of their release.[13] We kept only the news related to the imposition of tariffs by the US on China or by China on the US. For reasons explained in the previous section, we expect the dollar and the renminbi to have been moved by the tariffs between these two countries much more than by sectoral tariffs (on steel, solar panels, etc.) or by tariffs imposed by third countries.

Even with this narrow definition we obtained a relatively large sample of 112 pieces of news, which over two years implies a frequency of about one event per week on average. The news were mainly announcements of future trade policies, with some news headlining changes in the US-China trade relation. The source of these announcements varied: some were official statements by the US or Chinese government, others were tweets by the US president. The news were spread relatively evenly over time in 2018 and 2019. We then classified the news according to whether the tariff-imposing country was the US or China, and whether the news were about an increase or a decrease in tariffs. The news were relatively evenly distributed between these categories, although there were more news about US tariffs than Chinese tariffs, and news tended to be more about tariff increases than decreases.

The impact of the tariff news on the exchange rate was then measured first by regressing the change in the yuan per dollar exchange rate on dummy variables for the tariff news in non-overlapping time windows of different lengths (one, two, three, four and five hours). The regression specification is

$$\frac{E_t - E_{t-k}}{E_{t-k}} = \alpha + \beta_u U_t + \beta_c C_t + \varepsilon_t, \tag{25}$$

where E_t is the offshore CNH/USD exchange rate at time t, k is the length of the time window, and U_t and C_t are dummy variables for news about US tariffs and Chinese tariffs respectively. The dummy variables U_t and C_t take value 1 (-1) if there were news about a tariff

[13] The Bloomberg Terminal categorizes Bloomberg News by topics and by importance. One category is "Trade Tariffs, Wars" and the label "Hot" is attached to breaking news headlines with global impact as determined by editorial judgement. We used both sets of keywords, "Trade Tariffs, Wars" and "Hot," to identify the news in our sample. Bloomberg usually reports the news within two minutes after being released by an official source.

increase (decrease) during the time window $(t-k, t)$, and value 0 otherwise. The regression was run with 2018-19 data on the CNH/USD exchange rate at the ten-minute frequency. We used the offshore exchange rate rather than its onshore counterpart (CNY/USD) because the latter is not traded during the day in US time, when most of the news took place.[14]

The results are reported in the first row of Figure 4. The figure shows how the point estimates of β_u and β_c in regression (25) vary with the length of the time windows reported on the horizontal axis. The dashed lines show the 95 percent confidence intervals. Two results stand out. First, the renminbi depreciates against the dollar in response to an increase in US tariffs on Chinese exports. This effect is statistically significant at all horizons and seems quite persistent. The reminbi depreciates by about 0.2 percent after 5 hours. Second, and by contrast, the Chinese tariffs do not have a statistically or economically significant impact on the bilateral exchange rate.

Do these results reflect that the dollar appreciated or that the renminbi depreciated in response to tariff news? To answer this question we look separately at the nominal effective exchange rates (NEERs) of the dollar and the renminbi. We run regression (25) where E_t is now the NEER of the dollar or the renminbi. This is more consistent with the model presented in section 2, which makes predictions about the NEER of a small open economy rather than bilateral exchange rates.

We constructed high frequency series for the NEERs of the dollar and the renminbi with pared-down versions of the currency baskets used by the Bank for International Settlements (BIS) for its NEER daily series.[15] The NEERs are measured in such a way that an increase in the NEER corresponds to an effective appreciation of the currency. The regression results are reported in the second and third rows of Figure 4 for the dollar NEER and the renminbi NEER respectively for the same one to five hour time windows.

The second row of Figure 4 shows that news about US tariffs lead to an effective appreciation of the dollar, as predicted by theory. This response builds up over time and is statistically significant for all horizons. By contrast, news related to Chinese tariffs have no statistically significant impact on the dollar.

The third row of Figure 4 shows that the renminbi significantly depreciates following news of an increase in US tariffs, also consistent with theory. This effect is, again, statistically significant for all time windows. The impact of news about US tariffs is about three times larger for the reminbi than for the dollar.

The response of the bilateral exchange rate to US tariff news shown in the first row of Figure 4, thus, reflects both an effective depreciation of the renminbi and an effective appreciation

[14] We do not have exchange rate data from Friday 5:00pm to Sunday 4:50pm US eastern time because currency markets are closed on weekends. Thirteen pieces of news in our sample occurred during weekends. In our benchmark regression we treat weekends as if they were ten-minute intervals. In the robustness exercises at the end of this section we run regression (25) for weekends and weekdays separately and find similar results.

[15] Our currency baskets are composed of the top-ten currencies used in the BIS baskets. The BIS uses much broader baskets of 51 currencies. We limited ourselves to the top ten currencies because of limitations in the availability of high-frequency exchange rate data for the large number of currencies in the BIS basket. Our currency baskets are described in more detail in Appendix C2.

of the dollar, though the magnitude of the depreciation of the renminbi is larger. This is consistent with the calibrated model, which predicted a larger impact of tariffs on the renminbi than on the dollar. News related to Chinese tariffs have no statistically significant effect on the renminbi NEER. Thus, the Chinese tariffs do not seem to affect bilateral or multilateral effective exchange rates. Perhaps this is due to the fact that the Chinese authorities resisted the depreciation of the renminbi induced by their own tariff announcements.

We estimate the cumulative impact of tariff news in 2018-19 by adding up the impact of all the news observed in those two years. We implement this exercise using only news about US tariffs.[16] We measure the impact of increasing US tariff news by averaging the estimated β_u over the 3, 4 and 5 hour time windows. Based on this estimate, each piece of news appreciated the dollar NEER by about 0.08 percent and depreciated the CNH NEER by about 0.17 percent (see Figure 4). Cumulatively, the US tariff news resulted in a 0.9 percent appreciation of the USD NEER and a 2.0 percent depreciation of the CNH NEER over 2018-19. This estimated impact is not negligible if one compares it with the 4.2 percent multilateral appreciation of the US dollar and 3.1 percent multilateral depreciation of the renminbi observed in 2018-19. According to this computation, the US tariff news explain 65 percent of the renminbi depreciation and 22 percent of the dollar appreciation observed in 2018-19.

We would not necessarily expect our news-based analysis and the calibrated model to provides the same estimates for the exchange rate impact of tariffs. On one hand, the news analysis could underestimate the impact of tariffs as our news sample probably does not capture all the events that affected market participants' beliefs and expectations. On the other hand, the news might contain information unrelated to tariffs such as an increase in the likeliness of a war or increased global political uncertainty. It is nevertheless interesting to observe that the two approaches yield broadly consistent results. For the sake of comparison, Table 3 reports the appreciation of the dollar and the renminbi observed in 2018-19 (first row), the results of the calibrated model (second row), and the estimates from the event study analysis (third row). For the model predictions and event study analysis we consider only the US tariffs (which explains why the model predictions are not the same as in Table 2). The signs and orders of magnitude of the effects are broadly similar in the model and the news analysis.

Table 3: Comparison of theory and empirics

	Dollar	Renminbi
Observed	4.2%	-3.1%
Model	1.1%	-3.5%
News	0.9%	-2.0%

Robustness. Our empirical results are robust to a number of changes in the data or regression specifications.[17] First, we used a different source, Bown and Kolb's (2020) trade

[16] We leave Chinese tariff news aside since our regressions show that their impact is not statistically significant.

[17] More details about the robustness exercises summarized here can be found in Appendix C4.

war timeline, to identify tariff related news. This led to a different news sample (hereafter the BK sample) which is described in more detail in Appendix C3. There is some overlap but also differences between the two samples of news. About thirty percent of the news in the BK sample are not in the Bloomberg sample. Some news are in both samples but appear with different timing if they were reported by sources other than Bloomberg News first.[18]

The empirical results using the BK sample turned out to be almost the same as those using Bloomberg News. US tariff news appreciate the USD NEER and depreciate the CNH NEER and the results are statistically significant for all time windows except for the 3 hour and 4 hour time windows for the USD NEER. Chinese tariff news have no statistically significant impact on the USD NEER and CNH NEER at all time windows. One might have expected the impact of news to be larger with the BK sample, which includes fewer and more selective news data than the Bloomberg sample. However, this is not the case—the magnitude of the exchange-rate impact of tariff news is similar with the two samples.

We also checked for differences between weekdays and weekends in the impact of tariff news. We ran separate regressions for weekday and weekend news.[19] The results were similar to those obtained before for both currencies and for all time windows. We also tested for an asymmetry between increasing and decreasing tariffs by using separate dummies for each type of event. We did not find any evidence of asymmetry.

Finally we ran the regression using overlapping time windows and the Newey-West standard errors to correct for the bias in statistical significance caused by the autocorrelation of observations. Again, the results were close to our benchmark results for both currencies and for all time windows. US tariff news statistically significantly appreciate the dollar and depreciate the renminbi. Chinese tariff news have no statistically significant effect on both currencies.

4 Conclusions

This paper started with the observation that the tariffs implemented by the US in 2018-19 were partially offset by a concomitant depreciation of the renminbi against the dollar. We presented a calibrated model in which the depreciation of the reminbi results from the tariffs. Our model furthermore suggests that tariffs may explain a substantial fraction of the changes in the renminbi effective exchange rate observed during that period. This result is robust to various changes in the assumptions of the model.

The simple textbook model on which these conclusions are based does not incorporate all the relevant channels, for example the global supply chain disruption induced by the tariffs. It is not clear, however, how these other channels would change the results. Tariffs are similar to a negative productivity shock for the firms involved in the global supply chain.

[18] Bown and Kolb (2020) report only the day of the event. We use the Bloomberg Terminal to find the release time of the first news about the event, which includes news sources such as Twitter, Dow Jones news, reports from the ministry of commerce in China as well as Bloomberg News.

[19] We regress the rate of change in the NEER between Friday 16:50 and Sunday 17:00 on a constant and dummies that take non-zero values if there were news during this time interval.

Other things equal, tariffs should depreciate the currencies of the countries that own the production factors (both capital and labor) used in the global supply chain. This is an interesting question left for further research.

On the empirical side, we looked for evidence of an impact of tariff news on the dollar and the renminbi using a high-frequency event study. We found that US tariffs had a statistically significant impact on the dollar and the renminbi. Approximately 22 percent of the dollar appreciation and 65 percent of the renminbi depreciation observed in 2018-19 can be ascribed to the tariffs implemented by the US (at least through the channels considered in this paper). By contrast, we found that tariffs implemented by China did not have a significant impact on the dollar or the renminbi. The order of magnitude of these effects is consistent with the model predictions.

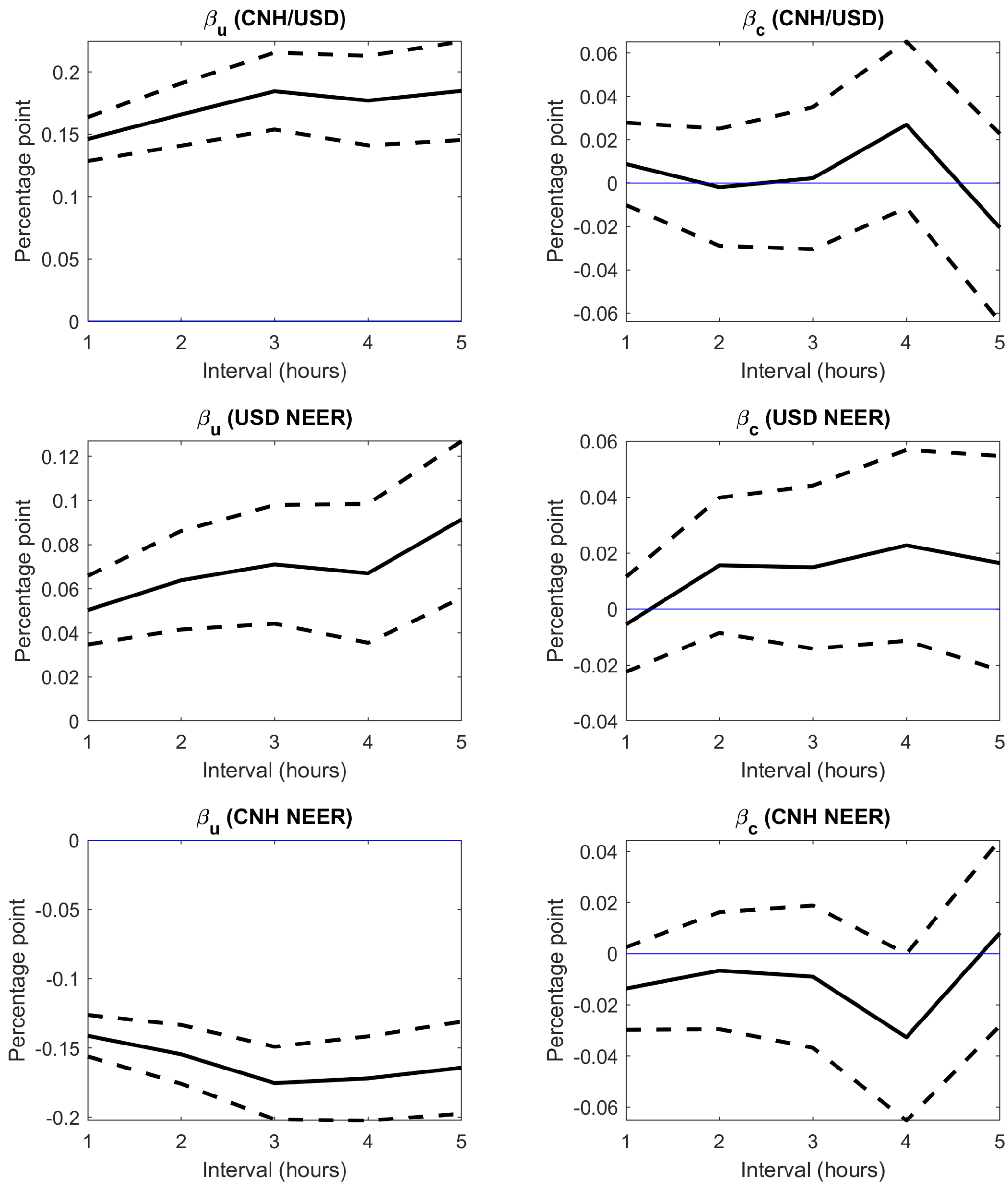

Figure 4: β_u (left-hand side panel) and β_c (right-hand side panel) for CNH/USD (first row), USD NEER (second row) and CNH NEER (third row)

Appendix A. Model Solution

A1. Phillips curve.

As mentioned in the text, the home good is a CES index of a continuum of varieties $j \in [0, 1]$ produced by monopolists. Each firm j chooses its price to maximize the present discounted value of its profits net of the price adjustment cost,

$$\int_0^{+\infty} \exp\left(-\int_0^t i_{t'} dt'\right)\left[\Pi_t(P_{jt}) - \Theta_t\left(\frac{\dot{P}_{jt}}{P_{jt}}\right)\right] dt.$$

The firm's nominal profit and adjustment cost are respectively given by

$$\Pi_t(P_{jt}) = P_{jt}\left(\frac{P_{jt}}{P_{Ht}}\right)^{-\varepsilon} Y_{Ht} - (1 - 1/\varepsilon)\, W_t \left(\frac{P_{jt}}{P_{Ht}}\right)^{-\varepsilon} Y_{Ht}, \tag{A1}$$

and

$$\Theta_t\left(\frac{\dot{P}_{jt}}{P_{jt}}\right) = \frac{\theta}{2}\left(\frac{\dot{P}_{jt}}{P_{jt}} - \hat{\pi}\right)^2 P_{Ht} Y_{Ht},$$

where $\hat{\pi}$ is the target inflation rate, ϵ is the elasticity of substitution between the varieties of home good, and θ is the price adjustment cost parameter. Equation (A1) includes a subsidy on the firm's labor cost to correct the monopolistic distortion.

Firms optimally choose prices, resulting in the Phillips Curve

$$(\pi_t - \hat{\pi})\left(i_t - \pi_t - \frac{\dot{Y}_{Ht}}{Y_{Ht}}\right) = \alpha\left(\frac{W_t}{P_{Ht}} - 1\right) + \dot{\pi}_t, \tag{A2}$$

where α is defined by,

$$\alpha \equiv \frac{\epsilon - 1}{\theta}.$$

Using (11) to substitute out the interest rate from the Phillips curve gives

$$(\pi_t - \hat{\pi})\left(r - \frac{\dot{S}_t}{S_t} - \frac{\dot{Y}_{Ht}}{Y_{Ht}}\right) = \alpha\left(\frac{W_t}{P_{Ht}} - 1\right) + \dot{\pi}_t.$$

The product $(\pi_t - \hat{\pi})\left(\frac{\dot{S}_t}{S_t} + \frac{\dot{Y}_{Ht}}{Y_{Ht}}\right)$ is dropped because it is second order, whence the Phillips curve (5).

A2. Equilibrium conditions

The optimal allocation of home consumption between the home and foreign goods is given by

$$C_{Ht} = \omega_H\left(\frac{P_{Ht}}{P_t^c}\right)^{-\epsilon_m} C_t = \omega_H\left[p_H\left(\frac{S_t}{1 + \tau_t}\right)\right]^{-\epsilon_m} C_t, \tag{A3}$$

$$C_{Ft} = \omega_F \left(\frac{P_{Ft}}{P_t^c}\right)^{-\epsilon_m} C_t = \omega_F \left[p_F \left(\frac{S_t}{1+\tau_t}\right)\right]^{-\epsilon_m} C_t, \tag{A4}$$

where

$$P_t^c = (\omega_H P_{Ht}^{1-\epsilon_m} + \omega_F P_{Ft}^{1-\epsilon_m})^{1/(1-\epsilon_m)},$$

is the CPI, and

$$\begin{aligned} p_H\left(\frac{S_t}{1+\tau_t}\right) &= \left[\omega_H + \omega_F \left(\frac{S_t}{1+\tau_t}\right)^{\epsilon_m - 1}\right]^{1/(\epsilon_m-1)}, \\ p_F\left(\frac{S_t}{1+\tau_t}\right) &= \left[\omega_H \left(\frac{S_t}{1+\tau_t}\right)^{1-\epsilon_m} + \omega_F\right]^{1/(\epsilon_m-1)}, \end{aligned}$$

are respectively the prices of the home and foreign goods in term of home consumption.

Solving for the optimal household choices of consumption and labor supply gives the Euler equation,

$$\frac{d}{dt}\left[u'(C_t)\frac{1}{1+\tau_t} p_F\left(\frac{S_t}{1+\tau_t}\right)\right] = 0, \tag{A5}$$

and the labor supply condition,

$$\frac{W_t}{P_t^c} = \frac{N_t^{1/\epsilon_\ell}}{u'(C_t)}. \tag{A6}$$

The balance of payment (BoP) identity is

$$\dot{B}_t = (1+\tau_t^*)^{-\epsilon_x} S_t^{1-\epsilon_x} M_t^* - \omega_F p_F \left(\frac{S_t}{1+\tau_t}\right)^{-\epsilon_m} C_t + r B_t. \tag{A7}$$

The balance of payment identity is derived from (4), (7), (8), (A4), $Y_{Ht} = N_t$ and

$$\begin{aligned} Z_t &= \tau_t C_{Ft} - \frac{1}{\epsilon}\frac{W_t Y_{Ht}}{E_t P_t^*} + \Theta_t(\pi_t)\frac{1}{E_t P_t^*}, \\ D_t &= \left[P_{Ht} Y_{Ht} - \frac{\epsilon - 1}{\epsilon} W_t Y_{Ht} - \Theta_t(\pi_t)\right]\frac{1}{E_t P_t^*}. \end{aligned}$$

The cost of adjusting prices is a transfer to households so that it does not affect the country's budget constraint.

A3. Linearization

We linearize the model around the steady state with $M^* = \omega_F$, $B = 0$, and $\tau = \tau^* = 0$. It is easy to see that the equilibrium conditions are satisfied for the following values,

$$S = C = Y_H = N = 1,$$

and $i = r + \hat{\pi}$.

First-order deviations from steady state are denoted with lower-case letters. The level of foreign assets B_t is first-order but for notational consistency we redenote it with a lower-case letter, $b_t = B_t$. Linearizing the Euler equation (A5) gives,

$$\frac{d}{dt}(c_t + \epsilon_i(\omega_H s_t + \omega_F \tau_t)) = 0, \tag{A8}$$

which implies (13).

Using (A3) to substitute out C_{Ht} in (8) and linearizing gives equation (14).

Linearizing the BoP identity (A7) gives:

$$\begin{aligned} \dot{b}_t &= -\omega_F \left[c_t + \omega_H \epsilon_m (s_t - \tau_t) + \epsilon_x (s_t + \tau_t^*) - s_t\right] + r b_t, \\ &= y_{Ht} - c_t + \omega_F s_t + r b_t, \end{aligned} \tag{A9}$$

where the second line was derived by using (14). Integrating this equation forward and using the transversality condition gives the intertemporal budget constraint,

$$b_0 + \int_0^{+\infty} \left(y_{Ht} - c_t + \omega_F s_t\right) e^{-rt} dt = 0. \tag{A10}$$

The labor supply condition (A6) and $Y_{Ht} = N_t$ imply

$$\begin{aligned} \frac{W_t}{P_{Ht}} &= \frac{P_t^c}{P_{Ht}} \frac{N_t^{1/\epsilon_\ell}}{u'(C_t)}, \\ &= \frac{1}{p_H\left(S_t/(1+\tau_t)\right)} \frac{Y_{Ht}^{1/\epsilon_\ell}}{u'(C_t)}, \\ &\approx 1 + \frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} - \omega_F\left(s_t - \tau_t\right). \end{aligned}$$

Using the last expression to substitute out W_t/P_{Ht} in (5) gives (15).

A4. Transitory and expected tariffs.

We now assume that the tariff rates can change at some time T,

$$\tau_t = \tau_0 \text{ for } t < T \text{ and } \tau_t = \tau_T \text{ for } t \geq T,$$

and a similar assumption for τ_t^*. This specification allows us to study the impact of a transitory tariff ($\tau_0 > 0$ and $\tau_T = 0$) or an expected tariff ($\tau_0 = 0$ and $\tau_T > 0$).

We solve for the equilibrium as follows. From T onwards the economy is in a steady state as characterized above. This steady state can be derived conditional on b_T.

Equation (A8) implies

$$c_t + \epsilon_i(\omega_H s_t + \omega_F \tau_0) = c_T + \epsilon_i(\omega_H s_T + \omega_F \tau_T) \tag{A11}$$

for $t < T$. We can derive the paths for s_t, π_t before T by shooting backwards on equations (15) and (16), using (14) and (A11) to substitute out y_{Ht} and c_t, and using the fact that s_t and π_t are continuous at time T, and $\pi_T = \hat{\pi}$. Finally, we derive b_T from the intertemporal budget constraint

$$b_0 = \omega_F \int_0^T \left[c_t + \omega_H \epsilon_m (s_t - \tau_t) + \epsilon_x (s_t + \tau_t^*) - s_t\right] e^{-rt} dt + e^{-rT} b_T.$$

We numerically solve for the value of b_T that satisfies this equation for $b_0 = 0$. We then derive the paths for c_t, s_t, e_t, y_{Ht}, π_t, and b_t.

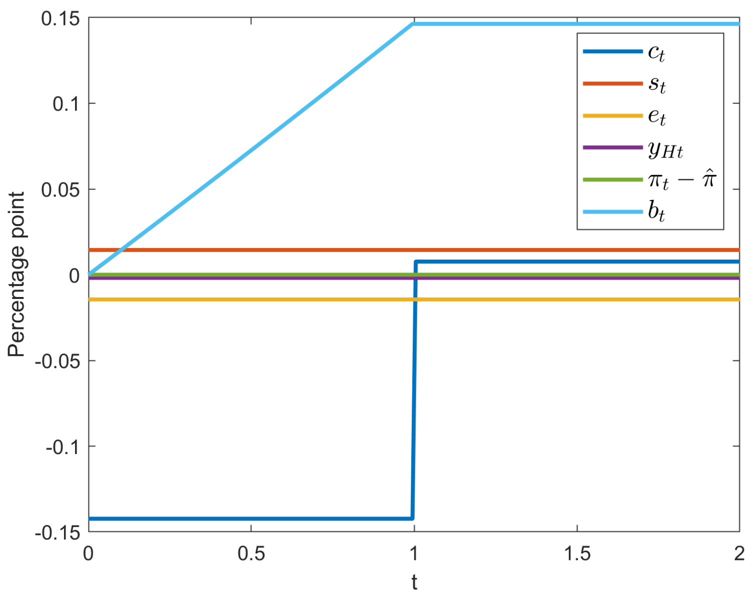

Figure A1: Transitory 1 percent tariff on imports

Figures A1 and A2 show the paths of c_t, s_t, e_t, y_{Ht}, π_t, and b_t when $T = 1$ for the transitory and expected tariff on imports respectively. Figures A3 and A4 show the paths for the same variables under transitory and expected tariff on exports.

A temporary tariff on imports has ambiguous effects on the demand for the home good. On the one hand, it is an intertemporal tax that reduces consumption. On the other hand, it shifts home demand towards the home good. Our benchmark calibration assumes $\epsilon_i = \epsilon_m$, which implies that the intratemporal and intertemporal substitution effects exactly offset each other. Thus there is no inflation, the nominal interest rate and the terms of trade stay constant. The home currency appreciates because the country accumulates a trade surplus while the tariff is in place.

A similar analysis applies to an expected tariff (Figure A2). The currency appreciation induced by the expected tariff tends to depress home demand, but the expectation of a tariff also stimulates home consumption. The two effects exactly cancel each other (under our benchmark calibration) so that there are no transition dynamics in the terms of trade. The

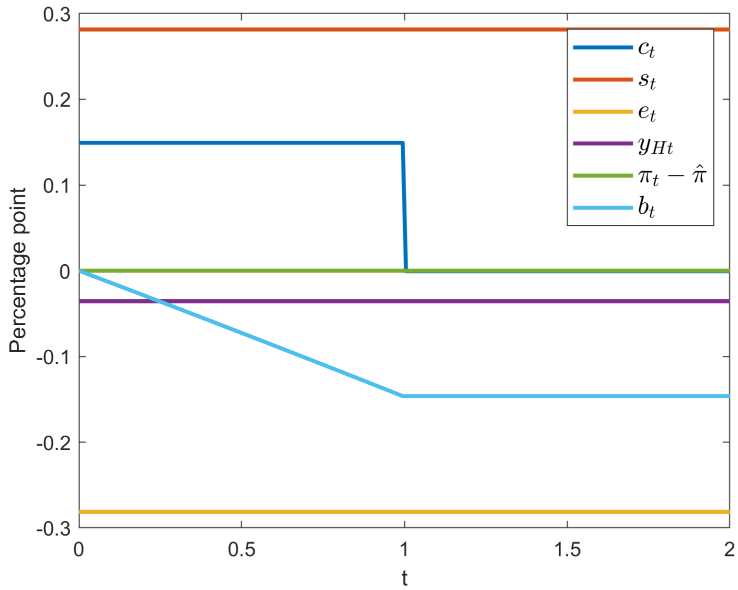

Figure A2: Expected 1 percent tariff on imports

appreciation is mitigated by the fact that the country accumulates trade deficits before the tariff is introduced.

Tariffs on exports require analyzing the transition dynamics. A transitory tariff on exports reduces foreign demand for home goods and home income while it is in place. Home households smooth their consumption by borrowing, and the accumulated foreign liabilities depreciate the home currency in real terms in the long run.[20] In addition, home producers respond to lower demand by lowering their prices. Inflation falls below target, inducing the home authorities to reduce the interest rate. As a result the real exchange rate overshoots the long-run real depreciation in the short run (see Figure A3).[21]

Home households smooth their consumption in anticipation of a tariff on exports by saving before the introduction of the tariff. Thus the economy accumulates net foreign assets, which slightly mitigates the depreciation of the currency when the tariff is introduced (s decreases by slightly less than 1 percent in the long run, as can be seen in Figure A4). The home currency depreciates before the introduction of the tariff, which through expenditure switching stimulates the demand for the home good. Home firms respond to increased demand by raising their prices faster than the inflation target and the home central bank raises the interest rate. This mitigates the depreciation of the home currency in the short run.

[20] The home currency appreciates in nominal terms in the long run because of home deflation while the tariff is in place.

[21] In addition the dynamics exhibit a low-frequency oscillatory component when T is high. We do not observe these oscillations in Figures A3 and A4 because they do not appear for $T = 1$.

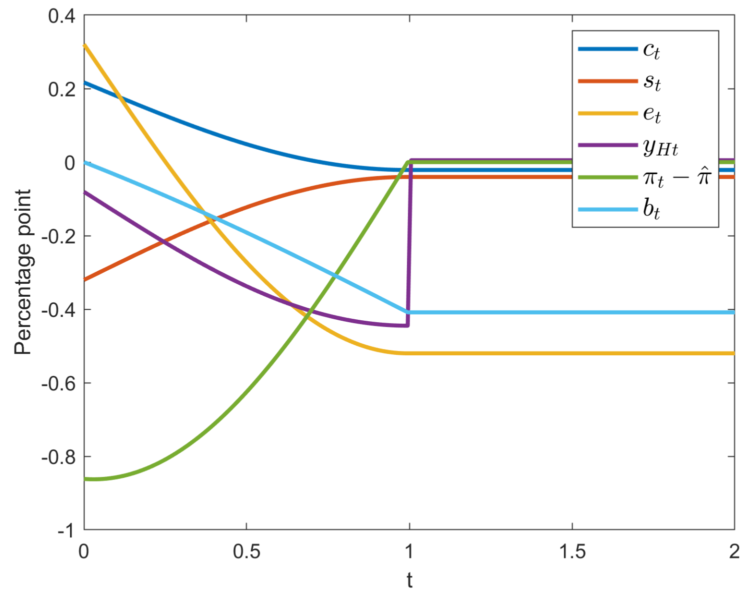

Figure A3: Transitory 1 percent tariff on exports

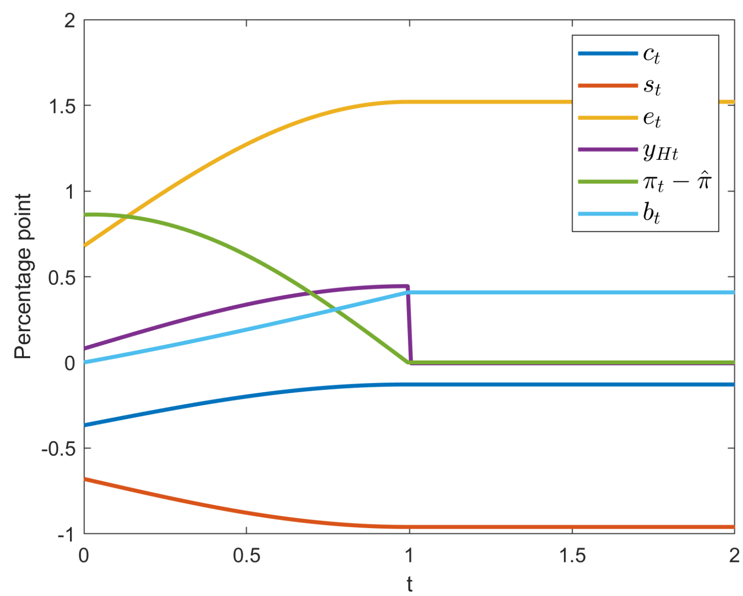

Figure A4: Expected 1 percent tariff on exports

A5. Dominant currency pricing

For a country that is not the US, the difference between DCP and PCP is that under DCP exports are priced in terms of foreign currency. Denote by P_H^* the foreign currency price of home exports and by $S^* = P_H^*/P^*$ the terms of trade in exports markets. We assume constant tariffs.

The home good market clearing condition (8) becomes

$$Y_{Ht} = \omega_H p_H \left(\frac{S_t}{1+\tau}\right)^{-\epsilon_m} C_t + \left[(1+\tau^*)S_t^*\right]^{-\epsilon_x} M_t^*,$$

or, after linearization (using $M_t^* = \omega_F$)

$$y_{Ht} = \omega_H c_t - \omega_F \left[\omega_H \epsilon_m (s_t - \tau) + \epsilon_x (s_t^* + \tau^*)\right]. \tag{A12}$$

By the definition of S^* and using π_t^* to denote the rate of inflation in the foreign currency price of exports,

$$\dot{s}_t^* = \pi_t^* - \hat{\pi}. \tag{A13}$$

The balance-of-payments equation becomes,

$$\dot{B}_t = (1+\tau^*)^{-\epsilon_x} \left(S_t^*\right)^{1-\epsilon_x} M_t^* - \omega_F p_F \left(\frac{S_t}{1+\tau}\right)^{-\epsilon_m} C_t + rB_t,$$

or, after linearization

$$\dot{b}_t = -\omega_F \left[c_t + \omega_H \epsilon_m (s_t - \tau) + \epsilon_x (s_t^* + \tau^*) - s_t^*\right] + rb_t. \tag{A14}$$

Equations (16) and (A8) imply

$$\dot{c}_t = \omega_H \epsilon_i (\phi - 1)(\pi_t - \hat{\pi}). \tag{A15}$$

Under DCP we have two Phillips curves, one for the home market and one for the export market. The Phillips curve for the home market is still given by equation (15). The Phillips curve for the export market is

$$\dot{\pi}_t^* = r\left(\pi_t^* - \hat{\pi}\right) - \alpha \left(\frac{W_t}{E_t P_{Ht}^*} - 1\right)\Bigg($$

or, after linearization,

$$\dot{\pi}_t^* = r\left(\pi_t^* - \hat{\pi}\right) - \alpha \left(\frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} + \omega_H s_t + \omega_F \tau - s_t^*\right)\Bigg(\tag{A16}$$

Using (A12) to substitute out y_{Ht} from equations (15), (16), (A13), (A14), (A15), and (A16) we obtain a first-order differential linear system in six variables: c_t, s_t, s_t^*, $\pi_t - \hat{\pi}$, $\pi_t^* - \hat{\pi}$

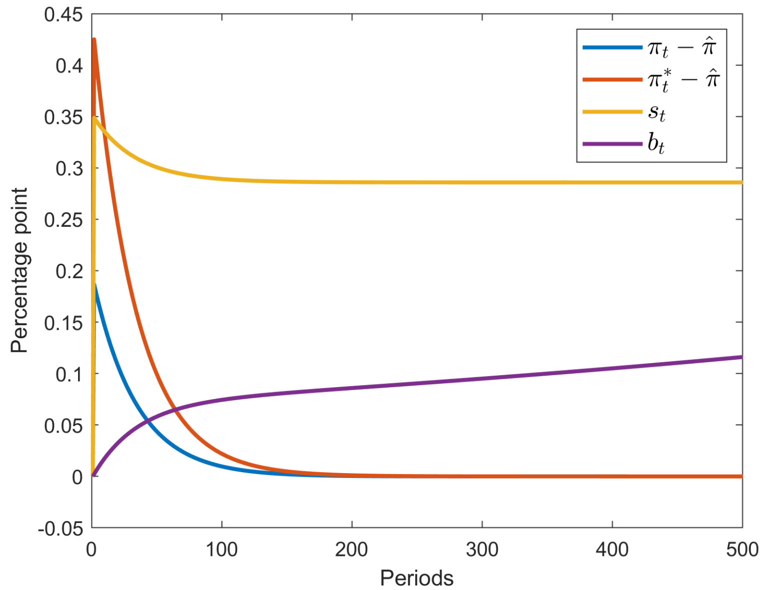

Figure A5: Impulse responses to 1 percent tariff on imports under DCP

and b_t. We solved this system with Dynare to obtain the transition dynamics reported in Figures A5 and A6.[22] The figures are discussed in the text.

DCP in the US. In the US, DCP implies that both exports and imports are invoiced in dollars. Hence, the difference between DCP and PCP is that under DCP imports are priced in dollars rather than in foreign currency. As mentioned in the text, the impact of tariffs under DCP is more complicated to analyze for the US because one can no longer maintain the small open economy assumption. One needs to solve for the transition dynamics both in the US and in the rest of the world. The details are reported in Appendix C.

To summarize, there are three Phillips curves to consider: one for the dollar price of US producers, one for the local currency prices and one for the dollar export price of non-US countries. The rest of the world is assumed to have the same type of Taylor rules as the US.

The main findings are similar to the case of DCP for a non-US country. A tariff on US imports appreciates the dollar whereas a tariff on US exports depreciates the dollar. These effects are larger than under PCP because of exchange rate overshooting. The main difference with the case of a non-US country is that exporters in the RoW adjust their dollar prices in response to the changes in the dollar effective exchange rate.

[22] We discretized the differential equations with a time increment of 0.02, corresponding to about one week given that a unit of time is one year. We also introduced a very small adjustment cost on external assets to make b_t stationary. We used Dynare in the same way to compute the other impulse response functions in the rest of the paper. See Adjemian et al (2011) for a presentation of Dynare.

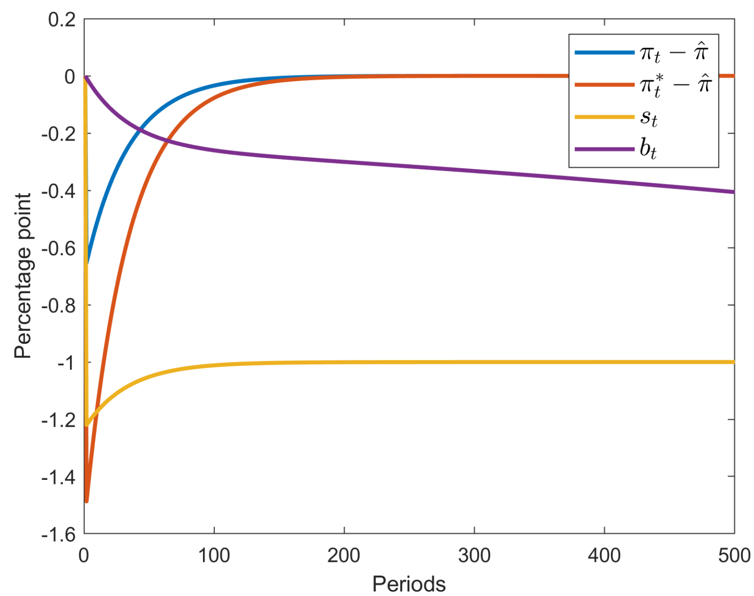

Figure A6: Impulse responses to 1 percent tariff on exports under DCP

A6. Average effective tariffs

One discrepancy between the model and reality is that neither the US nor China imposed a uniform tariff on all their imports. Each country imposed tariffs at different rates on different lists of imported goods. More formally, rather than a uniform tariff τ, we should consider a tariff *schedule* $(\mu_g, \tau_g)_{g=1,\ldots,G}$ where g indexes the lists of goods that are imposed the same tariff τ_g, and μ_g is the import value share of goods in list g before the imposition of the tariffs.

The home-currency price of imports is

$$P_F = \left[\sum_g \mu_g \left((1+\tau_g)EP^*\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}, \tag{A17}$$

where ϵ is the elasticity of substitution between imported goods. This can be rewritten

$$P_F = (1+\tilde{\tau})EP^* \tag{A18}$$

where $\tilde{\tau}$ is defined by

$$1+\tilde{\tau} = \left[\sum_g \mu_g \left(1+\tau_g\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{A19}$$

Variable $\tilde{\tau}$ is the average *effective* tariff that should be used in equation (23). It is equal to the average tariff $\tau = \sum_g \mu_g \tau_g$ in the limit case where the elasticity ϵ is equal to zero. If $\epsilon > 0$ the average effective tariff $\tilde{\tau}$ is lower than τ.

Similarly the tariffs on exports were not uniform. Rather than a uniform tariff τ^*, we should consider a tariff schedule $(\mu_x, \tau_x^*)_{x=1,\ldots,X}$ where x indexes the export markets that impose the same tariff τ_x^*, and μ_x is the share of these export markets in total exports before the imposition of the tariffs.

Foreign demand for the home good is then given by,

$$\sum_x \mu_x \left[(1+\tau_x^*)S\right]^{-\epsilon_x} M^* = \left[(1+\tilde{\tau}^*)S\right]^{-\epsilon_x} M^*, \tag{A20}$$

where the effective tariff on exports is given by,

$$1+\tilde{\tau}^* = \left[\sum_x \mu_x (1+\tau_x^*)^{-\epsilon_x}\right]^{-1/\epsilon_x}. \tag{A21}$$

Table A1: Average effective tariff

$\tilde{\tau}$ *US*	$\tilde{\tau}$ *China*	$\tilde{\tau}^*$ *US*	$\tilde{\tau}^*$ *China*
2.8%	0.7%	0.9%	2.7%

Table A1 shows the estimated average effective tariff rates for the US and China assuming $\epsilon = 3$ as in Feenstra et al (2018). The data used to compute the average effective tariffs are given in Tables B1, B2, B3 and B4. The effective tariff rates reported in Table A1 are between one fourth and one third lower than the simple averages that we have used for Table 2. The exchange rate impact of tariffs should accordingly be reduced by one fourth to one third.

Appendix B. US and Chinese Tariffs

The average tariffs in Table 2 are constructed using data from the International Trade Centre (ITC) and various publications from the Peterson Institute for International Economics (PIIE).[23] We include all the tariffs implemented in 2018-19 that are reported in the US tradewar timeline of Bown and Kolb (2020).

Table B1 reports the tariff rates, the value of imports affected by these tariffs, and the time of implementation for the various import tariffs introduced by the US in 2018-19. As explained in the text, we use the 2017 import values to compute the average tariff rate. The US first introduced a 30 percent tariff on solar panels and washing machines.[24] Following this, in March 2018 the US imposed a 25 percent and 10 percent tariff on steel and aluminum imports respectively following investigation results reporting a threat to "national security" as defined by Section 232 of the Trade Expansion Act of 1962. Most of the tariffs implemented in 2018-19 were on goods imported from China, however. The Trump administration imposed a 25 percent tariff on $50 billion of Chinese goods in the summer of 2018, followed by a 10 percent tariff on an additional $200 billion worth of Chinese goods in September which was later raised to 25 percent in May 2019, and 15 percent on $112 billion of Chinese goods in September 2019. The last row shows total US imports of goods in 2017 and the computed average tariff rate US imports face.

Table B2 reports the tariffs applied by the rest of the world on US exports in 2018-19. Most of these tariffs were implemented by China. In July 2018, China imposed a 25 percent tariff on $34 billion of US goods and in August 2018 additionally imposed a 25 percent tariff on $16 billion of US goods. In September 2018, China imposed another round of tariffs on $60 billion of US goods, with an average tariff rate eventually reaching 13 percent. In September 2019, China imposed an additional 6 percent average tariff on $29 billion of US goods. In 2018-19 China increased the average tariff rate on US goods by a total of 15 percent. The last row shows total US exports in 2017 and the computed average tariff rate US exports face.[25]

Similarly, Tables B3 and B4 report the tariffs on Chinese imports and exports respectively imposed in 2018-19. The tariffs included in Tables B3 and B4 are with the US. The only other changes in the Chinese tariff rates were related to changes in the most favored nation (MFN) status granted to non-US trade partners.

We mentioned in the introduction that the US imposed new tariffs of 15.1 percent on average on its imports from China. For this estimate we need to know the bilateral trade flows

[23] For total imports and exports, we use data from ITC and for tariff rates and import and export values for each tariff, we use data from the PIIE publications.

[24] The actual tariff schedule is more complicated than reported in the table. Tariff rates on washing machines start at 20 percent for the first year and decrease by 2 percent for the next two years while tariff rates on solar panels start at 30 percent and decrease by 5 percent for the next three years. The rates also differ according to how many washing machine units are imported and the gigawatt of solar cells. For simplicity we approximate the tariff rate to be 30 percent for solar panels and washing machines.

[25] Total US exports to China amounted to $154.8 billion in 2017. We disregard changes to Most Favored Nation (MFN) tariff rates by China and include only the changes in tariffs reported in Bown and Kolb (2020).

between the US and China. Table B5 reports the trade flows for goods between the US, China and the rest of the world (RoW) in billions of US dollars, based on the 2017 ITC import and export data. The table shows the flow of exports from the column entity to the row entity. For example, the flow of exports from the US to the rest of the world amounted to \$1,546.5 bn whereas the flow of exports from the rest of the world to the US (i.e., US imports) amounted to \$2,406.4 bn.

Table B1: US tariffs on imports

2017 import value (billion USD)	Tariff rate	Imports	Initiation Date
10.3	30%	Solar Panels and Washing Machines	2/7/2018
19.5	25%	Steel (excluding Canada, Mexico, and Turkey)	3/23/2018
9.7	10%	Aluminum (excluding Canada, Mexico, and Turkey)	3/23/2018
1.3	50%	Steel (Turkey)	8/10/2018
0.1	20%	Aluminum (Turkey)	8/10/2018
250	25%	Imports from China \$50 bn + \$200 bn	7/6/2018 (\$34 bn 25%) 8/23/2018 (\$16 bn 25%) 9/24/2018 (\$200 bn 10% raised to 25% on 5/10/2019)
112	15%	Imports from China	9/1/2019
2017 Total US imports: \$2406.4 bn Average tariffs on US imports: 3.7%			

Table B2: Tariffs on US exports

2017 export value (billion USD)	Tariff rate	Exports	Initiation Date
2.4	22%	China	4/2/2018
3.2	25%	EU	6/22/2018
50	25%	China	7/6/2018 (\$34 bn) 8/23/2018 (\$16 bn)
1.6	13%	Turkey	8/14/2018
60	13%	China	9/24/2018 6/1/2019 Rate increased
14.3	-24%	China suspension of tariff	1/1/2019
1.3	10%	India	6/15/2019
28.7	6%	China	9/1/2019
2017 Total US exports: \$1546.5 bn Average tariffs on US exports: 1.3%			

Table B3: Chinese tariffs on imports

2017 import value (billion USD)	Tariff rate	Imports	Initiation Date
2.4	22%	Imports from US	4/2/2018
50	25%	Imports from US	7/6/2018 ($34 bn) 8/23/2018 ($16 bn)
60	13%	Imports from US	9/24/2018 6/1/2019 Rate increased
14.3	-24%	Suspension of tariffs against US auto and parts	1/1/2019
28.7	6%	Imports from US	9/1/2019
2017 Total Chinese imports: $1841.0 bn Average tariffs on Chinese imports: 1.0%			

Table B4: Tariffs on Chinese exports

2017 export value (billion USD)	Tariff rate	Exports	Initiation Date
250	25%	US	7/6/2018 ($34 bn 25%) 8/23/2018 ($16 bn 25%) 9/24/2018 ($200 bn 10%) 5/10/2019 ($200 bn 25%)
112	15%	US	9/1/2019
1	25%	US tariff on steel	3/23/2018
1.8	10%	US tariff on aluminum	3/23/2018
0.9	30%	US tariff on Solar Panels and Washing Machines	2/7/2018
2017 Total Chinese exports: $2271.8 bn Average tariffs on Chinese exports: 3.5%			

Table B5: Trade flows ($bn, 2017)

	RoW	US	China
RoW	·	2,406.4	1,841.0
US	1,546.5	·	154.8
China	2,271.8	525.8	·

Appendix C. Supplementary material (not for publication)

C1. Model: US DCP

This appendix considers the case of dominant currency pricing when the home economy is the US. We continue to assume that the home economy is a small open economy in the sense that its size is atomistic relative to the rest of the world (RoW). However the dollar effective exchange rate is special because it affects trade flows in the RoW. We assume constant tariff rates. The RoW applies the tariff τ^* on US exports only.

For simplicity we assume that the non-US countries in the RoW are identical.[26] Each non-US country has its own currency but the exchange rate between all non-US currencies is equal to one.

Denote by Y^*_{Ht} and C^*_t the output and consumption of the representative non-US country. Denote by P_{Ft} the dollar price at which non-US goods are traded internationally, and by P^*_t the non-US currency price of the same goods (the price at which non-US goods are traded domestically). The associated inflation rates are denoted by π_{Ft} and π^*_t.

The Taylor rules need to be amended because we can no longer suppose that the world real interest rate in terms of foreign good is constant. We denote by ρ the psychological discount rate of all consumers (US or not). The Taylor rules in the US and in the representative non-US country are

$$\begin{aligned} i_t &= \rho + (1-\phi)\,\widehat{\pi} + \phi\pi_t, \\ i^*_t &= \rho + (1-\phi)\,\widehat{\pi} + \phi\pi^*_t. \end{aligned}$$

US. The terms of trade relevant both for home and foreign markets are $S_t = P_{Ht}/P_{Ft}$. Thus

$$\dot{s}_t = \pi_t - \pi_{Ft}. \tag{C1}$$

Since the relative price of US and foreign goods is the same in US and foreign markets, the demand for US goods is given by equation (8) like in the PCP case. The only difference with PCP is that we no longer assume RoW imports to be constant, so that linearized demand for US goods is given by,

$$y_{Ht} = \omega_H c_t - \omega_F\left[\omega_H \epsilon_m (s_t - \tau) + \epsilon_x (s_t + \tau^*)\right] + \omega_F m^*_t, \tag{C2}$$

where $M^*_t = \omega_F(1 + m^*_t)$. The Euler equation for the US consumer is

$$\dot{c}_t = \epsilon_i \left(i_t - \pi^c_t - \rho\right),$$

where $\pi^c_t = \pi_t - \omega_F \dot{s}_t$ is the US CPI inflation rate. Using the Taylor rule and (C1) to substitute out i_t and $\dot{s}_t$ gives

$$\dot{c}_t = \epsilon_i\left[(\phi - 1)(\pi_t - \hat{\pi}) + \omega_F(\pi_t - \pi_{Ft})\right]. \tag{C3}$$

[26] To avoid any ambiguity we call countries US and non-US rather than home and foreign.

The Phillips Curve for US goods sold at home is still given by (15). The US BoP equation is given by (A9).

RoW. The terms of trade relevant for the representative non-US country is the price of its home good in terms of foreign good (both expressed in terms of dollars),

$$S_t^* = \frac{E_t P_t^*}{P_{Ft}}, \tag{C4}$$

where E_t is the price of non-US currency in terms of dollars. Using interest parity

$$i_t = i_t^* + \dot{E}_t / E_t,$$

one gets

$$\dot{s}_t^* = i_t - i_t^* + \pi_t^* - \pi_{Ft},$$

and using the Taylor rules to substitute out $i_t - i_t^*$

$$\dot{s}_t^* = \phi\left(\pi_t - \pi_t^*\right) + \pi_t^* - \pi_{Ft}. \tag{C5}$$

The demand for the output of the representative non-US country is the sum of home demand and foreign demand

$$Y_{Ht}^* = \omega_H \left[p_H\left(S_t^*\right)\right]^{-\epsilon_m} C_t^* + \omega_F \left[p_F\left(S_t^*\right)\right]^{-\epsilon_m} C_t^*.$$

Linearizing this expression gives

$$y_{Ht}^* = c_t^*.$$

The Euler equation for the non-US consumer is

$$\dot{c}_t^* = \epsilon_i \left(i_t^* - \pi_t^{c*} - \rho\right),$$

where $\pi_t^{c*} = \pi_t^* - \omega_F \dot{s}_t^* = \omega_H \pi_t^* + \omega_F \left[\pi_{Ft} - \phi\left(\pi_t - \pi_t^*\right)\right]$ is CPI inflation in the non-US country. Using the Taylor rule to substitute out i_t^* gives

$$\dot{c}_t^* = \epsilon_i \left[\left(\phi - \omega_H\right)\left(\pi_t^* - \widehat{\pi}\right) - \omega_F\left(\pi_{Ft} - \widehat{\pi}\right) + \omega_F \phi\left(\pi_t - \pi_t^*\right)\right]. \tag{C6}$$

The non-US country's demand for imports is

$$M_t^* = \omega_F \left[p_F\left(S_t^*\right)\right]^{-\epsilon_m} C_t^*.$$

Linearizing this equation gives

$$m_t^* = c_t^* + \omega_H \epsilon_m s_t^*. \tag{C7}$$

The non-US country has two Phillips curves, one for home markets and one for exports markets

$$\begin{aligned}
\dot{\pi}_{Ft} &= \rho(\pi_{Ft} - \hat{\pi}) - \alpha\left(\frac{E_t W_t^*}{P_{Ft}} - 1\right)\Bigg(\\
\dot{\pi}_t^* &= \rho(\pi_t^* - \hat{\pi}) - \alpha\left(\frac{W_t^*}{P_t^*} - 1\right)\Bigg(
\end{aligned}$$

where the nominal wage is given by

$$W_t^* = P_t^{c*} \left(Y_{Ht}^*\right)^{1/\epsilon_\ell} \left(C_t^*\right)^{1/\epsilon_i} .$$

Linearizing these equations and using $y_{Ht}^* = c_t^*$ gives

$$\dot{\pi}_{Ft} = \rho(\pi_{Ft} - \hat{\pi}) - \alpha \left[\left(\frac{1}{\epsilon_\ell} + \frac{1}{\epsilon_i} \right) \left(c_t^* + \omega_H s_t^* \right) \right] \tag{C8}$$

$$\dot{\pi}_t^* = \rho(\pi_t^* - \hat{\pi}) - \alpha \left[\left(\frac{1}{\epsilon_\ell} + \frac{1}{\epsilon_i} \right) \left(c_t^* - \omega_F s_t^* \right) \right] \tag{C9}$$

Solving for the equilibrium. Using (C2) and (C7) to substitute out y_{Ht} and m_t^* we have a first-order differential linear system in 8 variables (s_t, c_t, π_t, s_t^*, c_t^*, b_t, π_{Ft}, π_t^*) with the following 8 equations: (C1), (C3), (15), (C5), (C6), (A9), (C8) and (C9). We solved this system with Dynare to obtain the transition dynamics reported in Figures C1 and C2.

As shown by Figure C1, the tax on US imports lead US producers to adjust their price upwards in the home market. The resulting increase in inflation induces the US central bank to raise the interest rate, which appreciates the dollar. The appreciation of the dollar can be seen in the initial fall in S^* and E (using the fact that P_t^* and P_{Ft} are sticky in equation (C4)). The dollar appreciates by 0.35 percent, more than under PCP. Observe that exporters in the RoW adjust their dollar prices downward (π_F goes below target) as the appreciation of the dollar increases their markups.

Figure C2 shows similar responses in reverse. The tax on exports leads US exporters to adjust their prices downward at home, and induces a US monetary relaxation which depreciates the dollar. The dollar overshoots, with a 1.19 percent depreciation (against 1 percent under PCP). Exporters in the RoW adjust their dollar prices upward as the dollar depreciation reduces their markups.

C2. Event study: the NEERs

For the high-frequency event study we construct NEER series for the US dollar and the Chinese renminbi at the 10-minute frequency. As explained in the text we use the BIS currency baskets pared down to the top-ten currencies. The BIS weights are calculated based on manufacturing trade flows, capturing both direct bilateral trade and third-market competition and adjusted for re-exports for China (see Klau and Fung, 2006, for a description of the methodology). The top-ten currencies amount to approximately 85 percent of the BIS basket for the dollar and 80 percent in the case of the renminbi. The weights are reported in Table C1. The exchange rate data are from Bloomberg. There are a total of 72118 observations for the USD NEER, 74449 observations of the CNH NEER, and 74449 observations for the CNH/USD bilateral exchange rate.

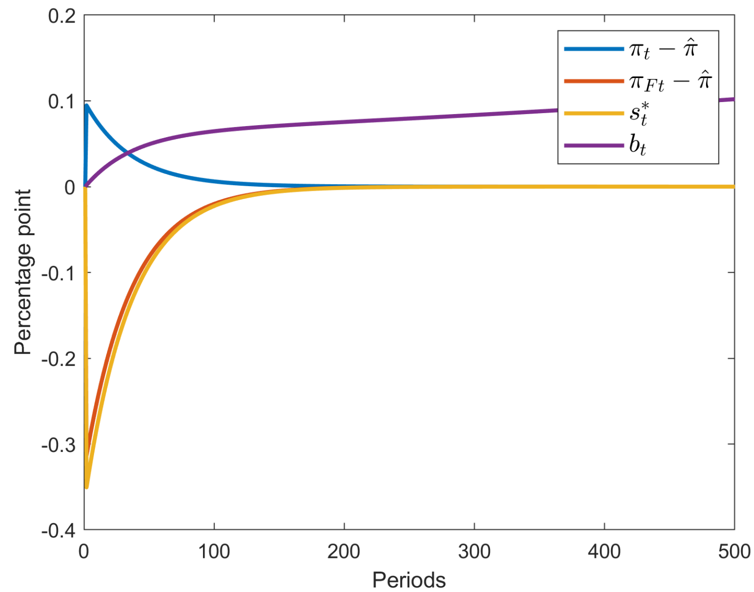

Figure C1: Impulse responses of 1 percent tariff on US imports under DCP

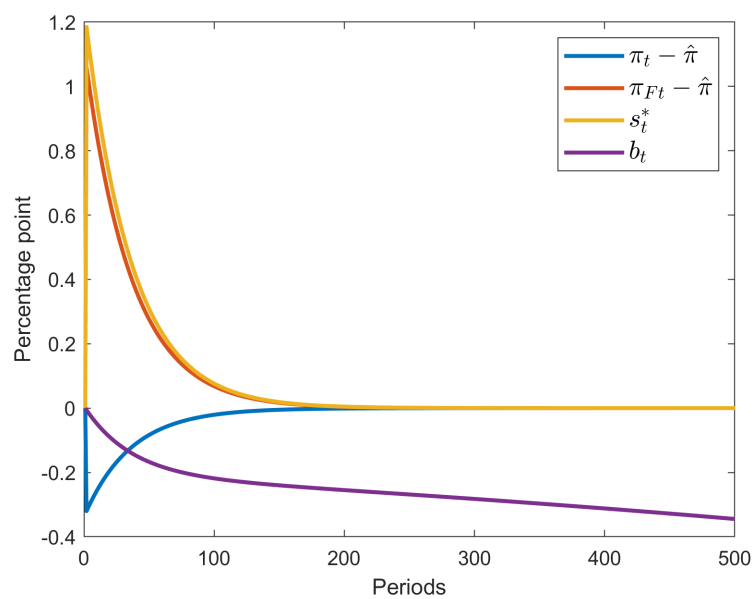

Figure C2: Impulse responses of 1 percent tariff on US exports under DCP

Table C1: Weights for USD NEER and CNH NEER

USD NEER		CNH NEER	
Renminbi	0.27	United States dollar	0.25
Euro	0.20	Euro	0.23
Mexican peso	0.16	Japanese yen	0.15
Canadian dollar	0.14	South Korean won	0.11
Japanese yen	0.08	New Taiwan dollar	0.08
South Korean won	0.04	Pound sterling	0.04
Pound sterling	0.04	Singapore dollar	0.04
New Taiwan dollar	0.03	Mexican peso	0.03
Indian rupee	0.02	Indian rupee	0.03
Swiss franc	0.02	Thai baht	0.03

C3. Event study: the Bown-Kolb news sample

Table C2 reports the events relevant to the US-China tradewar provided by Bown and Kolb (2020) as well as our coding of the news. There are a total of 37 events that include information about an increase or decrease of US or China tariffs. We identify 19 of these events to be related to an increase in US tariffs on imported goods from China, 5 to be related to a decrease in US tariffs on imported goods from China, 14 to be related to an increase in Chinese tariffs on imported goods from the US, and 3 to be related to a decrease in Chinese tariffs on imported goods from the the US.

Figure C3 shows the point estimates and 95 percent confidence intervals of coefficients β_u and β_c in regression (25) using the BK sample. The solid line reports the estimated coefficient when the length of time windows increased from one to five hours and the dashed line reports the confidence intervals. The figures show similar qualitative results as Figure 4, except for the statistical insignificance of US tariff news on the USD NEER for the three and four hour times windows.

C4. Event study: robustness

Figure C4 shows the point estimates and 95 percent confidence intervals of coefficients β_u and β_c in regression (25) using only tariff news that occurred on weekdays. The results are close to our benchmark results in Figure 4. US tariff news appreciate the dollar and depreciate the renminbi for all time windows. Chinese tariff news have no statistical significance for both currencies across all time windows.

Table C3 shows the 95 percent confidence intervals of coefficients β_u and β_c using only tariff news that occurred on weekends. Again, the results are similar to our benchmark case.

To check for asymmetry between increasing and decreasing tariffs, we run regressions that

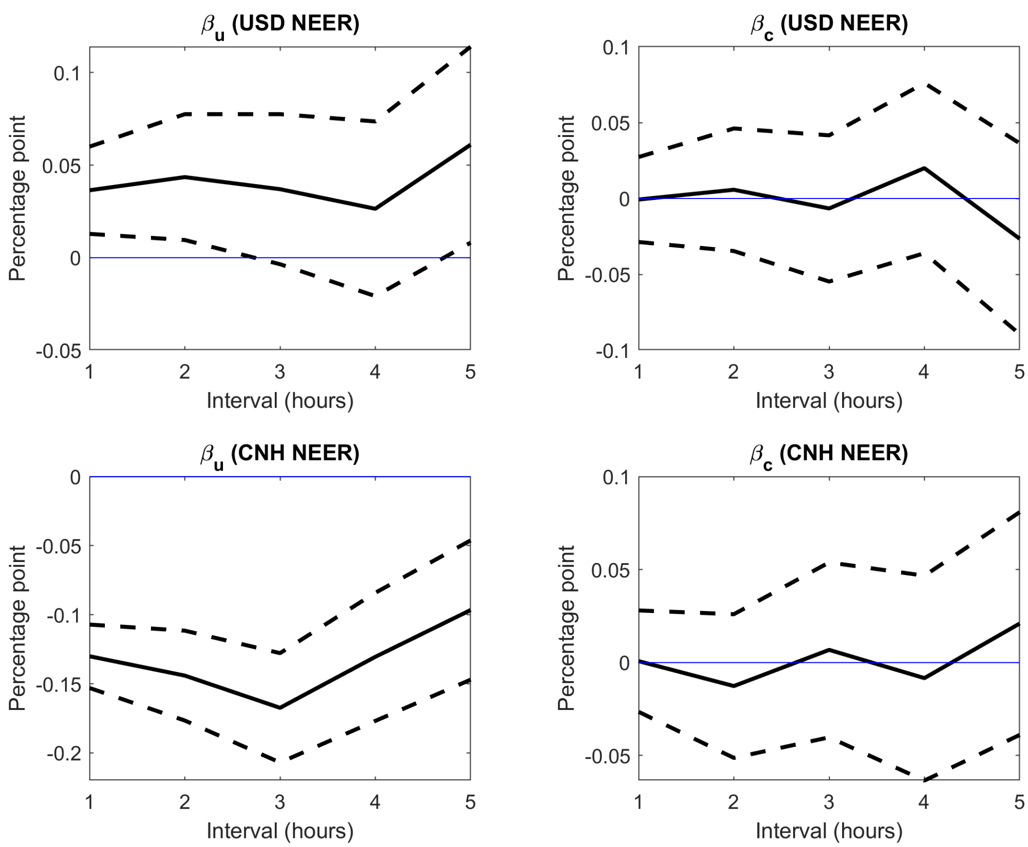

Figure C3: β_u (left-hand side panel) and β_c (right-hand side panel) for USD NEER (first row) and CNH NEER (second row) using BK news sample include separate dummies for each type of event,[27]

$$\frac{E_t - E_{t-k}}{E_{t-k}} = \alpha + \beta_u U_t + \beta_c C_t + \beta_{u+} U_t^+ + \varepsilon_t, \tag{C10}$$

and

$$\frac{E_t - E_{t-k}}{E_{t-k}} = \alpha + \beta_u U_t + \beta_c C_t + \beta_{c+} C_t^+ + \varepsilon_t. \tag{C11}$$

The 95 percent confidence intervals are reported in Figure C5. The null $\beta_{u+} = 0$ cannot be rejected for both currencies and all time windows. The same is true for $\beta_{c+} = 0$ except for the renminbi in the 4-hour time window. These results show no evidence of asymmetry.

We also run regression (25) using overlapping time windows and the Newey-West standard errors to correct for the autocorrelation of observations. The regression results are reported in Figure C6. The results are similar to our benchmark results. US tariff news appreciate the dollar and depreciate the renminbi for all time windows. Chinese tariff news have no statistically significant impact on both currencies for all time windows.

[27] U_t and C_t are defined as in regression (25). U_t^+ (C_t^+) is a dummy variable that takes the value of 1 if there were news about US (Chinese) tariff increases during the time window $(t-k, t)$ and 0 otherwise.

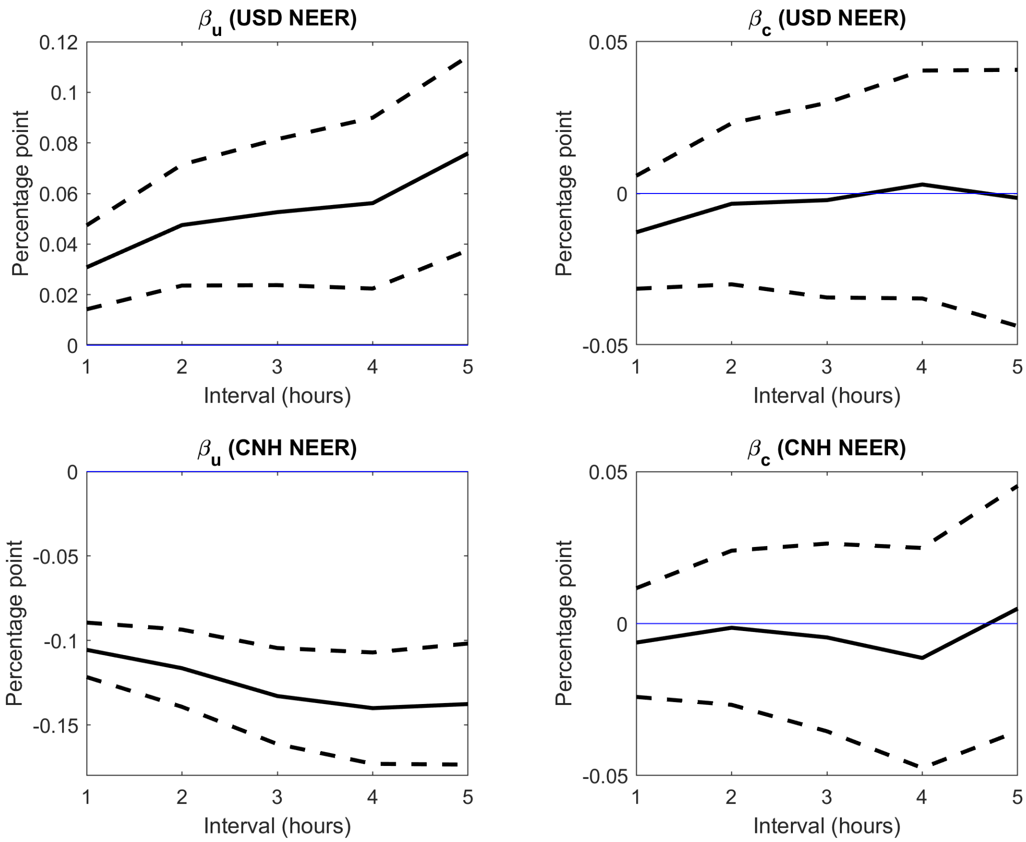

Figure C4: β_u (left-hand side panel) and β_c (right-hand side panel) for USD NEER (first row) and CNH NEER (second row) using weekday data

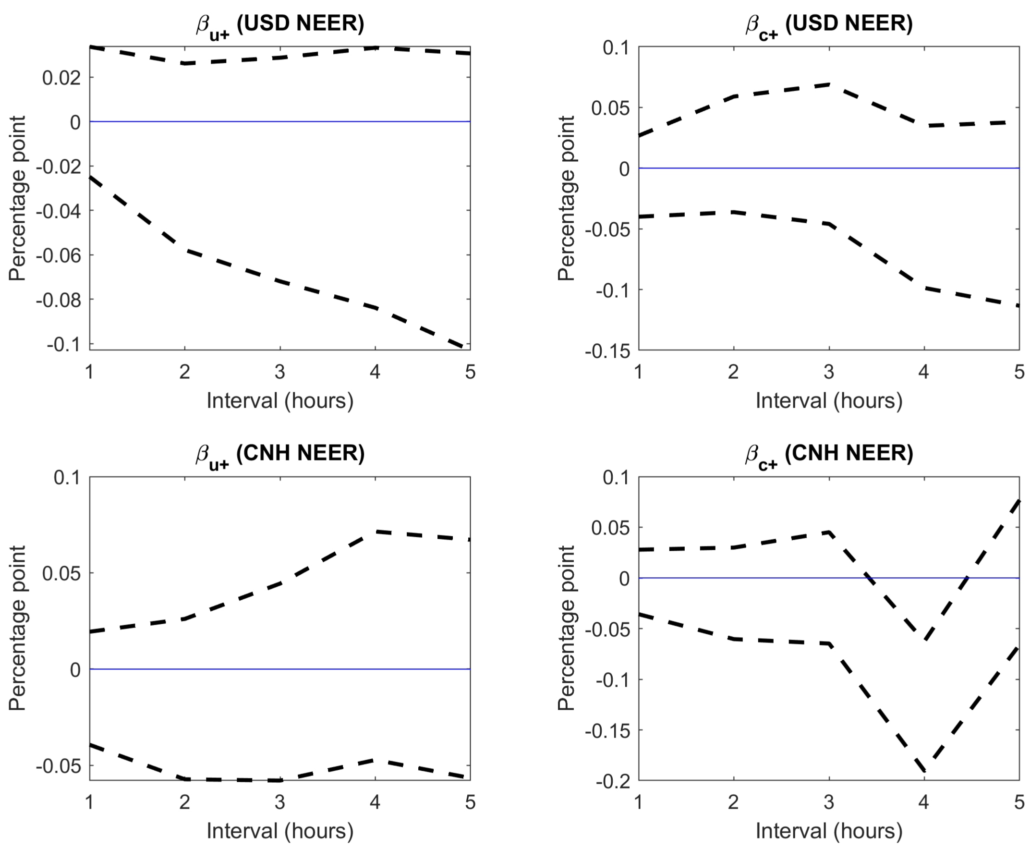

Figure C5: β_{u+} (left-hand side panel) and β_{c+} (right-hand side panel) for USD NEER (first row) and CNH NEER (second row)

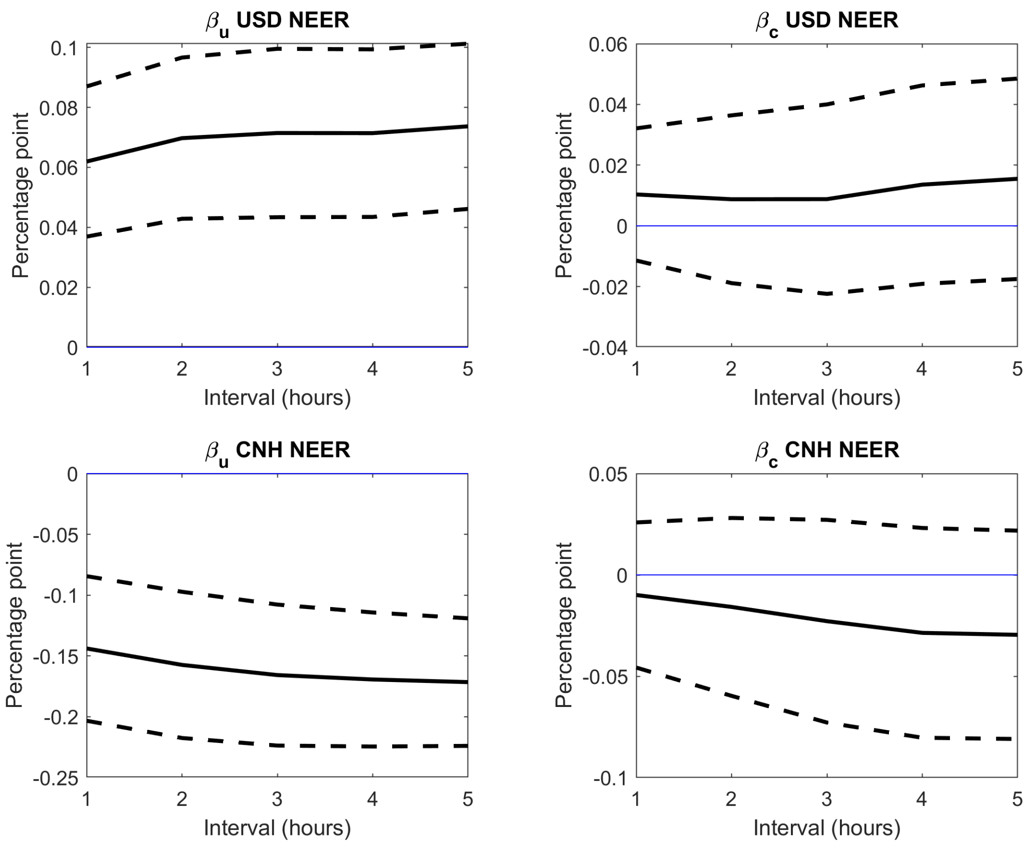

Figure C6: Regression results using overlapping time windows with Newey-West standard errors

Table C2: Bown and Kolb (2020) US-China tradewar timeline

Date	Event	U_t	C_t
2/4/2018	China investigates US exports of Sorghum	0	1
3/22/2018	Unfair trade practices investigation results	1	0
4/3/2018	China retaliates	0	1
4/3/2018	US threatens tariffs	1	0
4/4/2018	China threatens retaliation on autos, aircraft, and agriculture	0	1
4/5/2018	US considers additional tariffs on $100 billion	1	0
4/17/2018	China imposes preliminary tariffs on US Sorghum	0	1
5/17/2018	China ends tariffs on US Sorghum during negotiations	0	-1
5/29/2018	White house plans tariffs after brief hold	1	0
6/15/2018	US revises $50 billion tariff list	1	0
6/15/2018	China's revised retaliation list	0	1
6/18/2018	Trump asks for more tariffs	1	0
7/6/2018	US and China impose first phase of June 15 tariff list	1	1
7/10/2018	USTR announces $200 billion tariffs on China	1	0
7/20/2018	Trump threatens tariffs on all imports from China	1	0
8/1/2018	Trump wants 25% and not 10%	1	0
8/3/2018	China threatens $60 billion tariffs	0	1
8/7/2018	USTR finalizes second tranche of tariffs	1	0
8/8/2018	China revises its $ billion tariff list, removing crude oil	0	1
8/23/2018	US and China impose second phase of $50 billion tariffs	1	1
9/17/2018	Trump finalizes $200 billion tariff list	1	0
9/18/2018	China finalizes tariffs on $60 billion of US goods	0	1
9/24/2018	Next phase of tariffs goes into effect	1	1
12/1/2018	US-China tariff truce	-1	-1
2/24/2019	Tariff increase delayed	-1	0
5/5/2019	Trump renews tariff threats	1	0
5/10/2019	US raises tariff rate on previous list	1	0
5/13/2019	China plans to hike tariff rate	0	1
6/1/2019	China raises retaliatory tariffs	0	1
8/1/2019	US announces tariffs on almost all remaining imports from China	1	0
8/13/2019	Trump plans two major rollouts of fall 2019 tariffs	1	0
8/23/2019	China retaliates	0	1
8/23/2019	Trump announces more tariffs	1	0
9/11/2019	China removes a few tariffs	0	-1
9/11/2019	Trump moves tariff date	-1	0
10/11/2019	Trump cancels October tariffs, points to "Phase One" of deal with China	-1	0
12/13/2019	Trump calls off December tariffs in anticipation of deal	-1	0

NEER	β_u	β_c
USD	[0.146 0.268]	[-0.058 0.091]
CNH	[-0.557 -0.381]	[-0.132 0.084]

Table C3: 95 percent confidence interval for β_u and β_c using weekend data

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