To Which Extent Should We Expect Tariffs To Be Offset by Exchange Rates?[1]

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Abstract. In theory, we should expect tariffs to be partially offset by a currency appreciation in the tariff-imposing country. In practice, the offset seems to be small. Based on a calibrated model, the tariffs imposed by the US in 2018 can explain at most one tenth of the dollar appreciation observed that year. An event study looking at the impact of tariff-related events on the exchange rates of the US and its main trading partners does not find evidence that tariffs were a significant driver of exchange rates in 2018.

I. Introduction

In 2018 the US imposed new tariffs of 6.5% on average on its imports from China.[2] At the same time, the renminbi depreciated by 5.5% against the dollar, which may have offset a large part of the impact of the US tariff. Indeed, a common argument against tariffs is that their effect is likely to be mitigated by endogenous movements in exchange rates (Stiglitz, 2016). Of course, the appreciation of the dollar and the weakness of the renminbi could be explained by other factors, such as the increasing policy interest rate in the US and slowing growth in China.

The question in this paper is the extent to which we should expect tariffs to be offset by countervailing movements in exchange rates. The answer is based on both theory and evidence. I first present a simple model of an open economy applying a tariff on its imports. The authorities have domestic objectives in terms of inflation and employment and pursue these objectives through a Taylor rule. Introducing a tariff stimulates demand for home labor, leading to a currency appreciation. Importantly, the appreciation results from the fact that the central bank pursues domestic objectives in terms of inflation and employment and not that it tries to offset the tariff per se. I call the fraction of the tariff that is offset by currency appreciation the "exchange-rate offset." The model explains how the exchange-rate offset depends on the circumstances---such as whether the economy is at full employment or not, whether the tariff is implemented immediately or announced for a future date, the currencies in which exports and imports are invoiced, and so on.

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[1] This paper benefited from the excellent research assistance of Xiecun (Gloria) Li.

[2] The US imposed a 25% tariff on $50bn of Chinese imports in July, and 10% on $200bn in September. The total imports from China being about $500bn, this amounts to an average tariff of 6.5%

A calibrated version of the model shows that the exchange-rate offset is about 30 percent for an economy at full employment, and may be much smaller is there is slack in the home labor market. Even if one assumes that the US economy was at full employment, an offset of 30 percent cannot explain a substantial appreciation of the dollar in 2018. The reason is that the tariffs introduced by the US in 2018 amounted to a small fraction of its total imports (about 1.3%).[3] Based on the model, the tariffs introduced by the US in 2018 can explain a 0.4% appreciation of the dollar at most, much less than the appreciation of the dollar observed in 2018 (7.9% according to the Federal Reserve Broad Index).

This estimate is based on the tariffs effectively introduced in 2018. Other tariffs (for example on autos and auto parts) were discussed but not implemented and the tariffs implemented in 2018 may have signaled to market participants that more drastic measures were coming. One lesson from the model is that *expected* tariffs can move exchange rates as much as the actual measures. Could have exchange rates been moved more by the expectation of future tariffs than the actual ones?

I test this hypothesis with an event study looking how exchange rates have moved at the time of tariff-related events. The sample of events is constructed using the timeline reported by Bown and Kolb (2018) for the tariffs implemented by the US and its trade partners. I look whether there is a correlation at the daily frequency between tariff events and the dollar multilateral effective exchange rate, as well as the bilateral exchange rates of the dollar with the main US trading partners. I do not find any significant impact, suggesting again that tariffs have not been a significant driver of exchange rates in 2018.

The paper is related to several lines of literature. On the theoretical side, an older literature dating back to the 1980s examined the macroeconomic impact of tariffs (Eichengreen,1981; Krugman, 1982; Dornbusch, 1987). More recent papers have followed the resurgence of interest in that topic (see e.g. Erceg et al, 2018, Lindé and Pescatori, 2018).[4] The main difference between the older and more recent literatures is that in the new models, demand is determined by the intertemporal optimization of rational agents rather than an old-style Keynesian IS curve.

On the empirical side, some recent papers have compared the impact of exchange rates and of tariffs on trade flows. There is evidence that trade flows are more responsive to tariffs than to exchange rate movements (see e.g. Fontagné et al, 2018, for France). Benassy-Quéré et al (2018) find that exports are more responsive to a tariff cut in the destination country than to a real deprecation of the same amount in the source country. Using impulse response functions

[3] The number is slightly higher if one counts only the US imports of goods (excluding services).
[4] See Eichengreen (2018) for a review.

estimated over a large sample of countries, Furceri et al (2018) find that tariffs result in real exchange rate appreciations. Finally, there is a large literature on the impact of news on exchange rates (see for example Faust et al, 2006). Li (2019) finds evidence that the offshore yuan depreciated relative to the dollar when the U.S. imposed (prospective) tariffs and appreciated when trade talks result in the delay of tariffs.

II. Theory

I present in this section the implications of a simple model. The model assumptions, which are standard in modern international macroeconomic theory, are presented in more detail in the appendix. Domestic demand results from intertemporal optimization by domestic consumers. Wages are sticky in the short run and there is a Phillips Curve linking home production to wage inflation. The domestic monetary authorities implement a Taylor rule so as achieve an inflation target that is consistent with their definition of full employment. The monetary authorities, thus, care about the exchange rate or the trade balance only to the extent that these variables affect domestic inflation and employment. The prices of exports are set in the currency of the exporter (the producer-currency-pricing, or PCP, assumption).

The object of interest is by how much the currency appreciates when a tariff is introduced. I define the exchange-rate offset as the percentage amount by which the domestic currency appreciates following the imposition of a 1 percent tariff on imports. Assuming linearity, the impact of a tariff on the exchange rate can be estimated simply by multiplying the average tariff by the offset coefficient. An offset of 100 percent means that the exchange rate appreciates one-for-one in response to the tariff, which implies that the tariff has no impact on real variables.

The value of the exchange-rate offset depends on several ancillary assumptions about the state of the economy and the nature of the tariff. Is the home economy at full employment when the tariff is imposed? Is the tariff implemented immediately or in the future? I start with the case where the economy is at full employment and the tariff is permanent, and then proceed to discuss different circumstances.

2.1 Permanent tariff under full employment

The benchmark case is that of a permanent tariff unexpectedly introduced in a steady-state equilibrium with full employment. Other things equal, the tariff raises the demand for home labor (by shifting home demand away from imports), which generates inflationary pressures. The monetary authorities would respond to the inflation, if it materialized, by raising the interest rate. In a rational expectations equilibrium the interest rate does not need to increase: the home currency immediately appreciates to a level such that the economy stays at full employment and inflation remains equal to the target. The exchange rate adjusts to a new level that ensures that the total demand for the home good is unchanged after the introduction of the tariff.

Denoting the (log) value of the home currency in terms of foreign currency by e, it is possible to show that the exchange-rate offset is given by

$$\frac{de}{d\tau} = \varphi \frac{1}{1+(\varepsilon_x/\omega_H - 1)/\varepsilon_m} \quad (1)$$

where φ is the share of imports on which the tariff is imposed, ω_H is the share of the home good in home consumption, ε_m is the elasticity of substitution between the home good and foreign goods in home markets (the import elasticity), and ε_x is the elasticity of substitution between the home good and foreign goods in foreign markets (the export elasticity).[5]

If $\varepsilon_x > \omega_H$ (which as I will argue is the most plausible assumption) the exchange-rate offset is between zero and one. The offset is lower than one for the following reason. If the currency appreciated by the same amount as the tariff, the home goods would lose all the competitiveness gain from the tariff in home markets. On top of this, home goods would lose competitiveness in export markets so that on balance domestic employment would decrease. To keep the home economy at full employment, thus, the currency appreciation must be smaller than the tariff.[6]

Another implication of equation (1) is that the exchange-rate offset is increasing with the import elasticity but decreasing with the export elasticity. A larger import elasticity magnifies the impact of the tariff on employment and requires a larger offsetting appreciation. Conversely, a larger export elasticity means that a smaller currency appreciation is required to offset the increase in domestic employment induced by the tariff.

2.2 Calibration

Table 1 reports the proposed calibration of the elasticities. The value for the intertemporal elasticity of substitution is standard in the literature. This parameter does not appear in equation (1) but it will play a role in the analysis of expected tariffs, to be discussed later in this section. The elasticities for imports and exports are taken from Freenstra et al (2018). These authors find that the price elasticity between the goods exported by different countries is significantly higher

[5] New Keynesian open-economy macroeconomic models generally assume that these elasticities are different (see for example Gali, 2015, chapter 8). As discussed below, the recent empirical literature has estimated the export elasticity to be significantly larger than the import elasticity (Feenstra, Obstfeld and Russ, 2018).

[6] The exchange-rate offset would be equal to one if home exports were subsidized at the same rate as the tariff. An important assumption for the result that the exchange-rate offset is lower than 1 is that the government uses only tariffs on imports and not subsidies on exports.

than the elasticity between home goods and imports in a given importing country. Their estimates for the import elasticity are close to 1 whereas those for the export elasticity are close to 3 or 4. The value of ω_H 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 (1) for a uniform tariff on all imports is 0.28, i.e., a one percent tariff appreciates the currency by 0.28 percent.

The last parameter to estimate in equation (1) is φ, the share of imports on which the tariff is imposed. For this I treated separately the different "trade battles" between the US and the rest of the world described in Bown and Kolb (2018). The results are reported in Table 2. The table reports, for each trade battle, the share of imports that were affected, the average tariff that was applied, and the dollar appreciation predicted by equation (1).[7]

The first trade battle involves solar panels and washing machines. In January 2018, President Trump approved global safeguard tariffs on imports of solar panels and washing machines. The tariff applied to solar panels was 30 percent, as reported in Table 2.[8] The second trade battle is about steel and aluminum. In March 2018 the Trump administration announced tariffs of 25 percent on steel and 10 percent on aluminum under national security grounds. The average tariff on steel and aluminum, weighted by the 2017 value of imports, was 18.4 percent.[9] The third trade battle involves US tariffs on imports from China justified by alleged Chinese unfair trade practices for technology and intellectual property. The Trump administration imposed a 25 percent tariff on $50 billion of Chinese products in the summer of 2018, followed by a 10 percent tariff on an additional $200 billion worth of Chinese goods in September.[10] The average rate for those tariffs (weighted by import value) was 13 percent.

As shown by the bottom line of Table 2, the model-predicted impact of these tariffs on the dollar is negligible in the case of the solar panels, washing machines and steel and aluminum. The reason is simply that the share of these goods in US imports is too small to make the tariffs macroeconomically significant. The trade war with China involves larger trade flows but even it

[7] The table reports only the tariffs that were effectively introduced in 2018. Thus, it does not include the fourth "trade battle" about autos and auto parts. A 25% tariff on $200bn of autos would appreciate the dollar by approximately 0.5% according to equation (1).

[8] The tariff schedule, for this trade battle and the other ones, is more complicated than reported in the table. The tariff on solar panels is scheduled to fall to 15% after four years. The first 1.2 million washing machines imported each year face a 20 percent tariff, with additional imports facing a 50 percent tax. I assume a uniform tariff of 30 percent for simplicity.

[9] Exemptions of various durations were granted to selected countries. The tariff on Turkish steel was increased in August 2018 in response the depreciation of the Turkish lira. For simplicity, I assume that the tariffs announced in March 2018 apply to all US imports of steel and aluminum.

[10] A 15 percent increase in the second tariff, initially announced for January 2019, was later postponed by three months.

cannot explain a dollar appreciation much larger than 0.3%. Taken together, the tariffs implemented in 2018 can explain a 0.4% appreciation of the dollar, that is, less than one tenth of the dollar appreciation observed in 2018.

2.3 Alternative assumptions

In the model, a tariff leads to currency appreciation because the economy is at full employment before and after the tariff is introduced. How do the results change if there is less than full employment in the home economy?

In the appendix I consider a variant of the model in which because of low demand, the economy is initially below full employment and employment cannot be increased using monetary policy because the interest rate is at the zero lower bound (the home economy is in a liquidity trap). By imposing a tariff, the country shifts demand towards the home good and increases the demand for home labor. Thus, the country can raise employment and inflation towards their respective targets by imposing a tariff if the economy is in a liquidity trap.[11] Although the monetary authorities leave the interest rate at zero, the currency appreciates (slightly) because the country's trade balance increases. This raises the country's level of net foreign assets and appreciates the currency in the long run, when the economy is back to full employment. The exchange-rate offset in this case is given by,

$$\frac{de}{d\tau} = r\omega_H \varphi \frac{1}{1+(\varepsilon_x/\omega_H - 1)/\varepsilon_m} \ , \quad (2)$$

where r is the real interest rate in terms of foreign good. Comparing equations (1) and (2), one can see that unemployment has the effect of multiplying the exchange-rate offset by the factor $r\omega_H$. For example if r=5% the value of the offset implied by equation (2), under our benchmark calibration, is 1.2%. That is, only one percent of a tariff is offset by an appreciation. The exchange-rate offset is effectively very close to zero when the economy is in a liquidity trap with less than full employment.

What is the impact of an *expected* tariff? The model can be used to analyze the impact of announcing the introduction of a permanent tariff in the future. In the long run the currency appreciates, but how does it respond in the short run (at the time of the announcement)? This

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[11] The tariff is an effective tool to increase employment in a liquidity trap from a unilateral perspective, not from a multilateral one. In this type of models, tariffs reduce global demand and employment if they are used by all countries (Jeanne, 2019).

depends on the impact of the tariff announcement on output. If output is depressed by the announcement, the central bank lowers the interest rate, which tends to mitigate the appreciation of the currency. Conversely, if output is stimulated by the announcement, the central bank increases the interest rate, which tends to amplify the appreciation of the currency.

There are two countervailing effects to consider when trying to determine whether an expected tariff stimulates or depresses output. On one hand, the announcement of the tariff appreciates the currency prematurely (before the tariff is introduced), which tends to depress output. On the other hand, the announcement of a tariff, like the announcement of any tax on consumption, stimulates domestic consumption before the tariff is introduced. The first effect dominates if and only if the price-elasticity of imports is larger than the elasticity of intertemporal substitution of consumption ($\varepsilon_m > \varepsilon_i$). This is the case in our benchmark calibration, so we should expect tariff announcements to have a smaller impact on the exchange rate than actual tariffs. The case $\varepsilon_m = \varepsilon_i$ is not outside the range of plausible calibrations, however, so that the model does not exclude the possibility that a (credible) tariff announcement has the same impact on the exchange as an actual tariff.

The model assumes producer currency pricing (PCP), i.e., that the price of an exported good is fixed in the currency of the exporter. Gopinath (2016) argues that a more realistic assumption for many countries is that the price of imports and exports is fixed in terms of dollar (or euro), which she calls dominant currency pricing (DCP). If we interpret the home economy as the US, DCP implies that the dollar price of imports (net of tariff) does not change when the US introduces a tariff. As a result, the gross price of imports increases by the full amount of the tariff. DCP implies that foreign exporters do not take advantage of the depreciation of their currency to mitigate the impact of the tariff on their competitiveness in the US, which does not seem to be a more realistic assumption than PCP, at least in the long run.

Leaving realism aside, DCP magnifies the impact of the tariff on imports relative to the case of PCP, so that a larger offsetting currency appreciation is required on the side of exports. As shown in the appendix, under DCP the exchange-rate offset is now given by

$$\frac{de}{d\tau} = \varphi \frac{\varepsilon_m}{\varepsilon_x / \omega_H - 1}, \quad (3)$$

which is larger than the offset with PCP, given by (1). Under the benchmark calibration, the exchange-rate offset (for a permanent tariff under full employment) is 0.40 instead of 0.28.

In conclusion, the imposition of a tariff generally leads to an appreciation of the currency of the tariff-imposing country. The exchange-rate offset is partial and equal to about 30 percent under full employment in the calibrated model. The offset is likely to be smaller, possibly close to zero, if there is slack in the domestic labor market. It could be somewhat larger under different assumptions about pricing or the parameter values. The precise value of the offset does not affect our conclusion that the tariffs introduced in the US in 2018 cannot explain the appreciation of the dollar, which comes from the relatively small share of US imports that were affected by the tariffs.

III. Tariffs news and exchange rates: An event study

The calibrated model suggests that the tariffs implemented in 2018 can explain only a small fraction of the dollar appreciation observed in 2018. However, the impact might have been larger if one takes into account the expectations of future tariffs. The US administration announced increases in the existing tariffs, and entertained proposals to introduce new tariffs on macroeconomically significant imports, such as autos. The legal basis for the tariffs on steel and aluminum (that these imports threatened US national security) was unusual and constituted a radical departure from previous practices. Thus, market participants may have interpreted the 2018 tariffs as a signal about the trading partners' willingness to engage into a wider trade war. As shown by the model, the impact of expected tariffs may be as large as that of actual ones. Could the tariffs introduced in 2018 have had, through a signaling channel, a larger impact on exchange rates than estimated in the previous section?

I explore this hypothesis with an event study testing the existence of a correlation (at the daily frequency) between "tariff events" and the dollar multilateral effective exchange rate as well as the bilateral exchange rates of the dollar with the main trading partners of the US.

Tariff events are identified using Bown and Kolb's (2018) timeline of events. Bown and Kolb report the days since in which major news or events related to the US tariffs occurred. These events are heterogeneous in several ways. Some events consist in the imposition, or announcement, or consideration, of new tariffs by the US. Other events consist in the removal, announcement, or consideration, of lower tariffs by the US. Still other events relate to tariffs imposed by the rest of the world. Some tariffs apply to specific categories of goods, others to specific countries or regions.

I capture this heterogeneity by defining several event dummies (the events and dummies are reported in Appendix B). The first dummy variable, D_{US}, takes value +1 when the event is about an increase or likely increase in US tariffs, and value -1 when the event is a decrease or likely decrease in US tariffs. The second one, D_{ROW}, takes value +1 when the event is about an increase or likely increase in the rest of the world's tariffs (generally in retaliation to US tariffs), and value -1 when the event is a decrease or likely decrease in non-US tariffs. I also defined dummies to capture whether the events related to specific countries or regions (China, NAFTA) or trade battles. These additional dummies are not reported in Appendix B but their consideration does not change the main results.

The sample of countries is reported in Table 3. The sample includes the ten countries that had the highest ratio of exports (excluding mineral fuels) to the US in terms of their own GDP in 2017. The countries with 2017 GDP smaller than \$100bn or that have a fixed exchange rate with the dollar are excluded. I added the euro area, China and Japan, which were not part of the top ten countries according to the previous selection criteria.

I then regressed the change in the exchange rate on the tariff event dummies at the daily frequency. For each country *i* in the sample the regression was

$$\frac{e_{it+1}-e_{it-1}}{e_{it-1}} = a_i + b_i D_t + \varepsilon_{it} \quad (4)$$

where e_{it} is the exchange rate of country *i* and day *t* (home currency per dollar) and D_t is the dummy variable for the occurrence of a tariff event in day *t*. The regression attempts to detect whether the occurrence of a tariff event in day *t* has a statistically significant impact on country *i*'s exchange rate between days *t-1* and *t+1*. To the extent that the tariff news depreciate the currency of country *I,* the estimated coefficient b_i should be positive.

The results of the event study regressions are reported in Tables 4 and 5. The regressions were run with daily data over 2015-2018. Table 4 reports the results when the exchange rate *e* is defined as the Fed's multilateral effective exchange rate for the dollar, broad index (first line) and major currencies (second line). An increase in those indices means an appreciation of the dollar. To the extent that the imposition of a tariff by the US should appreciate the dollar, and that the imposition of a tariff by the rest of the world should have the opposite effect, we would expect the coefficients on DUS and DROW to be respectively positive and negative. As shown by Table 3, these coefficients are in fact not statistically different from zero.

Table 5 reports the results of regression (4) for the countries or regions in our sample. Most of the results are statistically insignificant. The only statistically significant results is that a US tariff seems to depreciate the Vietnamese currency but this is about the number of spurious results that we should expect to find given the number of regressions.

Thus, tariff events do not seem to affect exchange rates. I tested the robustness of this result in different ways. Positive and negative trade events were introduced separately. The regression was run over shorter time periods. The Chinese (and NAFTA) trade battle were treated separately. I found no indication that the renminbi was more affected by China-related trade events, or that Canada and Mexico were more affected by NAFTA-related events.

This event study analysis could be improved in several ways. In particular, the identified trade events are an imperfect measure of what we are trying to capture. Some of the events are not unexpected "news" and were perhaps already priced in exchange rates when they occurred. One might want to look at a smaller number of events that, based on narrative evidence, are more likely to qualify as news, and to look at them with higher-frequency exchange rate data. Thus, there is certainly scope for more research to try and detect correlations that may have been missed with the data used here. This being said, the results presented in this section are not encouraging for the view that tariffs have been a significant force driving exchange rates in 2018.

IV. Conclusions

This paper started with the observation that the tariffs implemented by the US in 2018 were largely offset by a concomitant appreciation of the dollar. The main point of the paper is that there is little theoretical or empirical justification to explain the latter by the former. The dollar appreciation did not result from the tariffs (or only to a very limited extent). Thus, the reasons for which tariffs are inadvisable do not include the fact that they are rendered ineffective by offsetting exchange rate movements. This conclusion rests on two observations.

In theory, first, there is no "theorem" that tariffs should be completely offset by currency appreciation. If the economy is not at full employment, the exchange-rate offset could be close to zero. We find the offset to be about 30 percent conditional on full employment. The simple textbook model on which these conclusions are based does not incorporate all the relevant channels one might think of, 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, they should depreciate the currencies of the countries that own the production factors (both capital and labor) used in that chain.

On the empirical side, we looked for evidence of an impact of tariff events on exchange rates and did not find any. Although the identification of the tariff events could be improved, the fact that we find no significant result suggests that studies using better identified news and higher frequency data are unlikely to find economically large effects (assuming that they are statistically significant), since these effects seem to be swamped by other factors at the daily frequency.

APPENDIX A. MODEL

Assumptions. The assumptions are similar to those in Jeanne (2019). I consider a small open economy populated by identical consumers who consume home goods as well as foreign goods. Time is discrete and infinite. The representative consumer's utility is given by

$$U = E[\sum \beta^t u(C_t)]. \qquad \text{(A1)}$$

Consumption is a CES index of the consumption of home goods (*H*) and foreign good (*F*),

$$C = \left[\omega_H^{1/\varepsilon_m} C_H^{(\varepsilon_m-1)/\varepsilon_m} + \omega_F^{1/\varepsilon_m} C_F^{(\varepsilon_m-1)/\varepsilon_m}\right]^{\varepsilon_m/(\varepsilon_m-1)}, \qquad \text{(A2)}$$

where ε_m is the import elasticity and $\omega_H + \omega_F = 1$. The foreign good is a CES aggregate of a large number of goods produced in different countries.

The home good is produced with home labor using a linear production function, $Y=L$. The home terms of trade are $S=EW/P*$, where E is the price of the home currency in terms of foreign currency, W is the home-currency wage, and $P*$ is the foreign-currency price of the foreign good. Denoting the tariff on imports by τ, the price of home consumption in terms of foreign good is $p(S/(1+\tau)) = (\omega_H(S/(1+\tau))^{1-\varepsilon_m} + \omega_F)^{1/(1-\varepsilon_m)}$.

The demand for the home good in foreign markets is $M^* S^{-\varepsilon_x}$, where M^* is global imports and ε_x is the export elasticity. Under these assumptions the demand for home output, and the country's next exports in terms of foreign good, can be written, in any period *t*

$$Y_t = \omega_H \left[\frac{p(S_t/(1+\tau_t))}{S_t/(1+\tau_t)}\right]^{\varepsilon_m} C_t + S_t^{-\varepsilon_x} M_t^*, \qquad \text{(A3)}$$

$$NX_t = S_t^{1-\varepsilon_x} M_t^* - \omega_F p\big(S_t/(1+\tau_t)\big)^{\varepsilon_m} C_t. \qquad \text{(A4)}$$

The two terms on the r.h.s. of (A3) are respectively the home and foreign demands for the home good. The r.h.s. of equation (A4) is the difference between home exports and imports.

There is free capital mobility, implying the interest parity relationship

$$1 + i_t = (1+r)(1+\pi_{t+1})\frac{S_t}{S_{t+1}}, \quad \text{(A5)}$$

where i_t is the home nominal interest rate, $\pi_t = W_t/Wt_{-1} - 1$ is home wage inflation, and r is the global interest rate in terms of foreign good.

The Euler equation for the intertemporal substitution of consumption is

$$\frac{u\prime(C_t)}{p(S_t/(1+\tau_t))} = \beta(1+r)\frac{u\prime(C_{t+1})}{p(S_{t+1}/(1+\tau_{t+1}))}. \text{ (A6)}$$

We assume that the relationship between home wage inflation and home output is characterized by the following Phillips curve,

$$\pi_t = \pi(Y_t), \quad \text{(A7)}$$

where $\pi(.)$ is an increasing function. Finally, we assume that the home monetary authorities follow a Taylor rule,

$$1 + i_t = (1+r)(1+\hat{\pi})^{-\alpha}(1+\pi_t)^{1+\alpha}, \quad \text{(A8)}$$

where $\hat{\pi}$ is the inflation target. We denote by $\hat{Y}$ the associated output target resulting from the Phillips curve (A7). The nominal interest rate is set to zero when the level implied by the Taylor rule is negative.

Steady states. Let us consider a steady state equilibrium with a constant tariff τ, constant global imports M^*, and zero foreign assets. Interest parity, the Phillips curve and the Taylor rule–equations (A5), (A7) and (A8)–imply that inflation and output are equal to their respective target levels. The terms of trade, S, and consumption, C, then result from equations (A3) and (A4) with $NX=0$. Differentiating (A3) and (A4) gives $ds/d\tau$. The wage level does not change with the tariff and under PCP, P^* is fixed so that $ds/d\tau=de/d\tau$. This gives equation (1) in the text. Under DCP, P^*/E is fixed so that the terms in $p(S/(1+\tau))$ must be differentiated assuming that S is fixed. This gives equation (3) in the text.

Liquidity trap. Assume that the economy is in a liquidity trap in period *1* (for example because global imports M_1^* are low). A small transitory tariff $d\tau$ is introduced in period 1. From period *2* onwards the economy is in a steady state with full employment and no tariff. Given that $i_1=0$, and the fact that inflation is equal to target in period 2 ($\pi_2 = \hat{\pi}$), interest parity (A5) implies

$$S_1 = \frac{S_2}{(1+r)(1+\hat{\pi})}.$$

Thus, S_1 and S_2 have the same elasticity with respect to the period-1 tariff τ. Differentiating (A4) shows that the tariff increases the period-1 trade balance by $NX_1 = C\omega_H\omega_F\varepsilon_m d\tau$. In the following steady state, the country imports the return on the foreign assets accumulated in period *1*, $\overline{NX} = -rNX_1$. Differentiating equations (A3) and (A4) w.r.t. $\overline{NX}$ gives equation (2).

APPENDIX B. DATA

The sample of countries is selected as follows. We selected the countries that had the highest ratio of exports to the US to GDP in 2017 excluding mineral fuels (exports FOB, source UN Comtrade). I then excluded the countries with GDP (2017, market prices) smaller than $100bn (Trinidad and Tobago, the Marshall Islands, Lesotho, Cambodia, El Salvador, Cambodia and Haiti), and the countries that have a fixed exchange rate with the dollar (most notably Hong Kong). The euro area, China and Japan were not part of the top ten countries and were included because their economic significance.

Table B1. Tariff event dummies

Date	Event	D_{US}	D_{ROW}
18-Aug-17	USTR Ligthizer self-initiates investigation of China's laws harming US Intellectual Property after Trump's memorandum	1	0
31-Oct-17	USITC recommends safeguard tariffs for imports of solar panels and washing machines	1	0
22-Jan-18	Trump approves Safeguard Tariffs on $8.5 billion imports of solar panels and $1.8 billion of washing machines	1	0
5-Feb-18	China investigates roughly $1billion of US Exports of Sorghum	0	1
16-Feb-18	National Security Investigation Result: steel and aluminum products threaten US National Security	1	0
1-Mar-18	Steel and Aluminum tariff announcement, covering $48 billion of imports from Canada, EU, Mexico, South Korea and China	1	0
7-Mar-18	EU announces retaliatory response in response to Trump's steel and aluminum tariff announcement	0	1
8-Mar-18	Steel and aluminum NAFTA tariff exemptions	-1	0
22-Mar-18	Steel and aluminum exemptions for EU, South Korea, Brazil, Argentina and Australia (through May 1, 2018)	-1	0
22-Mar-18	Trump administration releases report finding China is conducting unfair trade practices related to technology transfer, indicates forthcoming remedies of tariffs on up to $60 billlion of Chinese products	1	0
23-Mar-18	Steel and aluminum tariffs go into effect	1	0
28-Mar-18	South Korea receives permanent exemption for steel but agrees to quota	-1	0
2-Apr-18	China imposes retaliatory tariffs in response to US steel & aluminum tariff	0	1
3-Apr-18	Trump administration releases $50 billion list of 1,333 Chinese products under consideration for 25% tariff	1	0
4-Apr-18	China publishes list of 106 products subject to forthcoming 25% tariff as retaliation, covering $50 billion of Chinese imports from the US	0	1
5-Apr-18	US considers additional tariffs on $100 billion of US imports from China	1	0

17-Apr-18	China imposes tariff on US Sorghum	0	1
30-Apr-18	Trump administration extends the steel and aluminum tariff exemptions provided to the EU, Canada and Mexico until June 1, 2018.	-1	0
18-May-18	China ends tariffs on US Sorghum	0	-1
20-May-18	Treasury Secretary Mnuchin declares tariffs on hold	-1	0
23-May-18	Commerce Department initiates a national security investigation into imported autos and parts	1	0
29-May-18	White House releases statement: would impose tariffs on $50 billion of goods from China shortly after announcing the final list on June 15, 2018	1	0
30-May-18	China announced reduction in tariffs on a wide range of consumer goods for July 1	0	-1
1-Jun-18	US ends tariff exemptions on steel and aluminum for EU, Canada, Mexico	1	0
15-Jun-18	USTR releases revised list of tariffs on almost $50 billion of Chinese product starting July 6,2018	1	0
15-Jun-18	China issues an updated $50 billion retaliation list for a 25 percent tariff	0	1
18-Jun-18	In response to China's retaliatory tariff, Trump directs USTR to identify another $200 billion worth of Chinese goods for additional tariffs at 10%. Threatens another $200 billion if China retaliates again.	1	0
21-Jun-18	Turkey announced a tariff on US goods in retaliation for the US tariffs on steel and aluminum	0	1
22-Jun-18	EU retaliates to US steel and aluminum tariff by imposing tariffs on $3.2 billion of "iconic" American goods	0	1
1-Jul-18	Canada retaliates to US steel and aluminum tariff by imposing tariffs on $12.8 billion of US goods	0	1
6-Jul-18	US and China enforce first phase of June 15 tariff list	1	1
10-Jul-18	USTR releases a list of $200 billion of imports from China to be subjected to new 10% tariff	1	0
20-Jul-18	Trump threatens tariffs on all imports (totaling $504 billion) from China in Interview	1	0
1-Aug-18	Trump declares that the tariff on the $200 billion list of Chinese imports released in July will be 25 percent instead of 10 percent	1	0
3-Aug-18	China threatens adding duties of 5-25% on $60 billion of US goods following Trump's threat to raise tariff rates	0	1
7-Aug-18	USTR finalizes second tranche of tariff on $16 billion of Chinese goods	1	0
8-Aug-18	China revises its $50 billion tariff list, removing crude oil	0	-1
10-Aug-18	Trump increases steel tariff imposed on Turkey from 25% to 50% in reponse to the depreciation of Turkish lira	1	0
13-Aug-18	US passes law on trade and national security	1	0
14-Aug-18	Turkey announces new tariffs in response to Trump's doubling of US tariffs on Turkish steel and aluminum	0	1

23-Aug-18	US and China enforce second Phase of $50 Billion tariff	1	1
27-Aug-18	"Side Letter" on autos reportedly in new US-Mexico trade deal to replace NAFTA	-1	0
17-Sep-18	Trump finalizes tariffs on $200 billion of imports from China	1	0
18-Sep-18	China finalizes tariffs on $60 billion of imports from US	0	1
24-Sep-18	US tariffs on $200 billion of Chinese imports goes into effect, along with retaliatory tariffs by China on $60 billion of US imports	1	1
26-Sep-18	China announces tariff reduction for 1,585 products starting from Nov.1	0	-1
1-Oct-18	US and Canada reach a deal to update NAFTA	-1	0

REFERENCES

Amiti, Mary, Redding, Stephen and David Weinstein. 2019. The Impact of the 2018 Trade War on U.S. Prices and Welfare. NBER Working Paper 25672.

Bénassy-Quéré, Agnès, Bussière, Matthieu and Pauline Wibaux. 2018. Trade and Currency Weapons. CESifo, Working Paper Series 7112.

Bown, Chad, and Melina Kolb. 2018. Trump's Trade War Timeline: An Up-to-date Guide. Peterson Institute for International Economics https://piie.com/system/files/documents/trump-trade-war-timeline.pdf

Dornbusch, Rudiger. 1987. External Balance Correction: Depreciation or Protection? *Brookings Papers on Economic Activity*, 249-269.

Eichengreen, Barry. 2018. Trade Policy and the Macroeconomy. Mundell Fleming lecture presented to the IMF's Annual Research Conference, November 2, 2017, forthcoming in the *IMF Economic Review*.

Eichengreen, Barry. 1981. A Dynamic Model of Tariffs, Output and Employment Under Flexible Exchange Rates. *Journal of International Economics* 11, 341-359.

Erceg, C, A Prestipino, and A Raffo. 2017. The Macroeconomic Effects of Trade Policy." FRB International Finance Discussion Paper No.1242, Board of Governors of the Federal Reserve System.

Faust,Jon, Rogers,J.,Wang, S., and J. Wright. 2006. The High Frequency Response of Exchange Rates and Interest Rates to Macroeconomic Announcements. *Journal of Monetary Economics* 54, 1051-1068.

Fajgelbaum, Pablo D., Goldberg, Pinelopi K., Kennedy Patrick J. and Amit K. Khandelwal. 2019. The Return to Protectionism. NBER Working Paper 25638.

Feenstra, Robert C., Luck, Philip, Obstfeld, Maurice and Catheryn Russ. 2018. In Search of the Armington Elasticity. *Review of Economics and Statistics* 100(1), 135-150.

Fontagné, Lionel, Martin, Philippe, and Gianluca Orefice. 2018. The International Elasticity Puzzle is Worse Than You Think. *Journal of International Economics* vol. 115(C), pages 115-129.

Furceri, Davide, Hannan, Swarnali, Ostry, Jonathan and Andrew Rose. 2018. Macroeconomic Consequences of Tariffs. NBER Working Paper 25402.

Gali, Jordi. 2015. *Monetary Policy, Inflation, and the Business Cycle*. Princeton University Press.

Gopinath, Gita. 2016. The International Price System. Jackson Hole Symposium Proceedings.

Jeanne, Olivier. 2019. Currency Wars, Trade Wars and Global Demand. Johns Hopkins University. Manuscript.

Krugman, Paul. 1982. The Macroeconomics of Protection with a Floating Exchange Rate. *Carnegie Rochester Conference Series on Public Policy* 16, 141-182.

Li, Gloria. 2019. Onshore and Offshore RMB Response to Recent RMB Announcements. Johns Hopkins University. Manuscript (Senior Thesis).

Lindé, Jesper, and Andrea Pescatori. 2017. The Macroeconomic Effects of Trade Tariffs: Revisiting the Lerner Symmetry Result. CEPR DP 12534.

Stiglitz, Joseph. 2016. A Nobel Laureate Explains How Trump Could Nuke the Economy. *Vanity Fair*, December 27 2016.

Uribe, Martin and Stephanie Schmitt-Grohe. 2017. *Open Economy Macroeconomics*. Princeton University Press.

To Which Extent Should We Expect Tariffs to be Offset by Exchange Rates?

Olivier Jeanne

TABLES

Table 1. Calibration of elasticities

ε_i	ε_m	ε_x
0.5 [0.25,1]	1 [0.5,1.5]	3 [2,4]

Note. The table reports the benchmark calibration of the elasticity of intertemporal substitution of consumption (ε_i), the import elasticity (ε_m) and the export elasticity (ε_x). Ranges of admissible values are indicated in brackets.

Table 2. Estimated dollar appreciation in various trade battles

	Solar panels & washing machines	Steel & aluminum	China
Tariff, τ	30%	18.4%	13%
Share of imports, φ	0.4%	1.7%	8.6%
Resulting dollar appreciation	0.03% [0.01,0.06]	0.08% [0.04,0.17]	0.31% [0.13,0.59]

Note. The table reports the average tariff and share of US imports for the first three "trade battles" described in Bown and Kolb (2018). The bottom line reports the resulting dollar appreciation predicted by equation (1) under the benchmark calibration as well as the calibration intervals (in brackets).

Table 3. Country sample

Country	Export to US/GDP (2017, %)
Mexico	27.3
Vietnam	19.4
Canada	14.7
Singapore	7.2
Malaysia	6.6
Thailand	5.8
Switzerland	5.4
Israel	4.9
Korea	4.3
Chile	3.6
China	3.6
Japan	2.8
Euro area	2.6

Note. The table reports the country sample used in the event study presented in Section III of the paper. The selection criteria are reported in Appendix B. The source for the trade data is UN Comtrade.

Table 4. Impact of tariff events on dollar multilateral effective exchange rate

	D_{US}	D_{ROW}	D_{US}-D_{ROW}
Broad	0.03% (0.735)	0.05% (0.682)	0.00% (0.991)
Major Currencies	-0.02% (0.884)	0.04% (0.742)	-0.03% (0.732)

Note. The table reports coefficient b_i in regression (4), where the exchange rate is the Federal reserve multilateral effective exchange rate of the US dollar Broad index (first line) and for Major Currencies (second line). The p-values are reported in parenthesis. The exchange rate data are daily from 11/09/2015 to 11/02/2018 (source: FRED database). The construction of the tariff event dummies DUS and DROW is explained in section III and the dummy variables are reported in Appendix B.

Table 5. Impact of tariff events on selected exchange rates with the dollar (in %)

	D_{US}	D_{ROW}	D_{US}-D_{ROW}
Mexican peso	-0.207 (0.379)	-0.246 (0.422)	-0.044 (0.824)
Vietnamese dong	0.050 (0.058)	0.018 (0.581)	0.027 (0.224)
Canadian dollar	0.038 (0.776)	-0.068 (0.692)	0.056 (0.618)
Singapore dollar	-0.050 (0.564)	0.038 (0.737)	-0.052 (0.479)
Malaysian ringitt	0.025 (0.833)	0.087 (0.542)	-0.024 (0.808)
Thai baht	0.124 (0.116)	0.032 (0.742)	0.072 (0.277)
Swiss franc	-0.090 (0.460)	0.195 (0.220)	-0.147 (0.155)
Israeli shekel	-0.114 (0.228)	0.107 (0.386)	-0.127 (0.113)
Korean won	0.235 (0.109)	-0.078 (0.686)	0.195 (0.111)
Chilean peso	0.148 (0.369)	0.076 (0.721)	0.073 (0.597)
Chinese yuan	0.071 (0.251)	0.071 (0.363)	0.018 (0.722)
Japanese yen	-0.035 (0.820)	0.074 (0.714)	-0.057 (0.666)
Euro	0.015 (0.302)	-0.025 (0.881)	0.104 (0.332)

Note. The table reports coefficient b_i in regression (4), where the exchange rate is the price of a US dollar in terms of the currency reported in the first column. The p-values are reported in parenthesis. The exchange rate data are daily from 11/09/2015 to 11/02/2018 (source: FRED database). The construction of the tariff event dummies D_{US} and D_{ROW} is explained in section III, and the dummy variables are reported in Appendix B.