To What Extent Are Tariffs Offset By Exchange Rates?*

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Abstract

In theory, tariffs should 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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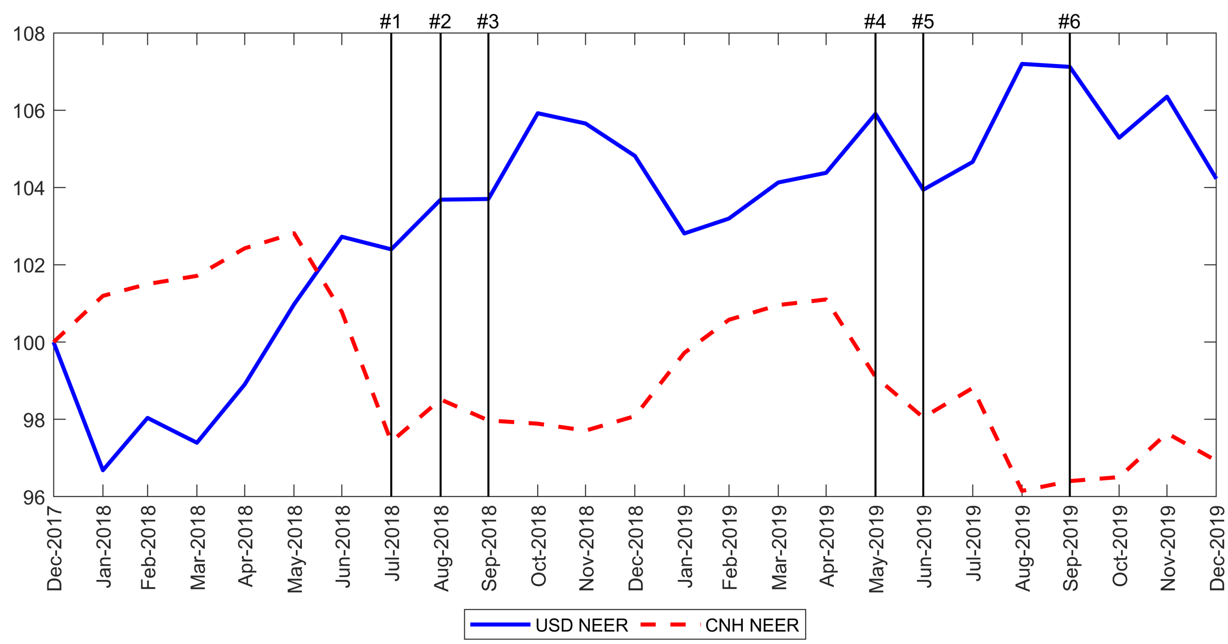
1 Introduction

In 2018-19 the US imposed new tariffs of 15.1 percent on average on its imports from China.[1] At the same time the renminbi depreciated by 3 percent while the dollar appreciated by 4 percent on a multilateral basis (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 USD and CNH effective exchange rates



1. US implements 25% tariff on $34 bn Chinese goods. China implements 25% tariff on $34 bn US goods.
2. US implements 25% tariff on $16 bn Chinese goods. China implements 25% tariff on $16 bn US goods.
3. US implements 10% tariff on $200 bn Chinese goods. China implements 5 to 10% tariff on $60 bn US goods.
4. US increases tariff on $200 bn Chinese goods to 25%.
5. China increases tariff on $60 bn US goods by 5 to 15%.
6. US implements 15% tariff on $112 bn Chinese goods. China implements 5 to 10% tariff on $75 bn US goods.

Note: An increase in the index means an effective appreciation of the currency (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 theoretical perspective and in the context of the US-China tariff war.

We first present a model of a small 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

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

inflation and pursue this objective through a Taylor rule.

The tariffs affect home inflation and the home monetary authorities respond to the change in inflation by adjusting the nominal interest rate, which has an impact on the exchange 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 can derive closed-form expressions for the exchange rate offsets in the special case where permanent tariffs are introduced in a steady state. This case can be analyzed in closed form because 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. In all cases, the exchange rate moves in a direction that tends to offset the impact of the tariff (a tariff on imports appreciates the home currency and a tariff on exports depreciates it). Under our baseline calibration 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.

The rest of the paper quantifies 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 independent approaches. First, we estimate the quantitative implications of the model calibrated to the tariffs that the US and China imposed on each other in 2018 and 2019. According to the calibrated model, 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 around 3 percent. This difference reflects that the average tariff increased more for exports than for imports in China whereas the opposite was 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 independent information on 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

[2]Our benchmark news sample was constructed using news reported by Bloomberg. We also use another sample of news constructed by Bown and Kolb (2023) for robustness analysis.

or Chinese tariffs. On the one hand, the estimated impact of US tariffs is quite consistent with our theoretical benchmark. We find that news about US tariffs appreciated the dollar and depreciated the renminbi, with an impact on the renminbi more than twice as large as on the dollar. On the other hand, news about Chinese tariffs did not have a statistically significant impact on the dollar or the renminbi.

Finally, we estimate the cumulative impact of US tariff news on the dollar and renminbi effective exchange rates implied by our regression results. We find that the US 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 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. Hwang and Turnovsky (2013) look at the effects of unanticipated and anticipated permanent tariffs on the exchange rate under PCP and local currency pricing (LCP) in a dynamic two-country model.

The tariffs imposed by the US in 2018-19 led to a 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] Some have analyzed in particular the impact of tariffs on exchange rates using a two-country or multi-country model and find that tariffs appreciate the currency of the tariff-imposing country in different settings. Bergin and Corsetti (2023) derive the optimal coordinated monetary policy response to symmetric and asymmetric tariff shocks under PCP and DCP in a two-country model. Bolt et al. (2019) use a large-scale multi-regional DSGE model to analyze the impact of the US-China tariff war on the US, China, and the EU. We contribute to this literature by quantifying the impact of tariffs on the exchange rate in a tractable small open economy model under PCP and DCP. Furthermore we show that a small open economy model provides a good approximation to a three-country model calibrated to the US, China and the rest of the world.

On the empirical side, some recent papers have compared the impact of exchange rates and 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. (2021) find that exports are more responsive to a tariff cut in the destination

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

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. (2022) find that tariffs on imports 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. (2022)).

Finally, our paper contributes to a large literature on the impact of news on exchange rates (see for example Faust et al. (2007), Andersen et al. (2007), or Rogers et al. (2014)). Matveev and Ruge-Murcia (2023) find that tweets by the US President that relay information regarding the termination of NAFTA appreciated the US dollar against the Mexican peso and Canadian dollar by 2 to 5 basis points within five minutes. They also find that these tweets affected forward rates in a quantitatively similar manner. 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 US 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. The rest of the paper quantifies the effect of tariffs on the dollar and renminbi exchange rates using two independent methods: a calibration of the model (section 3) and a high-frequency event study (section 4). Section 5 concludes.

2 Theory

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. 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 the change in the terms of trade.

The country is integrated into 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 nominal exchange rate E_t 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 household's budget constraint in terms of the foreign good is

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

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 including revenue from tariffs on imports.

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).

Demand for Home Good

The home terms of trade are equal to the price of the home good in terms of foreign good,

$$S_t = \frac{P_{Ht}}{E_t P_t^*}. \tag{6}$$

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

$$Y_{Ht} = C_{Ht} + C_{H,t}^* \tag{7}$$

where foreign demand for the home good is given by

$$C_{H,t}^* = \left[(1+\tau_t^*)S_t\right]^{-\epsilon_x} M^* \tag{8}$$

and M^* is a measure of foreign imports (assumed to be constant), 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 lowercase) is,

$$c_t = \gamma - \epsilon_i \left(\omega_H s_t + \omega_F \tau_t\right), \tag{13}$$

$$y_{Ht} = \omega_H c_t - \omega_F \left[\omega_H \epsilon_m (s_t - \tau_t) + \epsilon_x (s_t + \tau_t^*)\right], \tag{14}$$

$$\dot{\pi}_t = r\left(\pi_t - \hat{\pi}\right) - \alpha \left[\frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} - \omega_F \left(s_t - \tau_t\right)\right], \tag{15}$$

$$\dot{s}_t = -\left(\phi - 1\right)\left(\pi_t - \hat{\pi}\right). \tag{16}$$

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. Equation (16) is the linearized version of (12) and encapsulates the Taylor rule.

Given the exogenous tariff paths $(\tau_t, \tau_t^*)_{t\geq 0}$, one can solve for $(c_t, y_{Ht}, \pi_t, s_t)_{t\geq 0}$ using the system of equations (13)-(16). The question of interest is how the exchange rate responds to the introduction of tariffs. The next section looks at the case where the tariffs are permanent.

2.2 Permanent tariffs

Assume that permanent tariffs on imports or exports 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 respond to the change in inflation, if it materializes, by raising or lowering the interest rate. With constant tariffs, however, the interest rate does not need to change in equilibrium because the exchange rate immediately jumps to a steady state level where inflation remains equal to the target. The absence of transition dynamics simplifies the model and allows us to derive closed-form expressions for the exchange rate offset.[4]

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. A tariff makes imports 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 raise home income and consumption, the expenditure-switching effect dominates the income effect because $\epsilon_x > 1$. Demand for home goods increases with the tariff on imports but decreases with the tariff on exports because of expenditure-switching in the home and foreign markets.

[4] This also holds if we introduce nominal wage rigidity, as shown in Appendix A6.

Equation (20) gives the steady state supply of home goods. 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 (6) 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 ϵ_m (the import elasticity) and decreases with ϵ_x (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.

A similar logic applies to a tariff 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 given by,

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

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.[5] Thus, the exchange rate offsets the impact of the tariff on *foreign* demand for the home good by a depreciation of the same size as the tariff. If $\epsilon_m < 1$ and/or $\epsilon_i < 1$ a depreciation decreases home demand for the home good and/or increases its supply. The depreciation then must be larger than when $\epsilon_m = \epsilon_i = 1$ to bring back demand in line with supply.

A tariff on imports does not have the same impact on the exchange rate as a tariff on exports. To understand the difference between the two, it is convenient to look at the case where labor supply is inelastic. Assuming that the Frisch elasticity ϵ_ℓ goes to zero in equations (23) and (24), one obtains

$$\lim_{\epsilon_\ell \to 0} \frac{de}{d\tau} / \frac{de}{d\tau^*} = -\omega_H \frac{\epsilon_m}{\epsilon_x}. \tag{25}$$

The ratio of the exchange rate offset for an import tariff to the exchange rate offset for an export tariff is proportional to the ratio of the import elasticity to the export elasticity ϵ_m/ϵ_x. This is intuitive. Other things equal, increasing the import elasticity magnifies the expenditure-switching effect on the side of imports. Therefore it takes a larger appreciation to offset the impact of a tariff on imports and it takes a smaller depreciation to offset the impact of a tariff on exports. Increasing the export elasticity magnifies the expenditure-switching on the side of exports, which has the opposite effects.

2.3 Alternative assumptions

This section discusses the sensitivity of our results to changes in the assumptions. Our analysis is based on numerical results because we consider extensions of the baseline model for which closed-form expressions cannot be derived. The calibration of the model is reported in section 3, Table 1 and will be explained in detail in that section. We assume $\omega_H = 0.85$, which is approximately equal to one minus the share of imports in GDP in the US. With these values, the exchange-rate offset implied by equation (23) for a uniform tariff on all

[5] The impact of the exchange rate on 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 goods is captured by the term in $(\epsilon_i - 1)$ in equation (20).

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 equal to 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.

Transitory tariffs and tariff announcements

In Appendix A4 we analyze the case where the tariffs τ and τ^* are applied during a limited period T and the case where permanent tariffs 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 can be 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 effect and the expenditure switching effect exactly offset each other so that demand for the home good is constant over time. In this case, there are no transition dynamics in response to a tariff on imports and the exchange rate jumps to a constant level in period 0. A tariff has a smaller impact on the exchange rate if it is transitory or if it is implemented in the future than if if it is permanent and immediate.

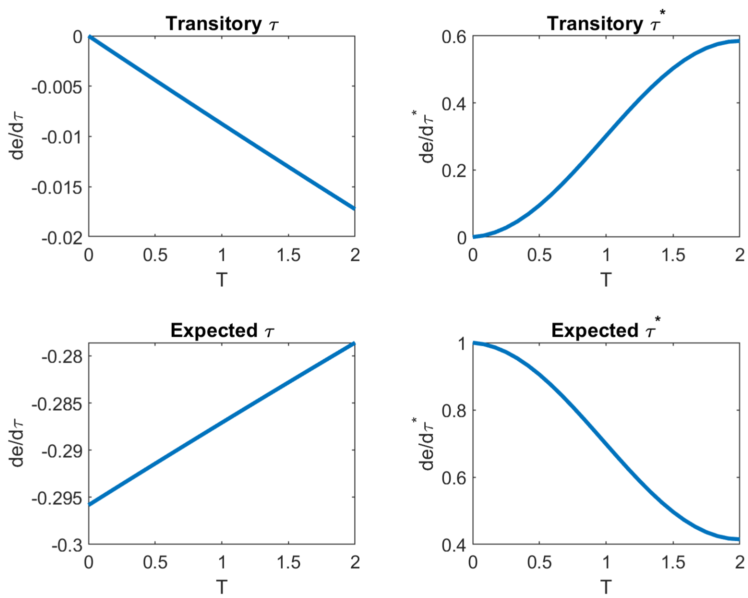
By contrast, tariffs on exports give rise to transition dynamics. With a transitory tariff on exports, home producers respond to lower demand by adjusting their prices downward. The home central bank lowers the interest rate which depreciates the currency more in the short run than in the long run (overshooting). By contrast, announcing a future 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 shows how the exchange rate offset varies with T.[6] 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 tariff announcements. They show how the exchange-rate offset varies with the lag between the announcement and the imposition

[6] A range of 2 years was used for T because the empirical exercises presented in Section 4 uses 2 years of data.

Figure 2: Variation of exchange rate offset with T.



Note: The two graphs in the upper half show the period 0 exchange rate impact of transitory import (left) and export tariffs (right) that are implemented for T years. The two graphs in the lower half show the period 0 exchange rate impact of expected import (left) and export tariffs (right) that are implemented after T years.

of the tariff. The case $T = 0$ corresponds to the permanent tariffs analyzed in the previous 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 (2015) argues that a more realistic assumption for many countries is that the prices of imports and exports are fixed in terms of the dominant currency, 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. 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. 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 dollars in export markets. The increase in home inflation leads the monetary authorities to raise the local currency interest rate. As a result, the home currency appreciates 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 affect trade flows and consumption in the rest of the world.[7] 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 lower for temporary or expected tariffs and somewhat higher under DCP than under PCP.

3 Calibration to the US-China Tariff War

This section quantifies the impact of the US-China trade war on the dollar and the renminbi. The renminbi depreciated against the dollar by 7.0 percent in 2018-19. As shown by Figure 1, this reflected 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 imposed on each other by the US and China in 2018-19?

[7] 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.

We answer this question following two complementary but independent approaches. In this section we calibrate the model presented in the previous section to the tariffs introduced in the US-China 2018-19 tariff war. In the next section we study the impact of the tariff war on the dollar and renminbi using high-frequency news about tariffs.

According to the model home tariffs appreciate the home currency but foreign tariffs depreciate it. Hence the impact of the US-China tariff war on the dollar and the renminbi could have gone either way. The main point of this section is to show that according to the calibrated model, the tariff war should have depreciated the renminbi whereas it should not have significantly affected the dollar.

3.1 Calibration

The baseline calibration is given in Table 1. We assume a logarithmic utility ($\epsilon_i = 1$) and set the Frisch elasticity of labor supply to 1/3.

The elasticities for imports and exports are taken from Feenstra et al. (2018). These authors measure the price elasticities at the good level in the US. They find that the price elasticity between different varieties of imports, which they call the micro-elasticity, is significantly higher than the elasticity between home goods and imported goods (the macro-elasticity).

The micro-elasticity estimated by Feenstra et al is the price elasticity that is relevant for a country's exporters competing with other exporters in foreign markets. It corresponds to the export elasticity ϵ_x in our model. Similarly, their macro-elasticity is the price elasticity that is relevant for a country's home producer competing with foreign producers in home markets. It corresponds to the import elasticity ϵ_m in our model. Based on Feenstra et al's estimates, we set the import elasticity to 1 and the export elasticity to 3.

The last three columns of 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. We assume a real interest rate of 3 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 change their price every year on average.[8]

The exchange rate offsets for the US and China are reported in Table 2. We use equations (23) and (24) with the parameter values reported in Table 1 for both countries but the US and China have different levels of trade openness. For the US we assume $\omega_H = 0.85$, which

[8] In the continuous time Calvo model the Phillips curve is given by (5) with $\alpha = \theta(r + \theta)$ where θ is the flow probability that a firm can change its price. If the average duration of sticky prices is one year, then $\theta = 1$, which gives $\alpha = 1.03$.

Table 1: Baseline calibration

ϵ_i	ϵ_ℓ	ϵ_m	ϵ_x	r	ϕ	α
1	1/3	1	3	0.03	1.5	1.03

is equal to one minus the share of imports in GDP in the US. For China, the same formula gives $\omega_H = 0.81$, reflecting China's more open economy. This results in a slightly muted exchange rate offset for import tariffs. Since $\epsilon_i = \epsilon_m = 1$, the exchange rate offset for export tariffs is equal to 1 for both countries.

Table 2: Exchange rate offsets

	$de/d\tau$	$de/d\tau^*$
US	-0.296	1
CH	-0.286	1

The exchange rate is about three times as responsive to a tariff on exports as to a tariff on imports. This three-to-one ratio is a direct implication of the fact that the exports elasticity is three times larger than the imports elasticity, as shown by equation (25).

The exchange rate offsets, thus, are sensitive to the values of ϵ_m and ϵ_x. A larger import elasticity magnifies the expenditure switching effect on the side of imports. Thus, it increases the exchange rate offset for an import tariff but reduces it for an export tariff. For example, if the import elasticity is increased from 1 to 1.5 (as measured by Imbs and Mejean (2016) for the US) the exchange rate offset increases from 0.296 to 0.383 in absolute value for a tariff on imports and decreases from 1 to 0.876 for a tariff on exports. Similarly, a larger export elasticity magnifies the expenditure switching effect on the side of exports, which increases the exchange rate offset for an export tariff but reduces it for an import tariff.

The exchange rate offsets are not very sensitive to the other elasticities. Increasing the Frisch elasticity from 1/3 to 2 (in line with the macroeconomic estimates of this elasticity) increases the exchange rate offset for imports by 0.02 and does not change the exchange rate offset for exports. Lowering the elasticity of intertemporal substitution ϵ_i from 1 to 0.5 (i.e., increasing risk aversion from 1 to 2) changes both exchange rate offsets by less than 0.01.

3.2 Tariff rates

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 average tariffs introduced by the US in 2018-19 amounted to 15.1 percent of the value of US imports of goods from China. China retaliated against the US by implementing their own tariffs on imports of goods from the US. As reported in Table B2, the average tariffs introduced by China on US goods amounted to 14.2 percent.

Contrary to the baseline model, the tariffs did not apply uniformly to all imports and exports. US imports from China represent only a fraction US imports and Chinese imports from the US represent only a fraction of Chinese imports. This matters because households can substitute taxed imports by non-taxed imports. We need to derive the average effective tariff rates faced by the US and China accounting for these substitution effects.

Assume that tariff τ is applied to a fraction μ of the home country's imports. The home currency price of imports is

$$P_F = \left[(1-\mu)\left(EP^*\right)^{1-\epsilon_x} + \mu\left((1+\tau)EP^*\right)^{1-\epsilon_x}\right]^{\frac{1}{1-\epsilon_x}}, \tag{26}$$

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

$$P_F = (1+\tilde{\tau})EP^* \tag{27}$$

where the *effective* tariff on imports $\tilde{\tau}$ is defined by

$$1+\tilde{\tau} = \left[1-\mu+\mu\left(1+\tau\right)^{1-\epsilon_x}\right]^{\frac{1}{1-\epsilon_x}}. \tag{28}$$

The average effective tariff on imports is equal to the arithmetic average $\mu\tau$ in the limit case where the elasticity ϵ_x is equal to zero. If $\epsilon_x > 0$ the average effective tariff $\tilde{\tau}$ is lower than τ because the country substitutes taxed imports by non-taxed imports. One can similarly define the effective tariff rate on exports.

To derive the effective tariffs, we need the tariff rates and the share of goods that bear the tariff. The shares of the US and China in each other's exports and imports are reported in Table 3. The table points to an asymmetry that is quite important for our results. The US imports from China represent a substantial share of both US imports and Chinese exports. The Chinese imports from the US amount to a much smaller share of Chinese imports or US exports. This is not surprising given the large bilateral trade deficit of the US with China. The Chinese exports to the US are more than three times as large as the US exports to China.

Using these values and the average tariff rates (reported in Tables B1 and B2 in the appendix) we derive the average effective tariff rates on imports and exports for the US and

Table 3: Shares of the US and China in each other's exports and imports

	US	CH
Imports share	0.219	0.084
Exports share	0.098	0.222

China and report the values in Table 4.

Table 4: Effective tariff rates (%)

	Imports	Exports
US	2.8	1.2
China	1.0	2.8

3.3 Exchange rate impact of tariffs

Using the effective tariff rates and the exchange rate offsets derived above, we are finally equipped to derive the exchange rate impact of the US-China tariff war. The impact of the tariffs on the effective exchange rates is estimated using the following formulas,

$$\Delta e_{US} = \left.\frac{de}{d\tau}\right|_{US} \cdot \tilde{\tau}_{US} + \left.\frac{de}{d\tau^*}\right|_{US} \cdot \tilde{\tau}^*_{US}, \tag{29}$$

$$\Delta e_{CH} = \left.\frac{de}{d\tau}\right|_{CH} \cdot \tilde{\tau}_{CH} + \left.\frac{de}{d\tau^*}\right|_{CH} \cdot \tilde{\tau}^*_{CH}, \tag{30}$$

The terms $de/d\tau$ and $de/d\tau^*$ are the exchange rate offsets reported in Table 2 and the $\tilde{\tau}$ are the effective tariffs on imports and exports reported in Table 4.

Table 5 reports the results. The first column reports the model predicted effective appreciation of the dollar and renminbi caused by the tariff on imports. The second column reports the effective depreciation caused by the tariffs on exports and the last column reports the net impact.

Table 5: Impact of tariffs on dollar and renminbi effective exchange rates

	Appreciation due to τ	Depreciation due to τ^*	Net appreciation
USD	0.8%	1.2%	-0.3%
CNH	0.3%	2.8%	-2.6%

Note: The numbers may not add up due to rounding

Table 5 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 more than twice as large as 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.

On the other hand, the model predicts that the tariffs introduced in 2018-19 depreciated the renminbi by 2.6%. Export tariffs were more than twice the size of import tariffs, creating a large response in the exchange rate. Although the US and China imposed similar tariff rates on each other, the asymmetry in the trade between the two countries leads to an asymmetry in the impact of these tariffs on exchange rates. The model predicts a minimal impact on the dollar but a sizable multilateral depreciation of the renminbi.[9]

3.4 Small open economy assumption

There are several discrepancies between the model and reality that one might be concerned about. Most importantly, the small open economy assumption is objectionable when applied to the US and Chinese economies. We do not believe that this problem would be well addressed by using a two-country model. Although the US and China are the two largest economies in the world, their economies taken together amount to about one-third of global GDP. [10] Given the limited trade dependence between the two countries, it would be misleading to consider a model where all the trade in the world takes place between the US and China.

Alternatively, we could use a three-country model with the third country representing the rest of the world. This precludes closed-form solutions—the advantage of using a small open economy model is that it is tractable due to the absence of complex cross-country interactions. But we can solve for the equilibrium of the three-country model numerically. Appendix A presents a three-country model embedding the same assumptions about preferences and parameter values as our small-open economy model. As shown in the appendix, we find that the implications of the three-country model for the exchange rate offset are quantitatively quite close to those of the small open economy model. Thus, it does not seem that general equilibrium effects are first-order and our small-open economy model provides a good approximation for the estimation of the exchange rate offset.

[9] We also derived the exchange rate impact of tariffs using the import elasticities estimated by Imbs and Mejean (2016) where $\epsilon_m = 1.5$ for the US and $\epsilon_m = 3$ for China. These import elasticities imply a net appreciation of the USD by 0.2% and a net depreciation of the CNH by 1.3% . Compared to the estimates shown in Table 5, the net depreciation of the CNH is reduced by about one half while the net appreciation of the USD remains close to 0%.

[10] The exact number is 34.1% in 2020 according to the PPP-adjusted data in the October 2020 World Economic Outlook database.

4 Tariff News, the Dollar and the Renminbi

This section investigates the impact of news about US and Chinese tariffs on the dollar and renminbi effective exchange rates. We use high-frequency data to identify the causal impact of the news on the exchange rate.

4.1 News sample

Our main sample of tariff news was constructed using news reported by Bloomberg. 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. We kept only the news related to the imposition of tariffs by the US on China or by China on the US.

More precisely, the Bloomberg Terminal categorizes news from all sources by topics and by importance. One category is "Trade Tariffs, Wars" and the label "Hot" is attached to breaking news headlines from Bloomberg News and Bloomberg First Word with global impact as determined by editorial judgment. We used both sets of keywords, "Trade Tariffs, Wars" and "Hot," to identify the news in our sample. This resulted in a total sample of 230 news from which we dropped the news that were not related to bilateral tariffs bwtween the US and China. Bloomberg usually reports the news within two minutes after being released by an official source.

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. All news contained information about the implementation or reduction of tariffs. The source of these announcements varied: some were official statements by the US or Chinese government, and others were tweets by the US president.[11] 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 renminbi per dollar exchange rate on dummy variables for the tariff news

[11] We do not directly use government announcements or tweets to identify news. Rather, we use news from Bloomberg that report such announcements and tweets. As a robustness check, we identify the relevant events using a timeline of the US-China Trade war by Bown and Kolb (2023) and identify the exact time of the events by using whatever media source reports it the earliest, including official government announcements and tweets. This did not significantly change the results.

in non-overlapping time windows of different lengths (one, two, three, four, and five hours). The regression specification is

$$\frac{E_t - E_{t-k}}{E_{t-k}} = \alpha + \beta_u U_t + \beta_c C_t + \varepsilon_t, \tag{31}$$

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 the value 1 (-1) if there were news about a tariff 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.[12]

The results are reported in the first row of Figure 3. The figure shows how the point estimates of β_u and β_c in regression (31) 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 renminbi 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 (31) 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.[13] The NEERs are measured in such a way that an increase

[12] We do not have exchange rate data from Friday 5:00 pm to Sunday 4:50 pm 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 (31) for weekends and weekdays separately and find similar results.

[13] 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. Our currency baskets are described in more detail in Appendix C2.

in the NEER corresponds to an effective appreciation of the currency. The regression results are reported in the second and third rows of Figure 3 for the same five-hour time window as in the first row.

The second row of Figure 3 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 3 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 renminbi than for the dollar.

The response of the bilateral exchange rate to US tariff news shown in the first row of Figure 3, thus, reflects both an effective depreciation of the renminbi and an effective appreciation 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. This is consistent with the model to the extent that Chinese tariffs apply to smaller trade flows than US tariffs. Perhaps this is also due to the fact that the Chinese authorities resisted the depreciation of the renminbi induced by their own tariff announcements, or to the imperfect identification of the time of Chinese tariff news by Bloomberg.

4.2 Cumulative Impact of News

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 since our regressions show that the impact of Chinese tariff news is not statistically significant. We measure the impact of increasing US tariff news by averaging the estimated β_u over the 3, 4, and 5 hour horizons. We find that news of a US tariff increase appreciated the dollar NEER by about 0.08 percent and depreciated the CNH NEER by about 0.17 percent (see Figure 3). 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 should not expect our news-based analysis to provide the same estimates as the calibrated model 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, e.g., changes in global political uncertainty. It is nevertheless interesting to observe that the two approaches yield results that are broadly consistent in terms of sign or magnitude. For the sake of comparison, Table 6 reports the rates of appreciation of the dollar and 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 5). The signs and orders of magnitude of the effects are broadly similar in the model and the news analysis.

Table 6: Comparison of theory and empirics

	Dollar	Renminbi
Observed	4.2%	-3.1%
Model	0.8%	-2.8%
News	0.9%	-2.0%

4.3 Robustness

Our empirical results are robust to a number of changes in the data or regression specifications.[14] First, we used a different source, Bown and Kolb (2023)'s trade war timeline, to identify tariff-related events. As Bown and Kolb report only the day of the event, we used the Bloomberg Terminal to find the release time of the earliest news that conveyed information about the event, which includes Twitter, Dow Jones news, reports from the Ministry of Commerce in China in addition to Bloomberg 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 twenty 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.

The empirical results using the BK sample turned out to be almost the same as those

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

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 across 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.[15] 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.

As an additional robustness check exercise, we increased the time window to one day, one week, and one month. We find that the US dollar appreciates in response to US tariff news at the daily frequency. However, we do not find a statistically significant result at the weekly and monthly frequencies. Also, the US dollar is not responsive to Chinese tariff news at the daily, weekly, and monthly frequencies. The Chinese renminbi depreciates in response to US tariff news at the daily and weekly frequency, but there is no statistically significant response at the monthly frequency. Surprisingly, we find that the Chinese renminbi actually depreciates in response to Chinese tariff news at the daily and monthly frequencies, but not at the weekly frequency. This response is at odds with what the theory predicts and may have to do with other events that took place within the larger time window that reverse the effects of the Chinese tariff on the exchange rate.

We also checked for the possibility of news affecting exchange rates with a lag. To do this we added five lags of the dependent and independent variables to the right-hand-side of equation (31) and ran the regression for both 1-hour and 5-hour time windows. We find that our results are robust. The US dollar appreciates and the Chinese renminbi depreciates in response to US tariff news released in the same time window but both currencies do not respond in a statistically significant manner to Chinese tariff news released in the same time window.

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

[15] 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.

depreciate the renminbi. Chinese tariff news have no statistically significant effect on both currencies.

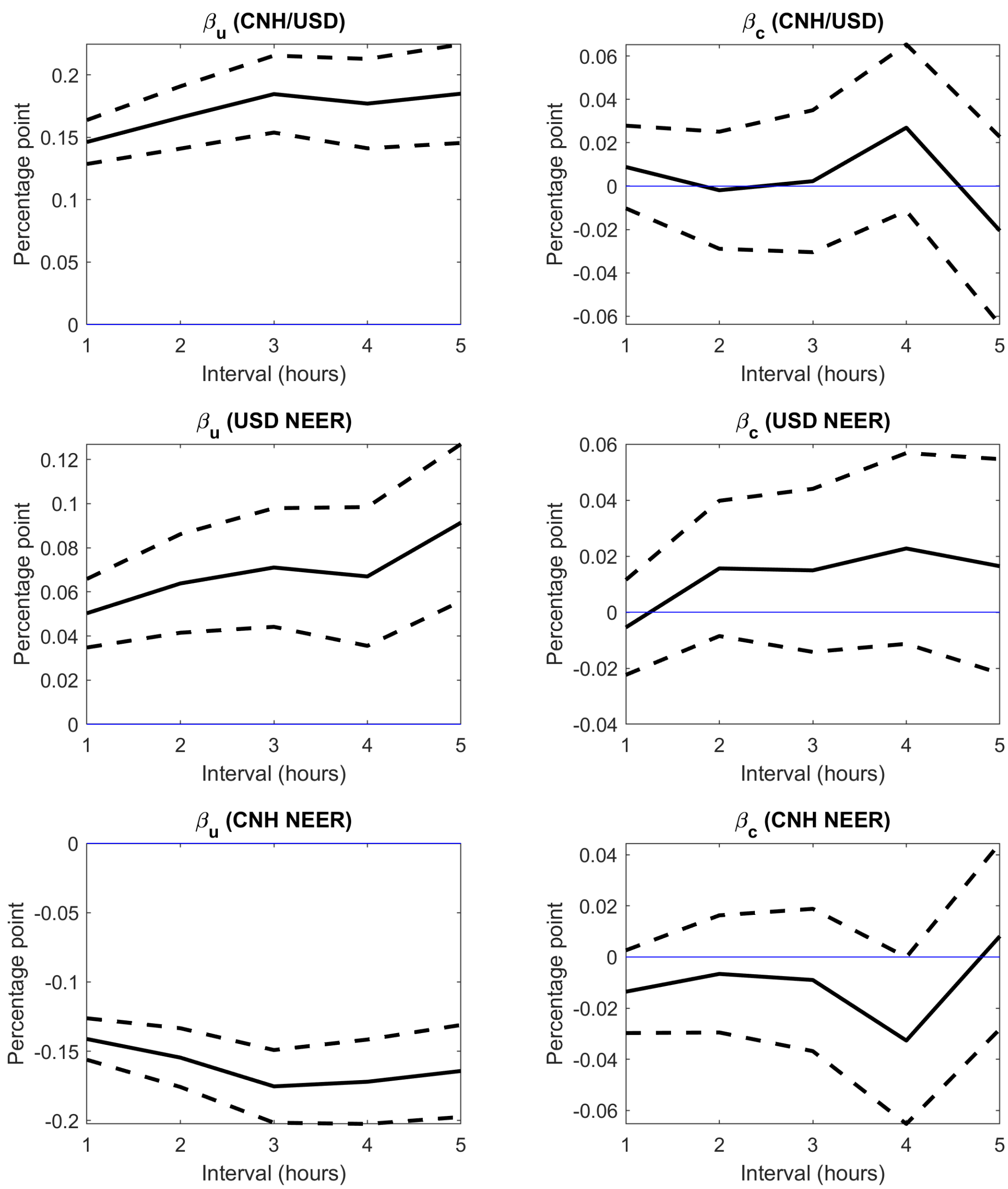
5 Conclusions

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 that explained how the tariffs may have caused a depreciation of the reminbi as well as an appreciation of the dollar. Our model furthermore suggests that tariffs may explain a substantial fraction of the changes in the renminbi (and to a lesser extent of the dollar) effective exchange rate observed during that period. This result is robust to various changes in the assumptions of the model.

On the empirical side, we looked for evidence of the 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 predictions of the model.

Our simple model does not incorporate all the potentially 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. 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.

Figure 3: 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 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 terms 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

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

The balance of payment identity is derived from (4), (6), (7), (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 (7) 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,

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

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

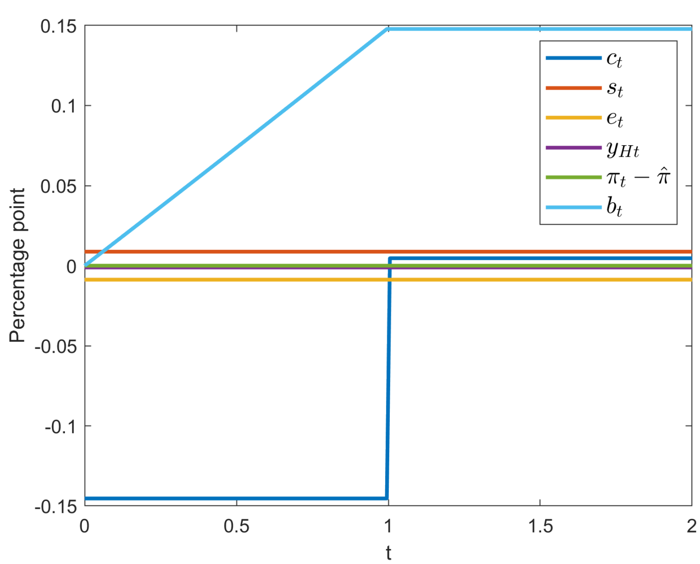
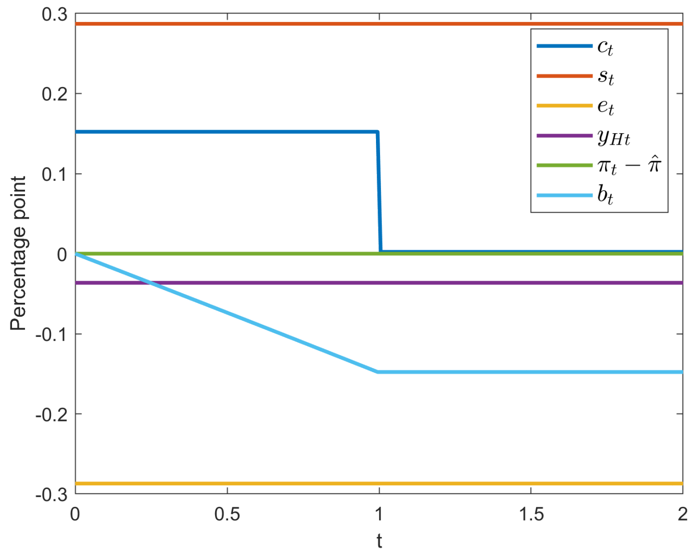


Figure A2: Expected 1 percent tariff on imports



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, and 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 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.[16] In addition, home producers

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

Figure A3: Transitory 1 percent tariff on exports

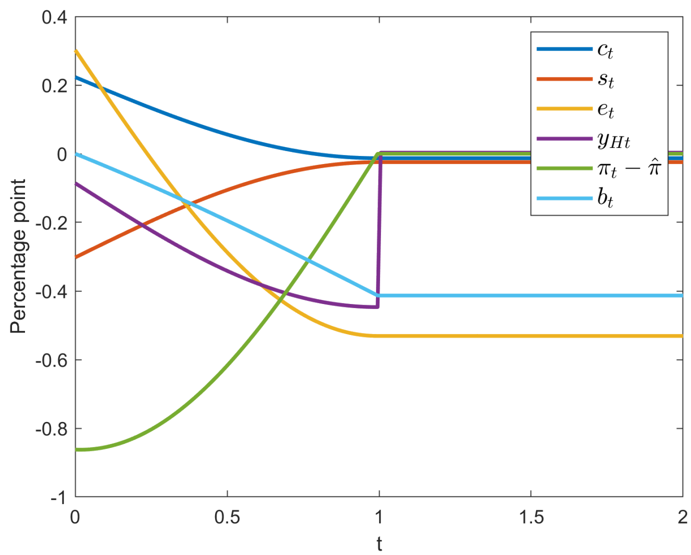
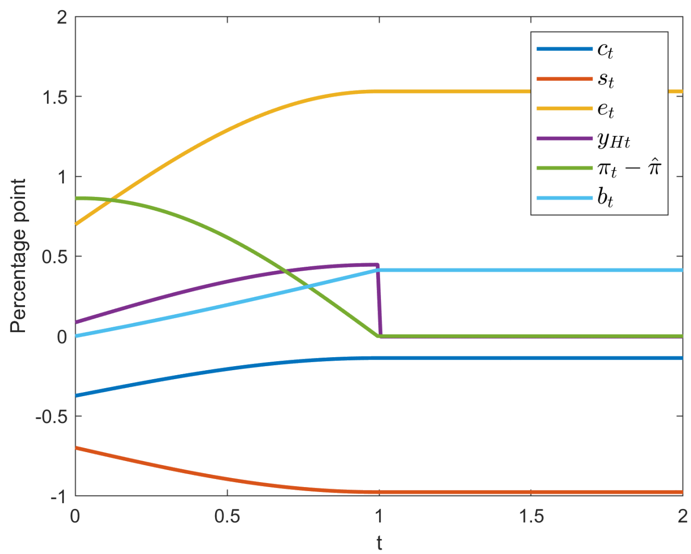


Figure A4: Expected 1 percent tariff on exports



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).[17]

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.

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 (7) 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,

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

[17] 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 $T = 1$.

or, after linearization

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

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

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

or, after linearization,

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

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^*, $\pi_t - \hat{\pi}$, $\pi_t^* - \hat{\pi}$ and b_t. We solved this system with Dynare to obtain the transition dynamics reported in Figures A5 and A6.[18] The figures are discussed in the text.

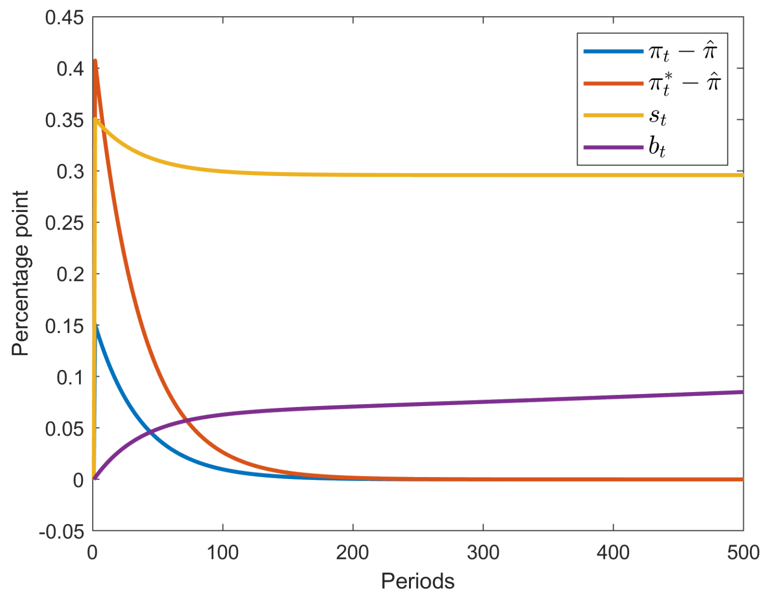
DCP in the US. In the US, DCP implies that both exports and imports are invoiced in dollars. Hence, the difference between DCP and PCP is that under DCP imports are priced in dollars rather than in foreign currency. As mentioned in the text, the impact of tariffs under DCP is more complicated to analyze 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

[18] 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. See Adjemian et al. (2022) for a presentation of Dynare.

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



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.

A6. Sticky wages

In this section, we explore the case of sticky wages by allowing households to be monopolistic suppliers of labor. Each household $j \in [0, 1]$ is a monopolistic supplier of its own labor. Household j maximizes the following lifetime welfare function

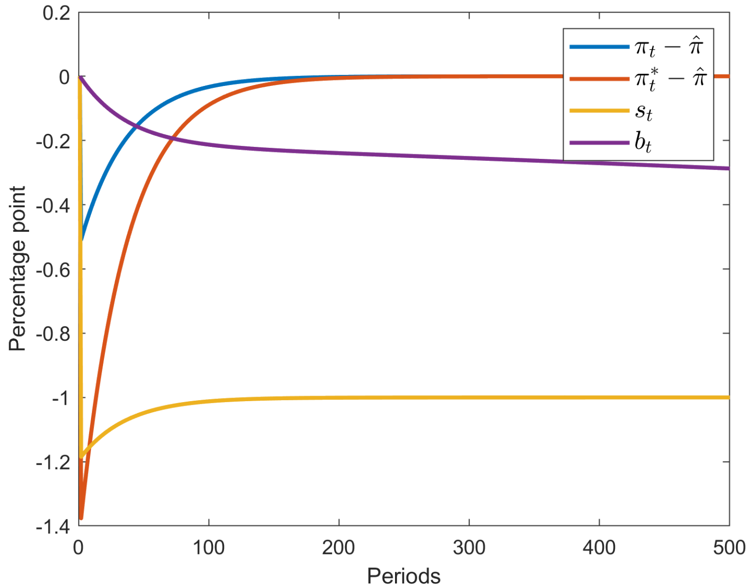
$$\int_0^{+\infty} \left(\frac{C_t^{1-1/\epsilon_i} - 1}{1 - 1/\epsilon_i} - \frac{N_{jt}^{1+1/\epsilon_\ell}}{1 + 1/\epsilon_\ell} \right) e^{-rt} dt$$

subject to the following budget constraint

$$\dot{B}_t + \frac{P_{Ht}}{E_t P_t^*} C_{Ht} + (1 + \tau_t) C_{Ft}$$
$$= (\frac{\epsilon_n}{\epsilon_n - 1}) \frac{W_{jt} N_{jt}}{E_t P_t^*} - \frac{\theta_W}{2} \left(\frac{\dot{W}_{jt}}{W_{jt}} - \hat{\pi}_W \right)^2 \frac{W_t N_t}{E_t P_t^*} + Z_t + D_t + r B_t$$

The budget constraint differs from that introduced in equation (4) by the quadratic cost of adjusting wages, introducing wage stickiness in the model akin to how we introduce price stickiness. θ_W is a parameter that determines how rigid wages are and $\hat{\pi}_W$ is the target wage

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



inflation. This equation includes a subsidy on wages to correct the monopolistic distortion. The household internalizes the demand for its demand by firms, which is given by the following:

$$N_{jt} = \left(\frac{W_{jt}}{W_t}\right)^{-\epsilon_n} N_t$$

where ϵ_n is the elasticity of substitution across varieties of labor.

The optimal choice of wages by households results in the wage Phillips Curve

$$(\pi_{Wt} - \hat{\pi}_W)(r - \frac{\dot{N}_t}{N_t} - \pi_{Wt}) = \frac{\epsilon_n}{\theta_W}(\frac{N_t^{\frac{1}{\epsilon_\ell}}/W_t}{C_t^{-\frac{1}{\epsilon_i}}/P_t} - 1) + \dot{\pi_{Wt}}$$

The product $(\pi_{Wt} - \hat{\pi_W})(\frac{\dot{N_t}}{N_t} - \pi_{Wt})$ is dropped because it is second order, and after linearizing the righthand side, we get the following wage Phillips Curve:

$$\dot{\pi_{Wt}} = r(\pi_{Wt} - \hat{\pi}_W) - \frac{\epsilon_n}{\theta_W}\left[\frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} - \omega_F\left(s_t - \tau_t\right) - \left(w_t - p_{Ht}\right)\right]$$

Under constant tariffs, the linearized model with both sticky prices and wages is

$$\begin{aligned}
c_t &= \gamma - \epsilon_i \left(\omega_H s_t + \omega_F \tau_t\right) \\
y_{Ht} &= \omega_H c_t - \omega_F \left[\omega_H \epsilon_m (s_t - \tau_t) + \epsilon_x (s_t + \tau_t^*)\right] \\
\dot{\pi}_t &= r\left(\pi_t - \hat{\pi}\right) - \alpha\left[w_t - p_{Ht}\right] \\
\dot{s}_t &= -\left(\phi - 1\right)\left(\pi_t - \hat{\pi}\right) \\
\dot{\pi}_{Wt} &= r(\pi_{Wt} - \hat{\pi}_W) - \frac{\epsilon_n}{\theta_W}\left[\frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} - \omega_F\left(s_t - \tau_t\right) - \left(w_t - p_{Ht}\right)\right]
\end{aligned}$$

where the first four equations are the same as in equations (13) - (16) except that (15) is changed since $w_t - p_{Ht} = \frac{y_{Ht}}{\epsilon_\ell} + \frac{c_t}{\epsilon_i} - \omega_F\left(s_t - \tau_t\right)$ no longer holds in general. $w_t - p_{Ht}$ is the first-order deviation from the steady state real wage $(\frac{W_t}{P_{Ht}})$.

By letting $\pi_{wt} = \hat{\pi}_W$ and $\pi_t = \hat{\pi}$, we can derive the same steady state supply and demand equations for the home goods as in (19) and (20). Therefore, permanent tariffs have the same exchange rate implications even if sticky wages are introduced since there are no transition dynamics.

A7. Three-country model

We compare our baseline results to those derived in a three-country model. We assume there are three countries indexed by 1, 2 and 3. Country 1 represents the US, country 2 represents China and country 3 represents the rest of the world. Households in each country are endowed with a constant endowment of home good Y_i and the price of this good in terms of home currency is normalized to 1. The law of one price applies for all goods. In a steady state equilibrium country i's households solve the following problem.

$$\begin{aligned}
\max \quad & u(C_i) \\
s.t. \quad & C_{ii} + (1+\tau_{ij})E_{ij}C_{ij} + (1+\tau_{ik})E_{ik}C_{ik} = Y_i + \Pi_i,
\end{aligned}$$

where C_{ij} is the consumption of good j by the households of country i, and the tax revenues from import tariffs are rebated to households as a lump sum, Π_i. For the US and China aggregate consumption C_i is defined as a CES index of domestic good consumption and imported good consumption:

$$C_i = \left[\omega_{ii}^{1/\epsilon_m} C_{ii}^{(\epsilon_m - 1)/\epsilon_m} + (1 - \omega_{ii})^{1/\epsilon_m} C_i^{*(\epsilon_m - 1)/\epsilon_m}\right]^{\epsilon_m/(\epsilon_m - 1)}$$

where C_i^* represents the aggregate imported goods consumption of households in country i. For the rest of the world aggregate consumption is defined by a similar CES index but with elasticity ϵ_x instead of ϵ_m. We assume that the elasticity of substitution across domestic and import consumption is ϵ_x as the rest of the world's domestic consumption encompasses trade between different countries within the rest of the world.

Aggregate imported goods consumption is a CES index of consumption from the two other countries:

$$C_i^* = \left[\theta_{ij}^{1/\epsilon_x} C_{ij}^{(\epsilon_x - 1)/\epsilon_x} + \theta_{ik}^{1/\epsilon_x} C_{ik}^{(\epsilon_x - 1)/\epsilon_x}\right]^{\epsilon_x/(\epsilon_x - 1)}$$

where $\theta_{ij} = \frac{\omega_{ij}}{1-\omega_{ii}}$.

The price of currency j in terms of currency i is denoted by E_{ij}. The no-arbitrage condition $E_{ij}E_{jk} = E_{ik}$ applies to all combinations of $i, j, k \in \{1, 2, 3\}$. The aggregate budget constraint of country i is then given by

$$C_{ii} + E_{ij}C_{ij} + E_{ik}C_{ik} = Y_i. \tag{A17}$$

The first-order conditions for households in country i are given by

$$u_{ii} = \frac{u_{ij}}{(1 + \tau_{ij})E_{ij}} = \frac{u_{ik}}{(1 + \tau_{ik})E_{ik}} \tag{A18}$$

where $u_{ij} \equiv \frac{\partial u(C_i)}{\partial C_{ij}}$.

We let ω_{ij} be the share of country i's spending that goes to country j and denote by $\Omega = (\omega_{ij})$ be the spending allocation matrix. Country i's endowment is equal to the demand coming from itself and the other countries, that is

$$Y_i = \sum_j \omega_{ji} Y_j. \tag{A19}$$

We solve for the three-country model by linearizing around the steady state. The three aggregate budget constraints given by Equation (A17), six household first-order conditions given by Equation (A18) and two market clearing conditions given by Equation (A19) allow us to solve for the consumption and price levels in the three countries.[19]

We calibrate the model by matching trade flows and GDP of the US, China and the rest of the world. We use the USD value of imports in 2017 from ITC and the current USD value of GDP in 2017 from the WB database.[20]

[19] There are only two market clearing conditions derived from Equation (A19) following Walras's Law.

[20] There are zero net trade flows since we assume a static model. This reduces the degree of freedom that

Using this calibration, we derive the exchange rate offsets for import and export tariffs under the three-country model and compare them to the baseline results in Table A1.[21] In the case of the three-country model, the exchange rate offsets are derived as changes in the effective exchange rate in response to a one percent tariff on all imports or all exports. The differences between the small open economy model and the three-country model are small.

Table A1: Exchange rate offsets for the US and China

	US		China	
	SOE	3-country	SOE	3-country
Import tariff	-0.296	-0.303	-0.286	-0.286
Export tariff	1	0.972	1	0.990

Appendix B. US and Chinese Tariffs

The average tariffs in Table 5 are constructed using data from the International Trade Centre (ITC) and various publications from the Peterson Institute for International Economics (PIIE).[22] We include all the tariffs implemented in 2018-19 that resulted from the US' Section 301 investigation of China with regards to unfair trade practices for technology and intellectual property. These are reported in the US tradewar timeline of Bown and Kolb (2023).

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 Trump administration first imposed a 25 percent tariff on $50 billion of Chinese goods in the summer of 2018 on grounds of unfair trade practices by China related to technology transfer, intellectual property, and innovation. This was soon 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 a 15 percent tariff on $112 billion of Chinese goods in September 2019. The last row shows total US imports of goods from China in 2017 and the computed average tariff rate imposed by the US on its imports from China.

Similarly, Table B2 reports the tariffs on Chinese imports from the US imposed in 2018-19. These tariffs were implemented as retaliations against the tariffs that US imposed on

we have for matching trade flows by two so that that we match four trade flows out of six (we do not match the ROW imports from the US and the ROW imports from China).

[21]We assume that labor supply elasticity is 0 in the small open economy model so that there is an exogenous supply of goods as in the three-country model.

[22]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.

goods from China. In 2017, the total amount of goods imported by China from the US was \$154.8 bn, resulting in an average tariff rate of 14.2% on goods imported from the US. We use tariff and import data at the 8-digit product level from Bown (2019) to derive the average tariff rates for incidents where the tariff rates were not uniform across products.

Table B3 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 data. The RoW is defined as the world without the US and China. 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 \$1,417.2 bn whereas the flow of exports from the rest of the world to the US (i.e., US imports) amounted to \$1,840.1 bn.

Table B1: US tariffs on imports from China

2017 import value (billion USD)	Tariff rate	Initiation Date
34	25%	7/6/2028
16	25%	8/23/2018
200	25%	9/24/2018 5/10/2019 Rate increased
112	15%	9/1/2019
2017 Total US imports from China: \$525.7 bn Average tariffs on US imports from China: 15.1%		

Table B2: Chinese tariffs on imports from the US

2017 import value (billion USD)	Tariff rate	Initiation Date
34	25%	7/6/2028
16	25%	8/23/2018
60	13%	9/24/2018 6/1/2019 Rate increased
28.7	6%	9/1/2019
2017 Total China imports from US: \$154.8 bn Average tariffs on Chinese imports from the US: 14.2%		

Table B3: Trade flows (\$bn, 2017)

	RoW	US	China
RoW	·	1,880.3	1,686.1
US	1,417.2	·	154.8
China	1,840.1	525.7	·

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.[23] 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 (7) 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,

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

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

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

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

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

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

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

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

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

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

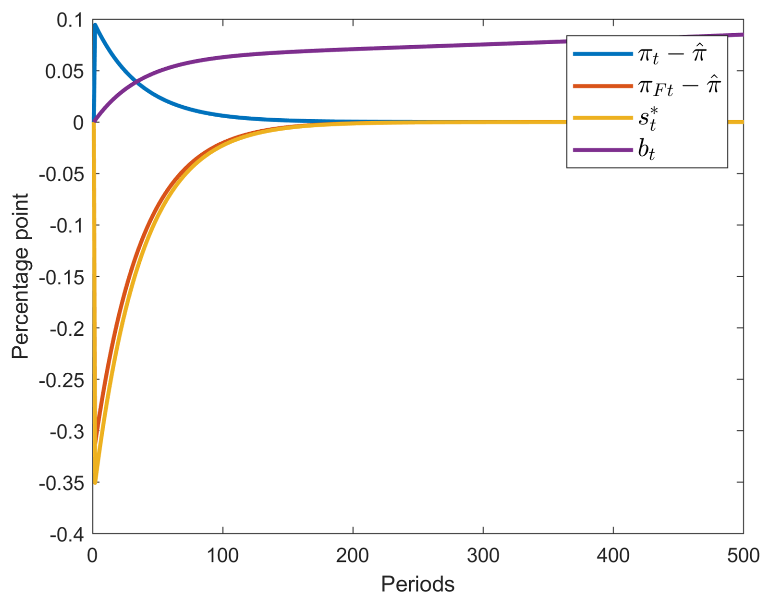
$$\dot{\pi}_t^* = \rho(\pi_t^* - \hat{\pi}) - \alpha \left[\left(\frac{1}{\epsilon_\ell} + \frac{1}{\epsilon_i}\right) c_t^* - \omega_F s_t^*\right]. \tag{C9}$$

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.

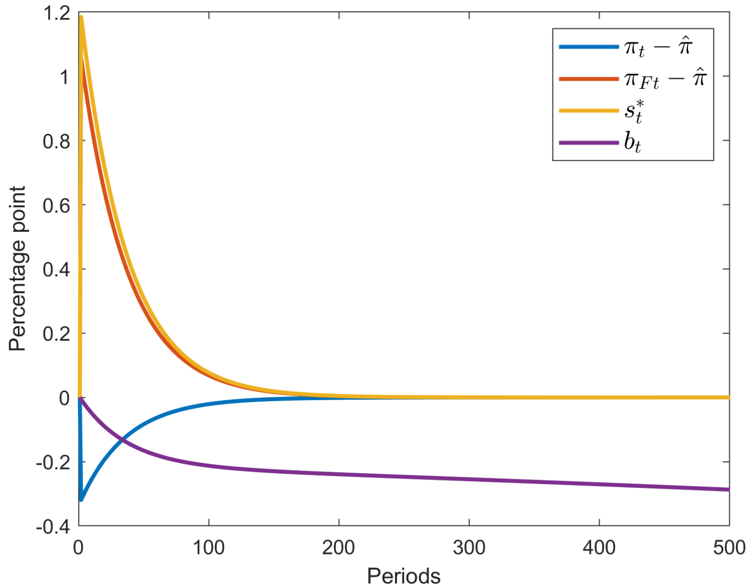
Figure C1: Impulse responses of 1 percent tariff on US imports under DCP



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



C3. Event study: the Bown-Kolb news sample

Table C2 reports the events relevant to the US-China tradewar provided by Bown and Kolb (2023) as well as our categorization of the news. Contrary to our benchmark sample that prioritizes news, the Bown and Kolb timeline reports distinct events that occurred. 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. In relation to our benchmark Bloomberg sample, 8 out of 37 events are explicit to the BK sample. These include all 3 events from the Trade Battle #1 defined by Bown and Kolb (2020) which is related to imports of solar panels and washing machines damaging the US industry. They also include 3 events that highlight the actual implementation or reduction of tariffs. Of the remaining two events explicit to the Bk sample, one of the events appears with different timing in the Bloomberg sample and one is simply missing.

Figure C3 shows the point estimates and 95 percent confidence intervals of coefficients β_u and β_c in regression (31) 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 95 percent confidence intervals. The figures show similar qualitative results as Figure 3, except for the statistical insignificance of US tariff news on the USD NEER for

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

the three and four-hour time 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 (31) using only tariff news that occurred on weekdays. The results are close to our benchmark results in Figure 3. US tariff news appreciate the dollar and depreciate the renminbi for all time windows. Chinese tariff news have no statistical significance for both currencies and the bilateral exchange rate 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 include separate dummies for each type of event,[24]

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

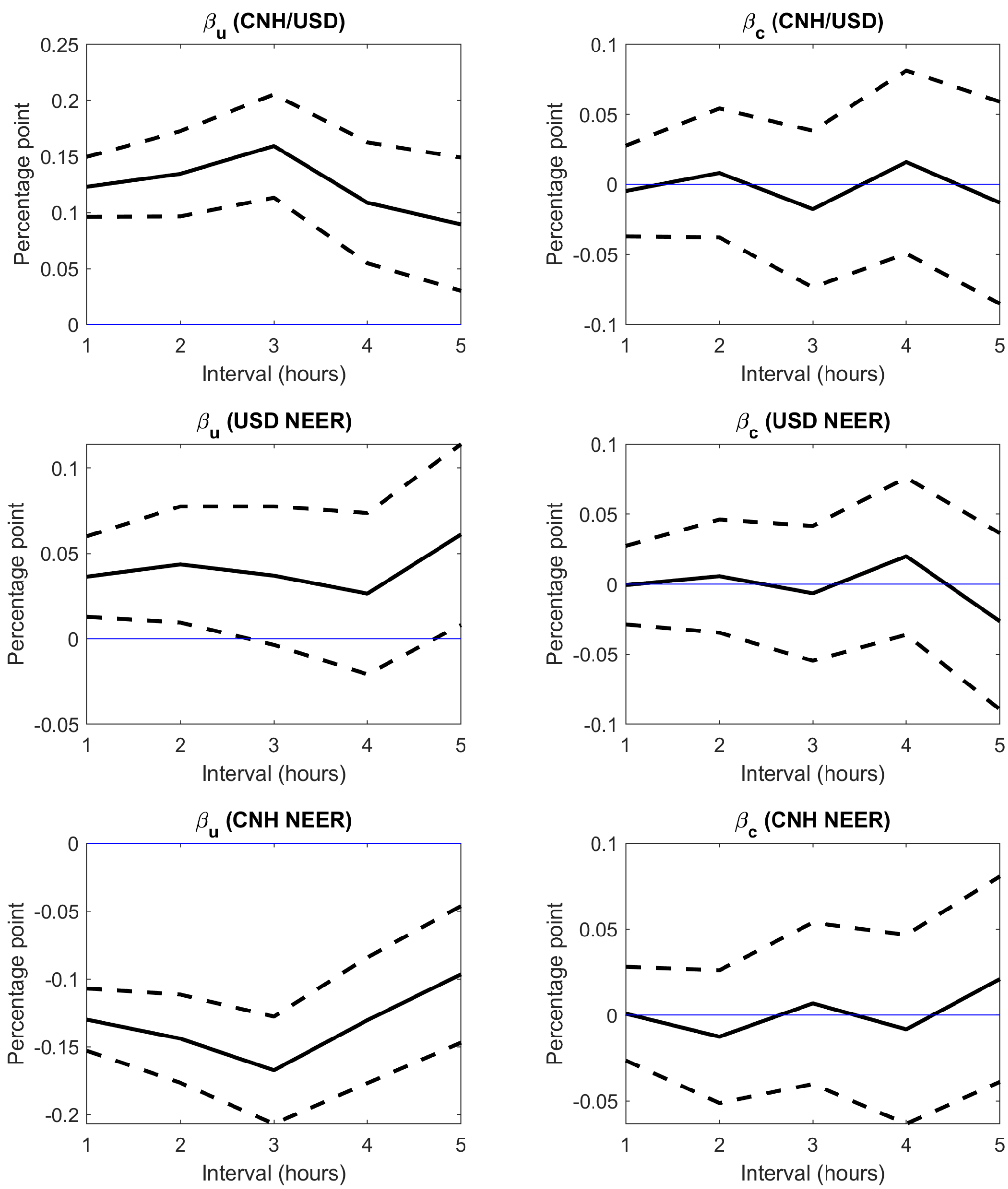
and

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

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

[24] U_t and C_t are defined as in regression (31). 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 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



To check how sensitive the results are to longer time windows, we run regression (31) under daily, weekly, and monthly frequencies. The results are reported in Figure C6. We find that at the daily frequency, the results are intact. US tariff news appreciates the USD relative to the CNH, appreciates the USD NEER, and depreciates the CNH NEER. These results disappear at the weekly and monthly frequencies. Additionally, the bilateral exchange rate and USD NEER do not show a statistically significant response to Chinese tariff news for all frequencies while the CNH NEER depreciates in response to Chinese tariff news at the monthly frequency but is unresponsive at the daily and weekly frequencies. This result is at odds with the theory telling us that the CNH NEER would appreciate in response to Chinese tariff news. This finding may be due to other non-tariff-related events that occurred in the same month as Chinese tariff news and emphasizes the importance of short intervals for event studies. Overall, we find that the benchmark results hold at the daily frequency, but disappear and may have become tainted at longer horizons.

We also conduct a robustness check to see how lagged dependent and independent variables may change our results. We run the following regression:

$$\Delta e_t = \alpha + \beta_u U_t + \beta_c C_t + \sum_{k=1}^{5} \beta_{e,k} \Delta e_{t-k} + \sum_{k=1}^{5} \beta_{u,k} U_{t-k} + \sum_{k=1}^{5} \beta_{c,k} C_{t-k} + \varepsilon_t \qquad \text{(C12)}$$

where Δe_t is the change in CNH/USD bilateral exchange rate or the appreciation of the NEER from period $t-1$ to period t. We check for the statistical significance of β_u and β_c for CNH/USD, the USD NEER, and the CNH NEER using 1-hour and 5-hour intervals. β_u is positive for CNH/USD and the USD NEER and negative for the CNH NEER and all are statistically significant at the 0.1%. β_c is statistically insignificant at the 5% for both currencies and the bilateral exchange rage for both time windows. These results imply that the results of our empirical exercise hold even after controlling for the possibility that news affect exchange rates after some time has passed and the possibility that markets expected the news prior to its release.

We also run regression (31) using overlapping time windows and the Newey-West standard errors to correct for the autocorrelation of observations. The regression results are reported in Figure C7. 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 and the bilateral exchange rate for all time windows.

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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

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

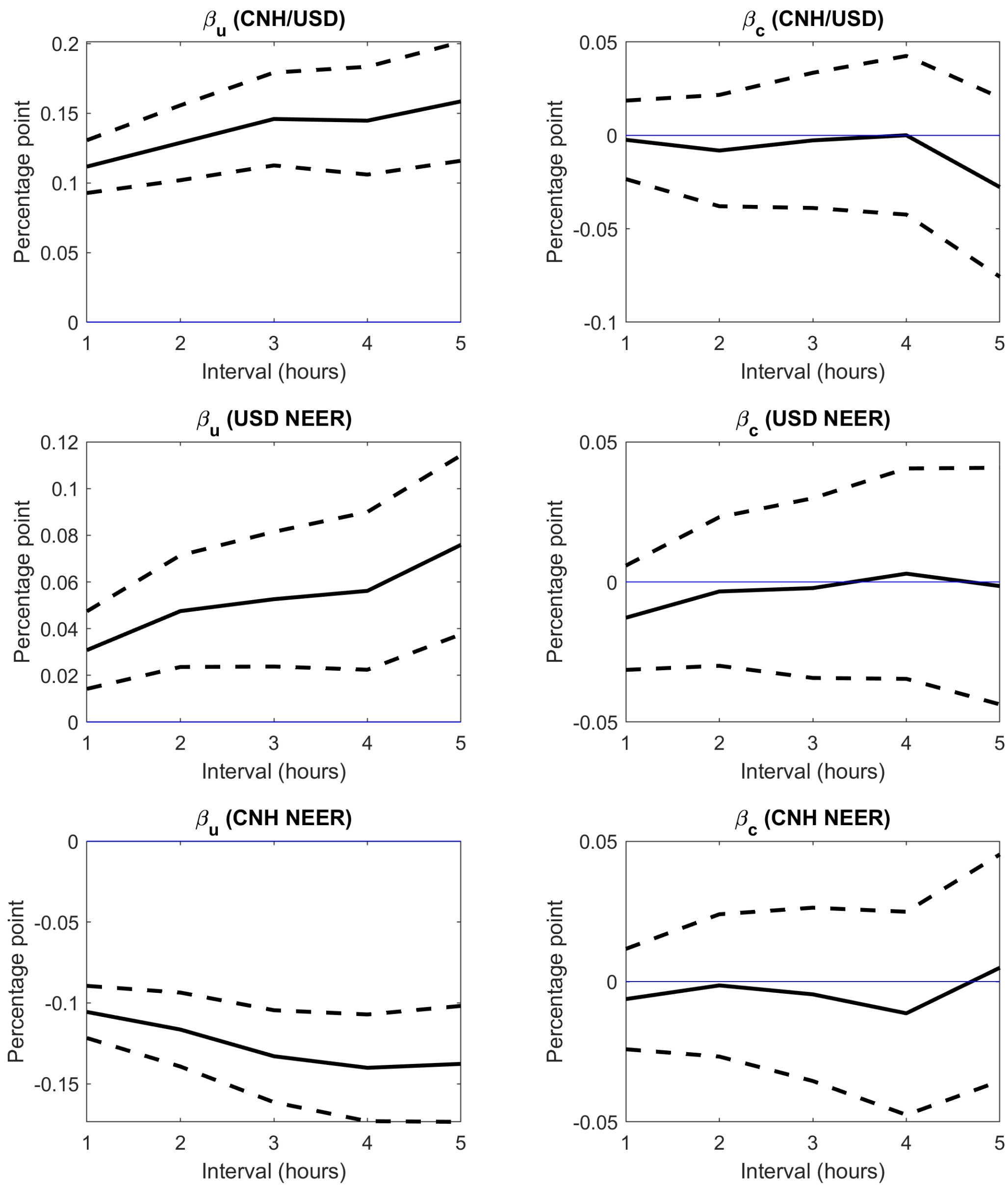

Table C3: 95 percent confidence interval for β_u and β_c using weekend data

Exchange rate	β_u	β_c
CNH/USD	[0.376 0.552]	[-0.077 0.139]
USD NEER	[0.146 0.268]	[-0.058 0.091]
CNH NEER	[-0.557 -0.381]	[-0.132 0.084]

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)

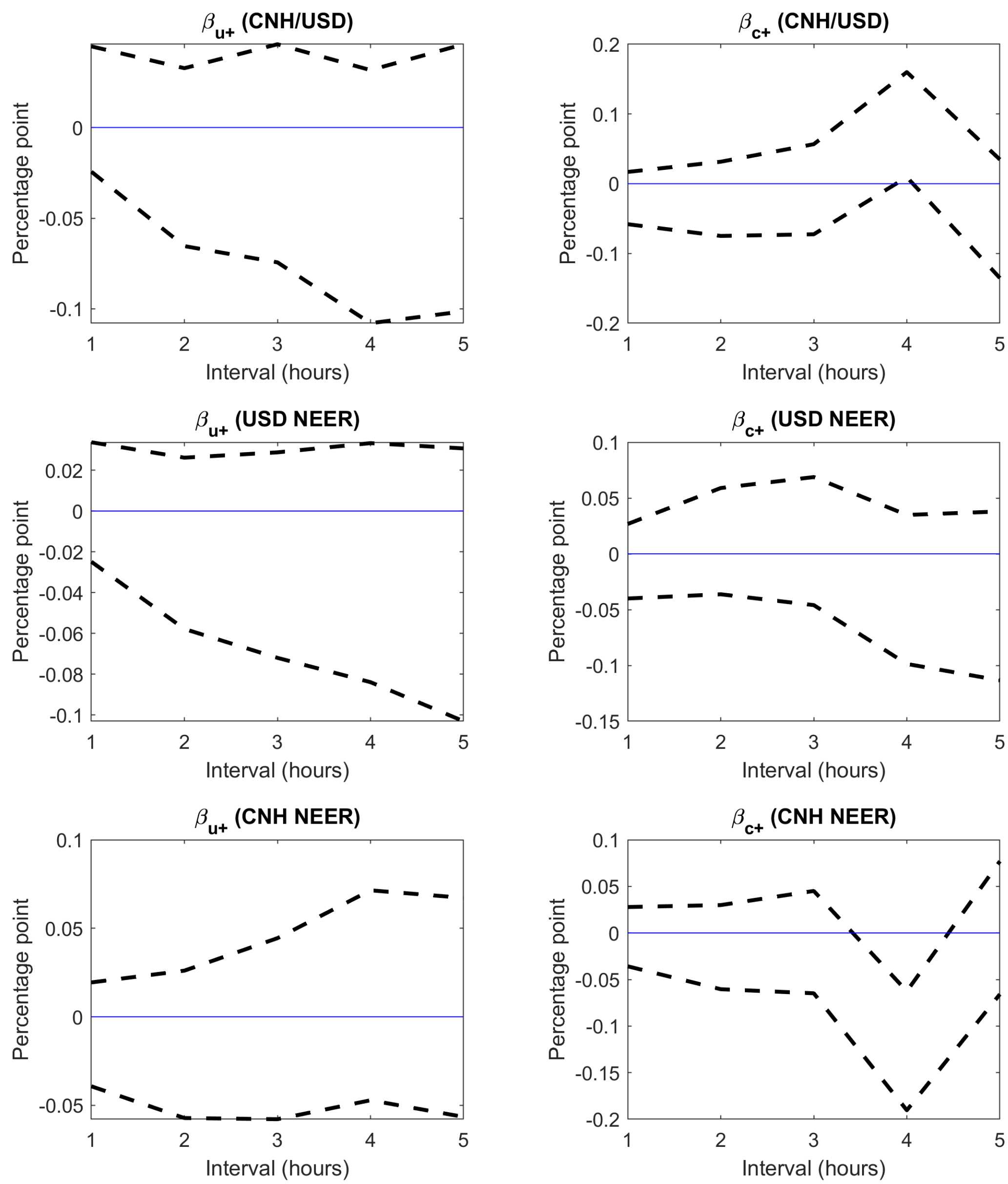

Figure C6: Regression results using varying frequencies

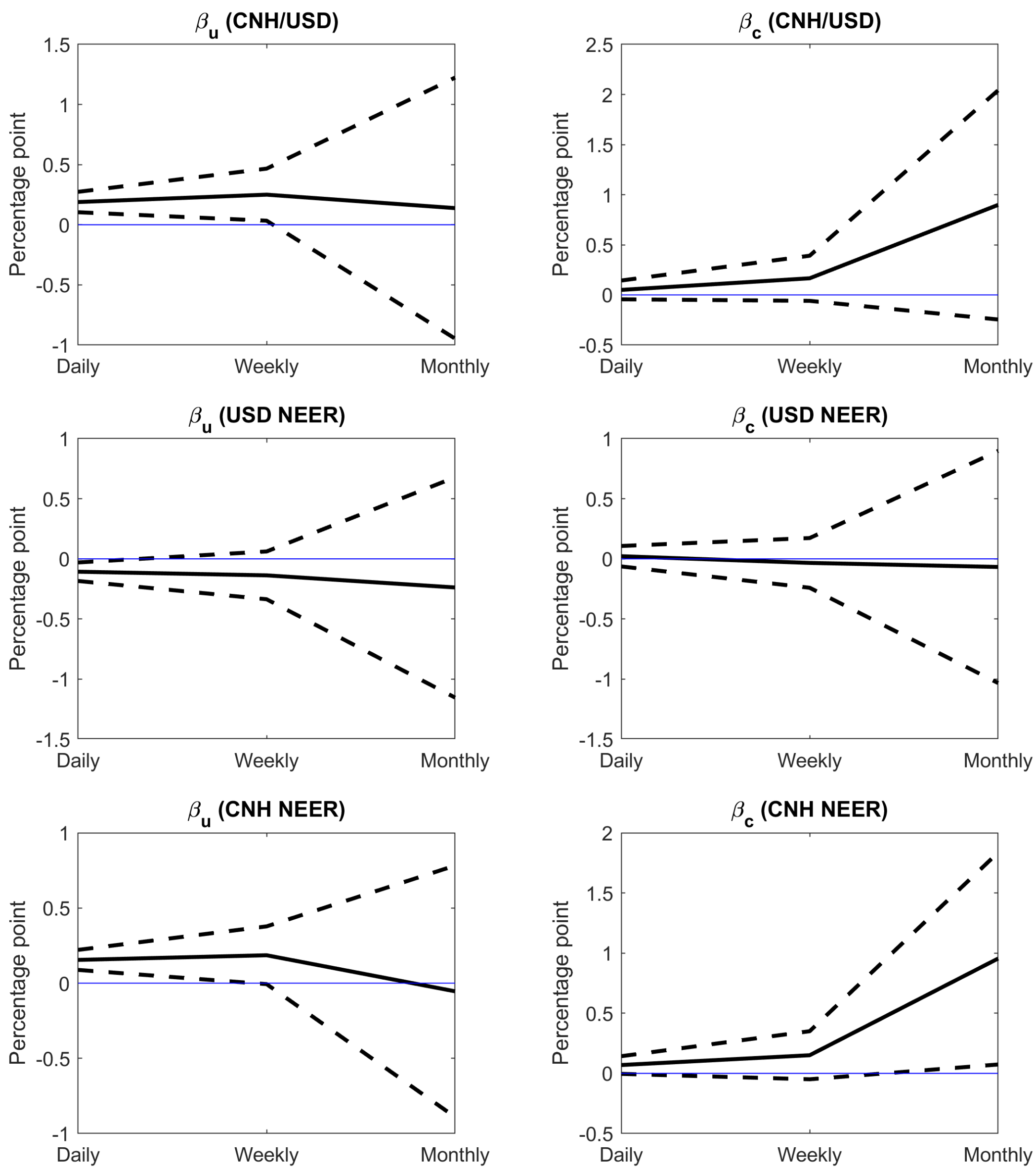

Figure C7: Regression results using overlapping time windows with Newey-West standard errors