The Macroeconomics of Tariff Shocks

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December 2025

Abstract

We study the short-run effects of import tariffs on GDP and the trade balance in an open-economy New Keynesian model with intermediate input trade. We find that temporary tariffs cause a downturn whenever the import elasticity is below an openness-weighted average of the export elasticity and the intertemporal substitution elasticity. We argue that this condition is likely satisfied in practice because durable goods generate great scope for intertemporal substitution, and because it is easier to lose competitiveness on the global market than to substitute between home and foreign goods. Unilateral tariffs tend to improve the trade balance, but when other countries retaliate the trade balance worsens and the contraction deepens. Taking into account the contractionary effect of tariffs dramatically lowers the optimal unilateral tariff derived in standard trade theory.

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First draft: April 2025. This research was conducted in part when Matthew Rognlie was visiting the Federal Reserve Bank of Minneapolis. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1 Introduction

Since its inauguration in January 2025, the Trump administration has proposed and partially implemented import tariffs of a magnitude unprecedented since World War II. Following the "Liberation Day" announcement on April 2, 2025, these plans have continued to shift, with some tariffs being cut or suspended, and others being raised further.

There is an extensive literature in international trade on the long-run effects of tariffs. Tariffs impose efficiency costs by distorting patterns of comparative advantage, but they can also benefit the country setting tariffs by improving its terms of trade. The tradeoff between these two forces is the traditional focus of the "optimal tariff" literature (Kaldor 1940, Johnson 1953, Dixit 1985).

For the recent tariffs, however, the long-run outlook is unclear. There are many ways in which these tariffs may be reversed in coming months or years: either deals reached by the administration, litigation invalidating the tariffs, or the arrival of a new administration.[1] Over time, importers may also learn how to avoid tariffs, or be granted exceptions. At least a large share of the tariffs, therefore, are plausibly temporary. Further, in the media and financial markets, the concern about tariffs is typically not about long-run efficiency loss, but rather about the possibility of a more immediate slowdown brought on by the short-run tariff shock—a question not typically considered by trade models.[2]

In this paper, we lay out a benchmark sticky-wage New Keynesian model with trade, and derive a simple condition for when a unilateral short-run tariff shock causes a domestic contraction, in the absence of monetary easing:

$$(1-\alpha)\sigma + \alpha\gamma > \eta. \tag{1}$$

Here, α is the steady-state trade share, σ is the elasticity of intertemporal substitution, γ is the elasticity of demand for exports, and η is the import substitution elasticity. On the left of (1), a rise in tariffs has two contractionary effects: it raises the cost of goods today, decreasing consumer demand in proportion to σ, and also makes exports less competitive, decreasing export demand in proportion to γ. On the right of (1), there is an expansion-

[1]On August 29, 2025, the Court of Appeals for the Federal Circuit ruled against the administration, finding that its proposed statutory basis did not authorize such sweeping tariffs. (V.O.S. Selections 2025.) If sustained, this decision would invalidate the Liberation Day tariffs. It is currently stayed upon appeal to the Supreme Court, where the administration's prospects are viewed as questionable. In the case of an adverse ruling, the administration hopes to implement tariffs through other means, such as Section 122 of the Trade Act of 1974, which explicitly authorizes the President to impose temporary import tariffs of up to 15% for 150 days. (See Khardori 2025.)

[2]Important exceptions include Barattieri, Cacciatore and Ghironi (2021) and Bergin and Corsetti (2023), both of which study the short-run output effects of a mean-reverting tariff shock. We discuss these below.

ary effect, as consumers and businesses substitute away from imports toward domestic output in proportion to η.

We argue that condition (1) is likely to hold, and thus that a tariff shock tends to cause a downturn. In the short run, σ is plausibly high, since there is great scope to substitute the timing of durable goods purchases, such as cars or equipment. γ is also likely to be higher than η, since it is easier to lose competitiveness on the global market than to substitute between home and foreign goods. If, in addition, there are equal retaliatory tariffs from abroad, then this adds another γ to the left of (1) and makes a downturn all but certain. The size of any implied contraction is simple to calculate, and equals the trade share α times the gap between the left and right of (1).

Tariffs are often motivated by a desire to improve the trade balance. In the absence of retaliation, we find that the trade balance is indeed likely to improve, thanks both to substitution away from imports and to the likely contraction. Retaliatory tariffs, however, directly hit exports and make the trade balance likely to deteriorate instead.

If monetary policy responds, it can potentially avoid a downturn by cutting nominal rates, in line with the falling natural interest rate. This, however, causes a depreciation of the home currency, which aggravates the inflationary impact of the shock. Such a depreciation is in stark contrast to the usual long-run analysis, where the exchange rate typically appreciates to enforce long-run trade balance—part of the classic "Lerner symmetry" result (Lerner 1936, Costinot and Werning 2019) that breaks down in our setting. One difficulty facing monetary policy here is that tariff shocks are inherently stagflationary: unlike cost-push shocks in the standard New Keynesian model, they are contractionary even in the absence of a monetary reaction.

Relative to the traditional trade literature, our short-run emphasis brings a new perspective on welfare. The standard welfare analysis of tariffs emphasizes the tradeoff between improving the terms of trade and the costs of distortion, with the optimal tariff balancing the two effects. For tariff shocks, we show that a third effect, the "output-gap effect" associated with a downturn, is generally equal to or larger than either of the other two effects. This implies a much lower optimal tariff, and a clear welfare loss from any tariff if there is retaliation.

We consider a number of variations on our basic model, including unbalanced trade, hand-to-mouth households, and incomplete pass-through. Although our focus is on the effects of short-run tariff shocks, we also show that the transitional effects from imposing large, permanent tariffs can be contractionary: the inability to substitute quickly between domestic and foreign inputs makes goods more expensive in the short run, leading to a decline in output.

We conclude by building a quantitative version of our model, featuring dynamic wage adjustment, durable goods, firm inventories, and persistent tariffs. This corroborates our main insights, and also allows us to consider some new questions. For instance, an anticipated shock causes imports and durable purchases to be pulled forward, leading to increased demand and a weaker trade balance in the short run, followed by a sharp reversal once tariffs are in place.

Our framework can help interpret a number of recent empirical papers, which study the historical effects of tariff shocks in the US. For the most part, this literature confirms that tariff shocks have negative effects on aggregate demand, though findings for inflation are mixed. In Franconi and Hack (2025), tariffs contract output and increase inflation, in spite of a lower short-term interest rate, consistent with our model. In Barnichon and Singh (2025) and Den Besten and Kanzig (2025), tariffs reduce output but also reduce inflation.[3] In Schmitt-Grohé and Uribe (2025), tariffs reduce consumption (though not output) and reduce inflation. The latter three papers argue that the decline in inflation comes from the contraction in aggregate demand.[4]

Finally, our analysis leaves out some potentially important channels through which tariff policy may have an impact. We do not, for instance, consider the effects of tariff uncertainty (Caldara, Iacoviello, Molligo, Prestipino and Raffo 2020) or financial frictions, both of which are likely to aggravate any contraction. A possible loss of confidence in the US dollar as a reserve currency, which may have driven a decline in the dollar beyond what one would expect from relative bond yields, is also outside the scope of our analysis, as are other recent events in the US economy that may have contributed positively to growth (e.g. the AI boom). Our aim is to show how, even in a very simple environment, tariff shocks can have contractionary effects.[5]

Relation to literature. Our model builds on the canonical Gali and Monacelli (2005) New Keynesian open economy framework, with a few key modifications: we assume sticky wages and flexible prices, allow for trade in intermediate inputs, and replace com-

[3] In Den Besten and Kanzig (2025), inflation only falls in the post-WWII subsample, while rising in the full sample—due in part to the contractionary effects of heavier retaliation post-WWII.

[4] In principle, this could be consistent with a version of our quantitative model with very flexible wages, where the decline in the prices of domestic goods through the domestic Phillips curve overwhelms the increase in prices of foreign goods in the CPI.

[5] Depending on their magnitude, these contractionary effects may or may not be large enough to overcome underlying trend growth and produce an official recession. Indeed, our numerical results suggest that the downturn from unilateral tariffs is likely smaller than annual trend growth; with full retaliation, the numbers are closer.

plete with incomplete international markets.[6]

A number of recent papers have explored the effects of tariffs in New Keynesian models. On the positive side, papers have found conflicting effects of unilateral, temporary tariffs on GDP in the absence of a monetary policy response. Bergin and Corsetti (2023) calibrate to $\sigma = 0.5$ and find that unilateral tariffs are expansionary. Barattieri et al. (2021), on the other hand, feature an investment channel and find a recessionary effect, consistent with a high effective σ from the elastic response of investment. Relative to these two papers, we provide a more stylized framework, which allows us to derive clean analytical formulas that clarify the role of underlying elasticities, including σ, η and γ. Monacelli (2025) shares our more analytical focus and derives a condition related to (1), but for natural output rather than the output gap.[7] Erceg, Prestipino and Raffo (2023) find import tariffs to be roughly neutral in a model calibrated to $\sigma = 1$, and trade elasticities η, γ close to 1. To make sure σ, η and γ are realistic in the current context, we allow for durables and inventories in the quantitative exercises in section 6.

On the normative side, Bergin and Corsetti (2023) is the seminal paper solving for optimal monetary policy in response to tariff shocks, finding optimal policy to be contractionary for unilateral tariffs but expansionary with retaliation. Both Bianchi and Coulibaly (2025) and Monacelli (2025), by contrast, find a clear role for expansionary policy in response to unilateral tariffs, with Bianchi and Coulibaly showing that optimal policy allows inflation to rise above the direct effects of tariffs. This causes depreciation, but through a different channel than our paper—expansionary monetary policy rather than a reduced natural interest rate. Werning, Lorenzoni and Guerrieri (2025) show analytically that in a New Keynesian model, tariffs can be isomorphic to cost-push shocks. Our paper emphasizes that temporary tariff shocks are stagflationary: they push inflation up and output down, even in the absence of contractionary monetary policy.[8] Although our paper does not explicitly solve for optimal policy, we do analytically characterize the welfare implications of tariff shocks, including a new term from a nonzero output gap.

[6]A literature dating back to Mundell (1961) studies the effect of tariff shocks in old Keynesian models. This literature generally finds that tariffs can reduce employment, because they drive exchange rate appreciation and increase savings via the so-called Laursen-Metzler effect (Eichengreen 1981, Krugman 1982). As Krugman (1982) acknowledges, this effect "rests on weak microfoundations". In our model, tariffs reduce employment even if monetary policy does not respond and the exchange rate does not move; moreover, the exchange rate depreciates rather than appreciates in the natural allocation.

[7]In the original Gali and Monacelli (2005) model without intermediate inputs, condition (1) becomes simply $\sigma > \eta$, as we show in section 4.4. This condition, in turn, is the same as Guerrieri, Lorenzoni, Straub and Werning (2022)'s condition for when shutting down a sector (here, imports) leads to a recession in the other sector (here, domestic production). Monacelli (2025) shows that this same condition governs the direction of natural output.

[8]Other work, including Auray, Devereux and Eyquem (2024) and Jeanne (2021), endogenizes tariffs and studies the interaction between tariff choice and monetary policy.

Kalemli-Özcan, Soylu and Yildirim (2025) and Nispi Landi and Moro (2024) study the effects of tariffs in models with multi-country trade networks. Although we abstract from networks, we do allow for intermediate inputs, and like these papers we find an important role for the transmission of tariffs to input costs. Closely related work, including Cuba-Borda, Queralto, Reyes-Heroles and Scaramucci (2025) and Ambrosino, Chan and Tenreyro (2024), examines the effects of shocks to trade costs rather than tariffs. Auclert, Monnery, Rognlie and Straub (2023) and Guerrieri, Lorenzoni and Werning (2025) study world energy shocks, which can also have stagflationary effects.

Finally, our paper is part of a broader literature inspired by the Trump administration's tariff announcements. On the theoretical side, Werning and Costinot (2025) study whether permanent tariffs can close an existing trade deficit. Aguiar, Amador and Fitzgerald (2025) focus on currency revaluation effects of tariffs in light of large gross positions, a focus that is shared with Itskhoki and Mukhin (2025). Other studies evaluated welfare and the terms of trade (Ignatenko, Lashkaripour, Macedoni and Simonoska 2025), or capital accumulation (Baqaee and Malmberg 2025). Alessandria, Ding, Yar Khan and Mix (2025) look at both short and long-run effects, with an emphasis on the benefits of tariff revenue in lowering distortionary taxation. Cavallo, Llamas and Vazquez (2025) track the effect of tariffs on both import and domestic prices.[9]

Outline of paper. The paper is structured as follows. Section 2 introduces our core model, section 3 analyzes the effect of tariff shocks in that model, and section 4 considers a variety of extensions. Section 5 conducts the optimal tariff analysis taking into account the costs of a contraction. Section 6 simulates an extended version of the model to study the effects of persistent and possibly anticipated tariff shocks. Section 7 concludes.

2 Baseline model

We center our analysis on a baseline model, which we keep simple to illustrate the key transmission mechanisms of tariff shocks. The model is based on Gali and Monacelli (2005), with three modifications. First, we assume incomplete rather than complete international markets, so that countries do not hedge the effects of tariff shocks. This is important for our welfare analysis. Second, we assume that imports are also used in the

[9] This question of pass-through was central to a literature studying the earlier Trump administration tariffs (Amiti, Redding and Weinstein 2019, Flaaen, Hortaçsu and Tintelnot 2020, Fajgelbaum, Goldberg, Kennedy and Khandelwal 2020, Cavallo, Gopinath, Neiman and Tang 2021). A rapidly growing recent literature has also studied the role of trade policy as a way of projecting geoeconomic power (Clayton, Maggiori and Schreger 2023, Becko and O'Connor 2025).

production of exports, not just domestic consumption. This is to reflect the important role of intermediate inputs and cross-border production chains in trade (e.g. Di Giovanni and Levchenko 2010, Johnson 2014).

Third, we assume sticky wages and flexible prices, rather than sticky prices and flexible wages. This is consistent with an empirical literature that documents much more rigidity in nominal wages than in prices—especially goods prices.[10] In our model, this assumption implies full pass-through of tariffs to prices. This is consistent with recent evidence on tariffs and border prices, although border prices do not always transmit fully to retail prices (Amiti et al. 2019, Flaaen et al. 2020, Fajgelbaum et al. 2020, Cavallo et al. 2021). We argue that retail margins are unlikely to be able to absorb a large share of a broad tariff shock like the U.S. 2025 shock, making full pass-through a plausible assumption in such cases.[11] We relax this assumption, however, and allow for imperfect pass-through into import prices in section 4.3. Importantly, we find that our condition for a downturn is unchanged in this case, although its potential magnitude is attenuated.

In section 4, we will study several variations of the baseline model, including extensions to a large open economy, unbalanced trade, and durables.

2.1 Setup

We first study the problem of a small open economy ("home", "domestic") that is surrounded by a continuum of symmetric small economies ("rest of the world", "foreign"). Variables describing the rest of the world have a star superscript. The home economy produces a single home good, and the rest of the world produces a single basket of foreign goods. The model is set in discrete time $t = 0, \ldots, \infty$, with perfect foresight from date 0 onward, but where an unexpected shock may perturb the steady-state economy at date 0.

Domestic households. Domestic households consume home goods C_t, and invest in domestic nominal bonds B_t paying interest i_t and foreign nominal bonds A_t paying interest i_t^*. We assume the latter to be a constant i^*.[12] Household utility is

$$\sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-1/\sigma}}{1-1/\sigma} \tag{2}$$

[10]For instance, Bils and Klenow (2004) document a 30% monthly frequency of price adjustment for goods, while Grigsby, Hurst and Yildirmaz (2021) document a less-than-7% monthly frequency of wage adjustment, with virtually no nominal wage declines (0.4% monthly).

[11]See also Cavallo, Lippi and Miyahara (2024) on why large shocks may transmit to prices more quickly.

[12]Except in section 4.7, we take rest-of-the-world aggregates to be constant in our analysis, since the home economy's tariff shock is too small to affect any of them.

where $\beta \in (0,1)$ denotes the discount factor and $\sigma > 0$ the elasticity of intertemporal substitution. The budget constraint in units of domestic currency is given by

$$P_t C_t + A_t + B_t = W_t N_t + \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} (1 + i^*) A_{t-1} + (1 + i_{t-1}) B_{t-1} + T_t. \tag{3}$$

P_t is the price of domestic gross output, which coincides with the domestic consumer price index (CPI), and $\mathcal{E}_t$ is the nominal exchange rate. B_t is in zero net supply and hence also zero initially ($B_{-1} = 0$). A_t is also the net foreign asset position (NFA) of the home economy, and, for now, also assumed to be zero initially ($A_{-1} = 0$). T_t is a transfer from the government.

Labor market. Domestic households supply labor $N_t \leq \overline{N}$, up to some labor endowment $\overline{N}$, to domestic firms, earning the nominal wage W_t. We assume that there is a downward nominal wage rigidity that restricts W_t to stay above W_{t-1}. We thus have that whenever $W_t > W_{t-1}$, households supply their full labor endowment $N_t = \overline{N}$; otherwise, it is possible that N_t falls short of $\overline{N}$, in which case there is involuntary unemployment (see, e.g., Schmitt-Grohé and Uribe 2016). Labor N_t is the only source of domestic value added, and to first order around our undistorted initial steady state it is therefore equal to domestic real GDP. To higher order, GDP includes the distortion in production from tariffs while labor does not (see appendix B.2).

Domestic production and imports. Domestic gross output Y_t, which is used both for consumption and exports, is produced by a representative firm from domestic labor N_t and imports M_t,

$$Y_t = \left((1-\alpha)^{1/\eta} N_t^{\frac{\eta-1}{\eta}} + \alpha^{1/\eta} M_t^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}. \tag{4}$$

Here, $\alpha \in (0,1)$ is the openness of the economy and $\eta > 0$ the elasticity of import substitution. By having imports enter into the production function for exports, (4) effectively allows for imported intermediate goods.[13]

With a price P_t^F of imported foreign goods, we can write the domestic price index as

$$P_t = \left[(1-\alpha) W_t^{1-\eta} + \alpha \left(P_t^F \right)^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{5}$$

[13] We do not explicitly model within-country intermediate goods linkages, and instead view them as part of the production technology (4). We generalize to allow for distinct production technologies for consumption and exports in section 4.4.

and demands for labor and imports as

$$N_t = (1-\alpha)\, Y_t \left(\frac{W_t}{P_t}\right)^{-\eta} \qquad M_t = \alpha Y_t \left(\frac{P_t^F}{P_t}\right)^{-\eta}. \tag{6}$$

Exchange rate. We denote the nominal exchange rate by $\mathcal{E}_t$, with a higher value for $\mathcal{E}_t$ representing a depreciation. No arbitrage implies that an uncovered interest parity (UIP) condition holds between all periods $t \geq 0$ and $t+1$,

$$\mathcal{E}_t = \frac{1+i^*}{1+i_t}\mathcal{E}_{t+1}. \tag{7}$$

The UIP condition, together with zero bond issuance at home, allows us to consolidate the household budget constraint as

$$P_t C_t + A_t = W_t N_t + T_t + (1+i_{t-1})\, A_{t-1}.$$

Pricing and tariffs. All prices, with the exception of the nominal wage W_t, are flexible. Foreign goods prices are thus given by

$$P_t^F = (1+\tau_t)\, \mathcal{E}_t, \tag{8}$$

where we normalize foreign goods prices P_t^* in the rest of the world to 1. τ_t is the import tariff and is the main shock of interest in this paper. The government transfers the proceeds of the tariffs to the household:

$$T_t = \tau_t \mathcal{E}_t M_t. \tag{9}$$

Exports. The rest of the world demands X_t domestically produced goods according to

$$X_t = \alpha Y^* \cdot \left(\frac{P_t}{\mathcal{E}_t}\right)^{-\gamma}, \tag{10}$$

where production in the rest of the world is constant at Y^*, and, with our normalization $P_t^* = 1$, the relevant relative price of home goods abroad is $P_t/\mathcal{E}_t$. Following Gali and Monacelli (2005), the elasticity of export demand γ is distinct from η, as γ characterizes substitution between different countries' exports, while η characterizes substitution between domestically produced goods and the entire import basket. We will generally assume that $\gamma > 1$; that is, that the home economy as a whole does not possess infinite market power.

Monetary policy. The nominal interest rate i_t is controlled by the domestic central bank. We assume that in all dates $t \geq 1$, the domestic central bank implements the full-employment allocation $N_t = \overline{N}$. At date $t = 0$, we will consider the polar cases of a "passive" central bank, which leaves i_0 at its steady state value unless there is wage inflation; and a "stabilizing" central bank, which adjusts i_0 to achieve full employment.[14] In all cases, we assume that the central bank stabilizes wage inflation, so that $W_t = W$ is fixed.

Equilibrium. Given a sequence of import tariff shocks $\{\tau_t\}$ and monetary policy, a *competitive equilibrium* in our economy is a sequence of quantities $\{C_t, Y_t, N_t, M_t, X_t, A_t, B_t, T_t\}$ and prices $\{P_t, P_t^F, \mathcal{E}_t, W_t\}$ such that: (a) domestic households maximize (2) s.t. (3), (b) $N_t = \overline{N}$ if $W_t > W_{t-1}$, (c) equations (4)–(10) hold, (d) the domestic asset market clears, $B_t = 0$, (e) the balance of payments is satisfied,

$$A_t = \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} (1 + i^*) A_{t-1} + \mathcal{E}_t TB_t, \tag{11}$$

where TB_t is the trade balance in units of foreign goods

$$TB_t \equiv \frac{P_t}{\mathcal{E}_t} X_t - M_t, \tag{12}$$

and (f) the goods market clears,

$$Y_t = X_t + C_t. \tag{13}$$

Steady state. We assume the economy starts at $t = -1$ in a *steady-state equilibrium,* in which all quantities and prices are constant, with a zero import tariff $\tau = 0 = T$. We denote the steady-state values of all time-varying objects without any subscripts. We normalize all steady-state prices to 1,

$$P = P^F = \mathcal{E} = W = 1,$$

and also normalize production to 1, $Y = Y^* = 1$, which pins down

$$M = X = \alpha \qquad C = N = 1 - \alpha.$$

Thus, for now, trade is assumed to be balanced in the initial steady state; we relax this in section 4.1. The steady-state interest rates are $i = i^* = \beta^{-1} - 1$.

[14] Passive monetary policy can be thought of either as a very inertial policy rule or as an outcome of a binding lower bound on the nominal interest rate.

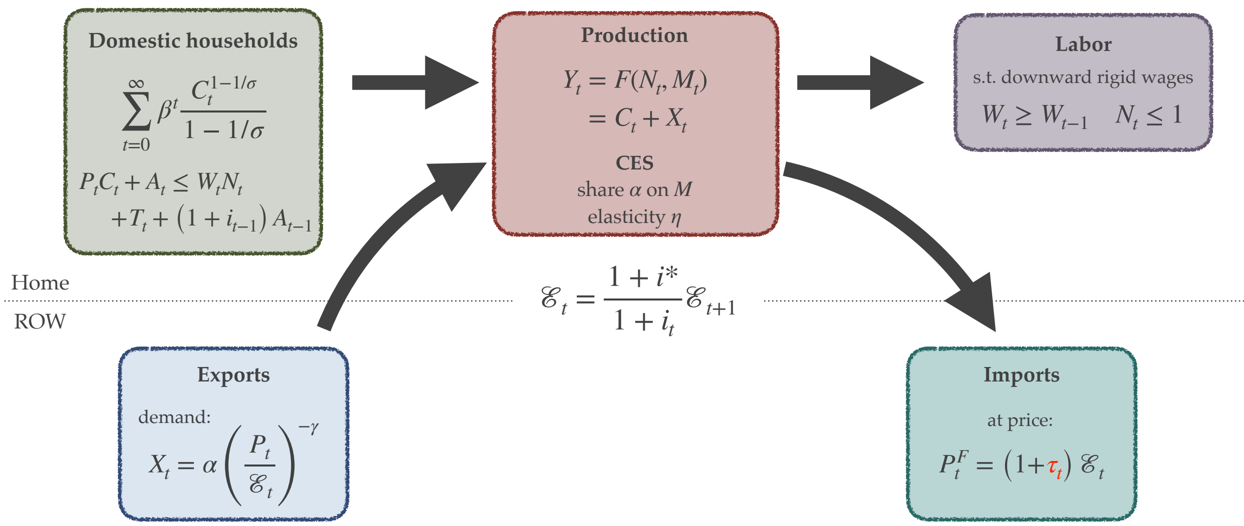


Figure 1: Summary of the spending flows in the baseline model

Model summary. We summarize the model in figure 1, with arrows indicating spending flows.

2.2 Long-run effects of tariffs

We will compare our results for temporary tariff shocks to a benchmark where there is a permanent shift in tariffs. In this case, the economy adjusts immediately to the new long-run equilibrium.

Proposition 1. *In response to a first-order permanent tariff increase, $d\tau > 0$, with either passive or stabilizing monetary policy, there is no change in GDP, $N_t = \overline{N}$, and no change in the trade balance. Exports and imports both decline,*

$$d\log X = -\frac{\eta\gamma}{(\gamma-1)(1-\alpha)+\eta} d\tau \qquad d\log M = -\frac{\eta(\gamma-1)}{(\gamma-1)(1-\alpha)+\eta} d\tau$$

$$\frac{dTB}{M} = d\log X + d\log(P/\mathcal{E}) - d\log M = 0 \tag{14}$$

and the exchange rate changes by

$$d\log\mathcal{E} = -\frac{\eta-\alpha(\gamma-1)}{(\gamma-1)(1-\alpha)+\eta} d\tau \qquad d\log(\mathcal{E}/P) = -\frac{\eta}{(\gamma-1)(1-\alpha)+\eta} d\tau. \tag{15}$$

The denominator in (14)–(15) is the sensitivity of the trade balance to the exchange rate. In equilibrium, the exchange rate moves to offset the shock to the trade balance from higher tariffs, resulting in an equal decline in exports and imports.

In principle, the nominal exchange rate can go either way: if $\alpha(\gamma - 1) > \eta$, export demand is so elastic that a decline in export competitiveness overwhelms substitution away from imports, weakening the trade balance and forcing the nominal exchange rate to depreciate ($\mathcal{E} \uparrow$). For countries like the U.S. with small α, however, this is implausible, and the nominal exchange rate is likely to appreciate. The real exchange rate $\mathcal{E}/P$ appreciates, and this appreciation limits the increase in relative import prices P^F/P from the tariff—consistent with the conventional view in the trade literature about the effect of tariffs on the exchange rate.

2.3 Reference calibration

Before continuing with our discussion of tariff shocks, we choose a reference calibration to anchor our analysis. To start, three parameters govern the long-run response (14)–(15): openness α, the import substitution elasticity η, and the export demand elasticity γ.

To calibrate α, we note that the model's steady-state ratio of imports (or exports) to GDP is $\frac{\alpha}{1-\alpha}$. We take the average of the US's 2023 import-to-GDP (13.9%) and export-to-GDP (11.0%) ratios to obtain a target of $\frac{\alpha}{1-\alpha} = 12.5\%$, which implies $\alpha = 1/9 \approx 11.1\%$. For the long-run export elasticity γ, which is the elasticity of substitution between varieties produced by different countries, we take $\gamma = 4$ from Simonovska and Waugh (2014) as the approximate midpoint of an extensive trade literature.[15]

The elasticity η of substitution between imports and domestic value added is in principle distinct from γ. To calibrate it, we use a result from Auclert, Rognlie, Souchier and Straub (2024), who show that a model with substitution between tradables and nontradables, and also substitution between domestic and foreign tradables, is locally equivalent to assuming a particular η. Assuming that preferences over tradables and nontradables are Cobb-Douglas, and that the elasticity between domestic and foreign tradables is also γ, we obtain a long-run estimate of $\eta = 3.07$. Details are provided in appendix A.2.

It is widely understood that trade elasticities are lower in the short run than the long run, since substituting between different goods and suppliers often takes time. Recent work by Boehm et al. (2023) finds a short-run elasticity in response to tariffs that is 3/8 of the central long-run elasticity. Since our analysis primarily deals with the short-run effects of tariffs, we multiply the long-run γ and η above by 3/8 to obtain our primary calibration: $\gamma = 1.5$ and $\eta = 1.15$.

For dynamics, we also need to calibrate the elasticity of intertemporal substitution

[15]On the lower end, Boehm, Levchenko and Pandalai-Nayar (2023) find a long-run elasticity of 2, while on the higher end, Eaton and Kortum (2002) find an elasticity of approximately 8.

Table 1: Reference calibration (short run)

	Description	Value
σ	Intertemporal elasticity	1.79
γ	Export elasticity	1.5
η	Import elasticity	1.15
α	Openness	0.11

σ. Here, we view it as crucial to take durable goods into account, since traded goods are disproportionately durable, and durable goods purchases are much more intertemporally substitutable—at least in the short run—than nondurable purchases. In section 4.5, we will show that the effective elasticity of intertemporal substitution in aggregate consumption for one-time shocks to tariffs is $(1-\omega)\,\sigma + \omega\epsilon_D$, where σ is the elasticity of intertemporal substitution for nondurable consumption, ϵ_D is the elasticity of durable investment to durable price, and $\omega = \frac{C^D}{C^{ND}+C^D}$ is the share of durables in total consumption. We take $\omega = 11\%$ from the 2023 national accounts, $\epsilon_D = 8.2$ from the main estimates in Baker, Kueng, McGranahan and Melzer (2019), and assume a standard nondurable elasticity of 1, leaving us with an effective elasticity of 1.79, to which we calibrate σ.

Table 1 summarizes this reference calibration.

Finally, though most of our results will be for arbitrary short-term shocks to τ, when quantifying our results (especially in section 6) we will sometimes use a specific tariff magnitude. We choose $d\tau = 10\%$ as our benchmark, since this is close to the increase in average effective tariffs from January to December 2025.[16]

3 Tariff shocks

Our main experiment in the next three sections is a one-time unexpected increase in tariffs, $\tau_0 > 0$, $\tau_t = 0$ for $t \geq 1$. We start with a first-order analysis, and write $\tau_0 = d\tau$.

We derive our results in the limit $\beta \nearrow 1$, following Woodford (2022); conceptually, this corresponds to period 0 being arbitrarily short. This limit greatly improves tractability, as any endogenous changes in the net foreign asset position as a result of the shock have a vanishingly small effect on consumption.[17] Since β is typically close to 1, this is a rela-

[16] According to https://www.tradewartracker.com/trade-war-redux-2025-edition.html, the average effective tariff increased from 2.3% to 14.0% over this period.

[17] The more common way to obtain tractability is to assume complete international markets, as in the original Gali and Monacelli (2005). For date-0 outcomes, this is identical to our $\beta \nearrow 1$ limit, but it has different implications for discounted utility, which matter in section 5. We thus avoid complete markets, since we find it unlikely that domestic households fully insure tariff shocks on international markets.

tively innocuous assumption. We relax this assumption in our simulations in section 6.

We first consider the case of passive monetary policy, and then the case of an output-stabilizing monetary policy.

3.1 When are tariff shocks contractionary?

With passive monetary policy and a binding downward wage constraint, we have $i_0 = i$, and, by the UIP condition (7), the exchange rate is stable, $\mathcal{E}_0 = \mathcal{E}$. Thus, the import price (8) moves one-for-one with the tariff, $d \log P_0^F = d\tau$. To first order, the CPI (5) increases by $d \log P_0 = \alpha d\tau$.

From the first-order condition for labor demand (6) and the assumption that nominal wages are stable, we see that labor demand is

$$d \log N_0 = d \log Y_0 + \eta d \log P_0. \tag{16}$$

This shows that labor demand is influenced by goods demand $d \log Y_0$ and a substitution effect $\eta d \log P_0 = \alpha \eta d\tau$. The latter *import substitution effect* is positive, creating a channel through which the tariff shock can increase GDP.

Goods demand (13) itself is the sum of export demand and domestic consumption,

$$d \log Y_0 = \alpha d \log X_0 + (1 - \alpha) d \log C_0. \tag{17}$$

Both unambiguously fall in response to the shock, albeit with different elasticities. Exports (10) fall in proportion to the export demand elasticity γ,

$$d \log X_0 = -\gamma d \log P_0 = -\gamma \alpha d\tau, \tag{18}$$

as higher import prices hurt the competitiveness of the home economy's exports.

Consumption is determined by the Euler equation,

$$\frac{1}{P_0} C_0^{-1/\sigma} = \beta (1 + i_0) \frac{1}{P_1} C_1^{-1/\sigma}. \tag{19}$$

With a constant interest rate, $1 + i_0$ is independent of the shock. C_1 is also independent of the shock in the limit $\beta \nearrow 1$, since it is unaffected by any net foreign asset position accumulated at the end of period 0. For the same reason, P_1 is also unaffected by the shock. Thus, date-0 consumption is given by

$$d \log C_0 = -\sigma d \log P_0 = -\sigma \alpha d\tau.$$

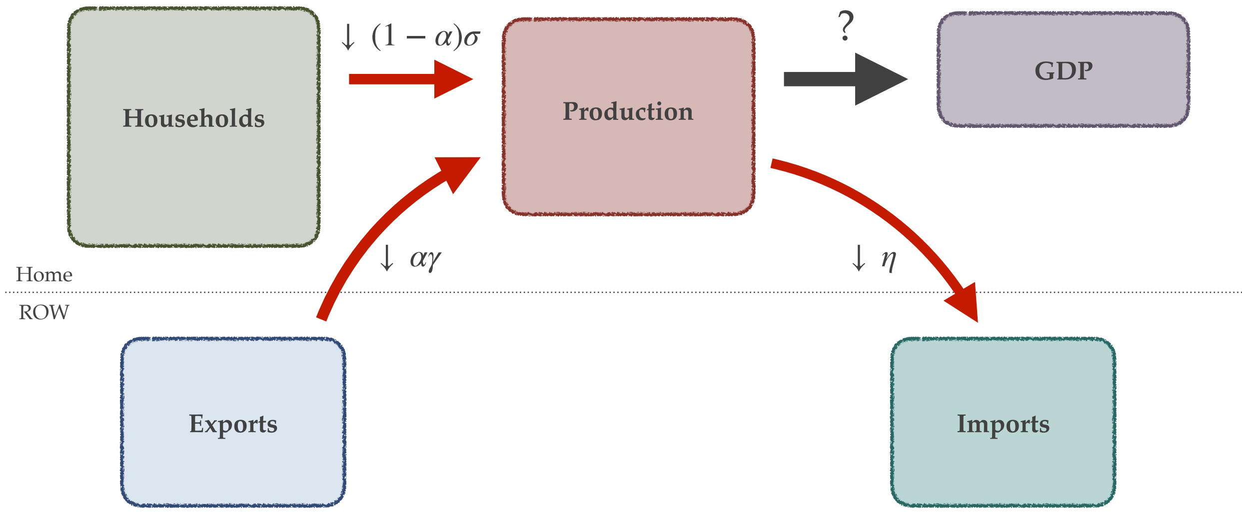


Figure 2: Three transmission channels of the import tariff shock

A greater intertemporal elasticity σ leads to lower consumption, as households postpone purchases in light of high current prices.

Taken together, both consumption and exports pull goods demand (17), and thus labor demand (16) down, while import substitution pushes labor demand up:

$$d \log N_0 = -\left(\alpha\gamma + (1-\alpha)\,\sigma\right)\alpha d\tau + \eta\alpha d\tau.$$

Figure 2 illustrates all three channels. Overall, the tariff shock is contractionary when the export demand and intertemporal substitution channels dominate import substitution:

$$(1-\alpha)\,\sigma + \alpha\gamma > \eta. \tag{20}$$

The following proposition summarizes this result and derives implications for other macroeconomic variables.

Proposition 2. *Assume passive monetary policy. The economy contracts at date 0, $N_0 < \overline{N}$, if and only if* (20) *holds. In that case, real GDP falls by*

$$d \log GDP_0 = d \log N_0 = -\alpha\left((1-\alpha)\,\sigma + \alpha\gamma - \eta\right) d\tau, \tag{21}$$

exports and imports fall by

$$d \log X_0 = -\alpha\gamma d\tau \qquad d \log M_0 = -\left((1-\alpha)\,\eta + \alpha\left((1-\alpha)\,\sigma + \alpha\gamma\right)\right) d\tau,$$

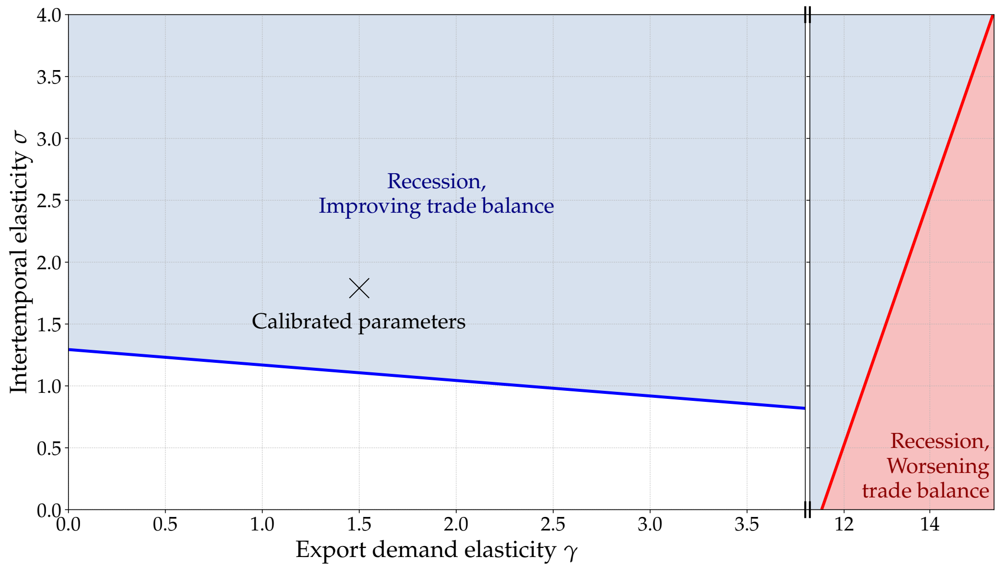


Figure 3: Unilateral tariff shock: Conditions for recession and improving trade balance

the sign of the trade balance response is ambiguous,

$$\frac{dTB_0}{M} = (\alpha + (1-\alpha)\,\eta + (1-\alpha)\,\alpha\,(\sigma - \gamma))\,d\tau, \tag{22}$$

and the CPI rises by $d\log P_0 = \alpha d\tau$.

Proposition 2 shows that, if condition (20) holds, the tariff shock *itself* (without a monetary policy response) is stagflationary. Prices rise at the same time as economic activity slows down: $d\log P_0 = \alpha d\tau > 0$ and $d\log GDP_0 < 0$. Unlike transitory cost-push shocks in the textbook New Keynesian model, which under passive monetary policy only increase inflation without changing GDP, the import tariff shock not only raises inflation but also simultaneously reduces GDP. This aggravates the trade-off between stabilizing the output gap and CPI inflation. This stagflationary nature of tariff shocks echoes the empirical findings of Furceri, Hannan, Ostry and Rose (2018), as well as the theoretical results in Bergin and Corsetti (2023)—though, in their calibration, tariffs are only stagflationary when there is retaliation.

Proposition 2 also characterizes trade flows and the trade balance. In the likely case where $\alpha(\gamma - 1) < \eta$, exports fall by less than in response to a permanent tariff—since a permanent tariff, unlike here, causes the exchange rate to appreciate (see section 2.2). Meanwhile, the effect on the overall trade balance is in principle ambiguous.

In a version of the model without trade in intermediate inputs, equation (20) becomes $\sigma > \eta$, as we show in section 4.4. This is closely related to Guerrieri et al. (2022), who find that, in a two-sector model, temporary supply shocks to a sector reduce employment in the other sector when σ is larger than the elasticity of substitution between sectors.

For our model, we illustrate the conditions under which a recession occurs and the trade balance improves in figure 3, which plots the intertemporal elasticity σ on the y-axis and the export demand elasticity γ on the x-axis, holding η fixed at our calibrated $\eta = 1.15$. With sufficiently high σ or γ, the two contractionary channels dominate the expansionary one in (20), placing us in the recession region above the blue line. For high enough γ, it is possible that the trade balance deteriorates—but this requires γ over 12, well beyond a plausible short-run value. We mark the calibration from table 1 with an "X", and see that it puts us in the region with recession but an improving trade balance. Numerically, with this calibration, a 10% tariff shock contracts the economy by 0.66% and improves the trade balance by 1.4% of GDP, or 11.6% of imports.[18]

In sum, the effects of a short-run tariff shock are quite different from the long-run tariff we examined in section 2.2. Here, in response to a short-run tariff, GDP declines, the trade balance improves, and the exchange rate remains unchanged—while for a long-run tariff, GDP and the trade balance remain unchanged, and the exchange rate appreciates.

3.2 Monetary policy response

Next, we study a stabilizing monetary policy that adjusts i_0 to implement full employment $N_0 = \overline{N}$. We call the interest rate i_0 that achieves this the *natural* interest rate, since $N_0 = \overline{N}$ is the natural allocation in this economy—the allocation that would prevail in the absence of wage rigidity.

The interest rate i_0 matters for aggregate demand in several ways. First, a lower interest rate stimulates demand directly via intertemporal substitution in the Euler equation (19) of domestic households. Indeed, linearizing the Euler equation we see that

$$d \log C_0 = -\sigma d \log (1 + i_0) - \sigma d \log P_0. \tag{23}$$

Second, because it depreciates the exchange rate via the UIP condition (7), $d \log \mathcal{E}_0 = -d \log (1 + i_0)$, a lower interest rate increases the price of imports even further,

$$d \log P_0^F = d\tau - d \log (1 + i_0) \qquad \text{and} \qquad d \log P_0 = \alpha d \log P_0^F. \tag{24}$$

This price increase is contractionary assuming condition (20).

Finally, a lower interest rate makes exports more competitive, increasing export de-

[18]Note that while this is a significant contraction, in the presence of trend growth it is unlikely to cause an official, NBER-dated recession on its own.

mand according to

$$d\log X_0 = -\gamma d\log P_0 - \gamma d\log\left(1+i_0\right). \tag{25}$$

Substituting (23)–(25) into (16) and (17), we derive the following.

Proposition 3. *In response to the tariff shock, the natural interest rate is given by*

$$d\log\left(1+i_0\right) = -\frac{\alpha}{1-\alpha}\frac{\left(1-\alpha\right)\sigma+\alpha\gamma-\eta}{\left(1-\alpha\right)\sigma+\alpha\gamma+\frac{\alpha}{1-\alpha}\eta}d\tau. \tag{26}$$

In particular, the natural rate falls iff condition (20) is satisfied. Under the same condition, the exchange rate $d\log\mathcal{E}_0 = -d\log\left(1+i_0\right)$ depreciates. The trade balance unambiguously improves:

$$\frac{dTB_0}{M} = \frac{\eta}{1-\alpha}\left(\frac{\left(1-\alpha\right)\sigma+\alpha}{\left(1-\alpha\right)\sigma+\alpha\gamma+\frac{\alpha}{1-\alpha}\eta}\right)d\tau. \tag{27}$$

Under condition (20), the natural interest rate falls, depreciating the exchange rate—exactly the opposite of the exchange rate movement from a permanent tariff. This aggravates the tariff shock to some extent, as import prices and the CPI now rise by even more. This leads to a further contraction in imports, and mitigates, to some extent, the decline in exports. The trade balance unambiguously improves. Appendix C.8 shows that under the same condition, the natural level of output falls in a version of the model with elastic labor supply.[19]

Given our calibration, the natural interest rate (26) falls by 40 basis points for a 10% tariff shock. These 40 basis points are to be interpreted over the length of the tariff shock. If the shock lasts one quarter, this corresponds to a 1.60pp decline in the annualized natural interest rate. The trade balance improves by roughly the same as before, around 11.6% of imports, as the result of two offsetting factors: on the one hand, no longer having a recession hurts the trade balance (greater imports), while on the other hand, the depreciation helps the trade balance (greater exports).

3.3 Comparison with export tax and the failure of Lerner symmetry

Lerner symmetry (Lerner 1936) is the proposition that an import tariff is equivalent to an export tax.[20] In our model, this is indeed true for the permanent case: permanent export and import taxes have identical implications for trade flows.

[19] In a related model without intermediate inputs and $\gamma = \eta$, Monacelli (2025) finds the condition $\sigma > \eta$ for natural output to fall.

[20] See Costinot and Werning (2019) and Barbiero, Farhi, Gopinath and Itskhoki (2019) for recent work on Lerner symmetry.

To investigate the extent to which Lerner symmetry holds for *temporary* import tariffs and export taxes, we now introduce an export tax shock, denoted by τ_t^X. We assume that the import tariff is zero in this subsection, $\tau_t = 0$.

In contrast to (10), the export tax directly reduces export demand:

$$X_t = \alpha Y^* \cdot \left(\left(1+\tau_t^X\right)\frac{P_t}{\mathcal{E}_t}\right)^{-\gamma}.$$

Since the export price at the border is inclusive of the export tax, the tax enters the equation for the trade balance

$$TB_t \equiv \left(1+\tau_t^X\right)\frac{P_t}{\mathcal{E}_t}X_t - M_t,$$

and as with an import tariff, export tax revenue is transferred to households: $T_t = \tau_t^X P_t X_t$.

We study a small export tax at date 0, $\tau_0^X = d\tau$, $\tau_t^X = 0$ for $t > 0$. Assume first that monetary policy is passive. Then the export tax acts by reducing export demand directly,

$$d\log X_0 = -\gamma d\tau,$$

which decreases goods demand and thus demand for labor and imports,

$$d\log N_0 = d\log M_0 = -\alpha\gamma d\tau.$$

An export tax shock thus always causes a short-run recession, irrespective of η and σ.

We summarize this finding in the next proposition, and also derive implications for the case of stabilizing monetary policy.

Proposition 4. *An export tax shock of size $d\tau$ with passive monetary policy causes a recession*

$$d\log GDP_0 = -\alpha\gamma d\tau, \tag{28}$$

and reduces exports and imports, $d\log X_0 = -\gamma d\tau$ and $d\log M_0 = -\alpha\gamma d\tau$. The trade balance worsens for any $\gamma > 1/(1-\alpha)$,

$$\frac{dTB_0}{M} = -\left(\left(1-\alpha\right)\gamma - 1\right)d\tau. \tag{29}$$

With stabilizing monetary policy, the natural interest rate unambiguously falls

$$d\log\left(1+i_0\right) = -\frac{\alpha}{1-\alpha}\frac{\gamma}{\left(1-\alpha\right)\sigma + \alpha\gamma + \frac{\alpha}{1-\alpha}\eta}d\tau, \tag{30}$$

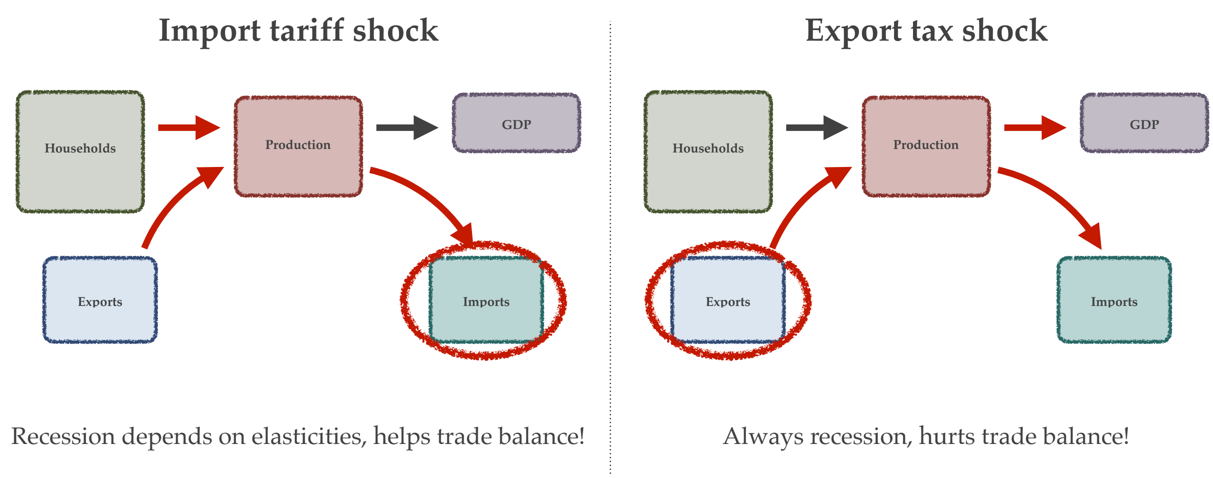


Figure 4: Import tariff vs. export tax

leading to an exchange rate depreciation, $d\log\mathcal{E}_0 = -d\log(1+i_0)$.

Figure 4 highlights the main differences between import and export tax shocks at $t = 0$. An import tariff hits import prices, and leads to substitution away from imports and any goods produced using imports. Whether GDP falls depends on relative elasticities. By contrast, an export tax hits export prices, which leads to lower goods demand and an unambiguous decline in GDP. The trade balance, for reasonable export demand elasticities $\gamma > 1/(1-\alpha)$, worsens rather than improves. Even when monetary policy is stabilizing, import and export tax shocks differ.

Why does Lerner symmetry not apply here? In the long run, trade must balance, so that all exports are ultimately used to pay for imports. This transaction—of exports for imports—is distorted in the same way by import and export taxes, leading to the Lerner symmetry result. In the short-run analysis of proposition 4, by contrast, there is no need for trade to balance, and the home economy is free to adjust exports and imports separately in response to differing taxes.

3.4 Retaliation

So far, we have considered purely unilateral policies. Next, we consider a case in which the rest of the world retaliates and imposes symmetric import tariffs on domestic exports. The world's retaliatory tariff $\tau_t^r = \tau_t$ acts, in many ways, like the export tax in the previous subsection. For example, it reduces export demand according to

$$X_t = \alpha Y^* \cdot \left((1+\tau_t^r)\,\frac{P_t}{\mathcal{E}_t} \right)^{-\gamma}$$

There are two differences, however. First, transfers to households are still given by (9), as import tariffs abroad do not contribute to domestic tax revenue. Second, τ_t^r does not enter the trade balance, since the price at the border excludes τ_t^r. TB_t is still given by (12).

Our next proposition characterizes the solution in this case. We focus on the case of passive monetary policy.

Proposition 5. *With retaliation, $\tau_0 = \tau_0^r = d\tau$, and passive monetary policy, domestic GDP declines whenever*

$$(1-\alpha)\,\sigma + \alpha\gamma + \gamma > \eta, \tag{31}$$

in which case it falls by

$$d\log GDP_0 = -\alpha\left((1-\alpha)\,\sigma + \alpha\gamma + \gamma - \eta\right)d\tau, \tag{32}$$

and the trade balance changes by

$$\frac{dTB_0}{M} = \left(\alpha + (1-\alpha)\,(\eta-\gamma) + (1-\alpha)\,\alpha\,(\sigma-\gamma)\right)d\tau. \tag{33}$$

With stabilizing monetary policy, the natural rate falls by more than with unilateral tariffs.

Relative to (20), the recession condition (31) under retaliation adds a γ on the left, reflecting the direct hit to export demand from a retaliatory tariff. This new condition is easily satisfied if, for instance, $\gamma > \eta$. We illustrate this condition as the blue line in figure 5, varying σ and γ as we fix η and α at their calibrated values from table 1. Relative to the unilateral case in figure 3, retaliation rotates this line clockwise, making a downturn even more likely.

The trade balance with retaliation, (33), is always strictly worse than without retaliation, (22), by an additional term $-(1-\alpha)\gamma d\tau$ that captures the direct hit to export demand. In fact, for plausible calibrations, this term is sufficiently large to cause the trade balance to deteriorate in response to the shock. In figure 5 these calibrations lie to the bottom right of the red line, a region that includes our reference calibration in table 1. For this calibration, we find that a 10% import tariff with retaliation implies a 2.3% decline in GDP, and a trade deficit of 1.7% of imports.

One may wonder how it is possible that the home economy sees its trade balance fall, despite seemingly symmetric tariffs at home and in the rest of the world. The reason is that the rest of the world's import tariffs are only applied to imports from the home economy, not from each other. This effectively singles out the home economy and damages its competitiveness on global markets, which for high enough γ leads to a deterioration in

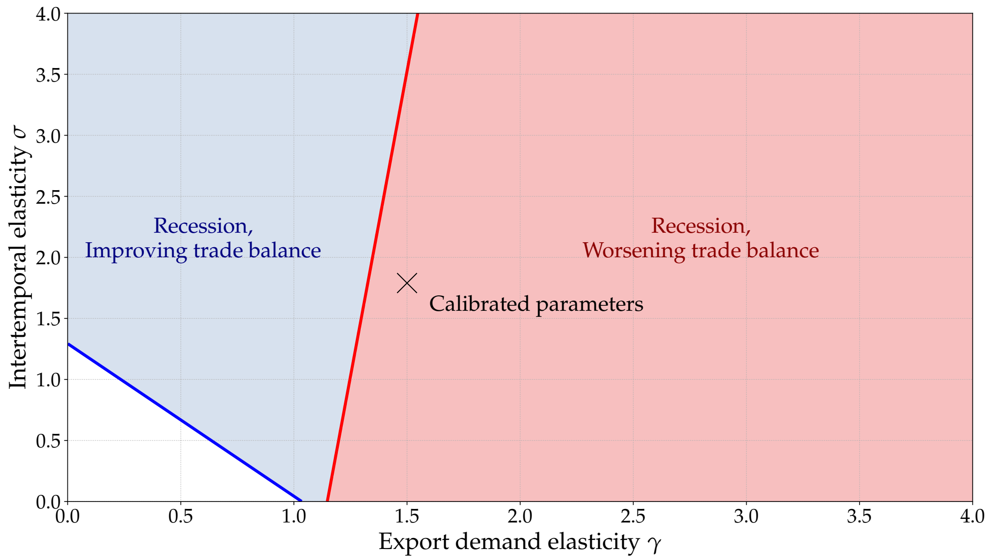


Figure 5: Retaliation: Conditions for recession and improving trade balance

the trade balance. In section 4.7, where we consider the case of a "large" home economy relative to the rest of the world, we show that this result hinges on the home economy being smaller than the rest of the world combined.

4 Extensions

Our baseline model in section 2 made several simplifying assumptions. Among other things, it assumed balanced trade in the initial steady state, fully Ricardian agents, full pass-through of tariffs to prices, and a small open economy. In this section, we relax these assumptions. For simplicity, we focus mostly on the case of a unilateral import tariff by the home economy and a passive monetary policy.

4.1 Initial trade deficit

In our baseline model, we start from a steady state that features balanced trade: $X = M$. To break this, we now suppose that there is a permanent per-period transfer D in foreign goods from foreign to domestic households.[21] This implies a steady-state home trade deficit $TB = -D$. The following proposition then extends the key results of proposition 2.

[21] This D could reflect, for instance, the proceeds from issuing a global reserve currency. If D is instead fixed in home goods, Proposition 6 goes through unchanged.

Proposition 6. *With unbalanced trade in steady state and passive monetary policy, the home economy enters a recession in response to a unilateral temporary tariff shock if and only if*

$$\left(1-\alpha^X\right)\sigma+\alpha^X\gamma>\eta$$

where α^X is the ratio of exports to gross output. If there is a recession, GDP falls by

$$d\log GDP_0=-\alpha^M\left(\left(1-\alpha^X\right)\sigma+\alpha^X\gamma-\eta\right)d\tau$$

where α^M is the ratio of imports to gross output, and CPI inflation is $d\log P_0=\alpha^M d\tau$.

Now that the export and import shares no longer equal the same α, proposition 6 shows that they play distinct roles in the transmission of a tariff shock. The export share determines the relative weight on the export elasticity γ in the recession condition, but the import share—which governs the direct importance of tariffs to domestic costs—determines both the inflation effect and the magnitude of any recession.

4.2 Hand-to-mouth agents

Our baseline results assumed a single domestic representative agent, who can frictionlessly borrow and save over time. We now instead assume that a fraction $\mu\in(0,1)$ of households are hand-to-mouth: they are unable to hold assets, and must consume exactly their labor income in every period. We assume that the remaining $1-\mu$ of households continue to borrow and save frictionlessly, and for simplicity we assume that per-capita labor income W_tN_t is the same for all households. We also assume that the tariff revenue is rebated to only the $1-\mu$ Ricardian households.[22]

Proposition 7. *With a share μ of hand-to-mouth households and passive monetary policy, the home economy enters a recession in response to a temporary tariff shock if and only if*

$$(1-\alpha)(1-\mu)\sigma+(1-\alpha)\mu+\alpha\gamma>\eta \tag{34}$$

If there is a recession, GDP falls by

$$d\log GDP_0=-\alpha\frac{(1-\alpha)(1-\mu)\sigma+(1-\alpha)\mu+\alpha\gamma-\eta}{1-(1-\alpha)\mu}d\tau, \tag{35}$$

[22] Assuming that the date-0 tariff revenue is saved by the government, leading to a permanent increase in transfers T_t out of the interest, leads to the same expressions regardless of how transfers are allocated between households. If, on the other hand, the revenue is immediately rebated uniformly to all households, the $(1-\alpha)\mu$ term disappears in the numerators of (34) and (35).

and CPI inflation is still $d \log P_0 = \alpha d\tau$.

Relative to the original condition (20), condition (34) replaces the elasticity of intertemporal substitution σ with $(1-\mu)\sigma + \mu$. This is because hand-to-mouth agents effectively act as if they have σ of 1, cutting their consumption one-for-one with rising prices. If σ is greater than 1, as in our calibration, then this makes a recession less likely. If there is a recession, however, it is amplified by a Keynesian multiplier of $\frac{1}{1-(1-\alpha)\mu}$, which reflects the fact that μ hand-to-mouth agents spend $1-\alpha$ of current income domestically.

4.3 Incomplete pass-through

We now consider a simple model of incomplete pass-through from tariffs to domestic prices. More details are provided in appendix C.3.

Assume that there is a continuum of monopolistically competitive "importers", each of which purchases raw imports on the international market at price $(1+\tau_t)\mathcal{E}_t$ and then costlessly transforms them into a differentiated variety. A CES aggregate of all varieties with price P_t^M enters the domestic production function (4). Importers set prices at an intended markup μ^I over marginal cost; but a fraction $1-\psi_M$ set prices one period ahead, and cannot adjust them in response to shocks. As a result, in response to a surprise tariff shock at $t=0$, the pass-through of tariffs and exchange rates to import prices will be only ψ_M: $d\log P_0^M = \psi_M(d\tau_t + d\log \mathcal{E}_t)$.

We then have the following extension of proposition 2, where we take the limit $\mu^I \to 1$ for simplicity.

Proposition 8. *In the model with importers and incomplete pass-through, all price and quantity effects in response to a temporary tariff shock are equal to those in proposition 2, multiplied by* ψ_M. *The condition (20) for a recession is unchanged.*

In short, incomplete pass-through of the tariff shock scales down the import price shock and all its downstream effects by the same factor ψ_M. The signs of each effect, however, are unchanged, so that the same condition $(1-\alpha)\sigma + \alpha\gamma > \eta$ still governs whether or not we have a recession.[23]

4.4 Different consumption and export technologies

Our baseline model assumes that the same good is used both for consumption and exports. We now allow for consumption and exports to be different goods, each produced

[23] If there is also incomplete pass-through $\psi_X < 1$ on the export side, then ψ_X multiplies γ in all formulas.

using technologies of the form (4), with potentially different import substitution elasticities η^C and η^X and steady-state import shares θ^C and θ^X. We continue to assume that consumption and exports have steady-state shares α and $1-\alpha$ of combined gross output, and that steady-state trade is balanced, so that $(1-\alpha)\theta^C + \alpha\theta^X = \alpha$.

Proposition 9. *With distinct production technologies for consumption and exports and passive monetary policy, the home economy enters a recession in response to a temporary tariff shock if and only if*

$$(1-\alpha)(1-\theta^C)\theta^C(\sigma-\eta^C) + \alpha(1-\theta^X)\theta^X(\gamma-\eta^X) > 0. \tag{36}$$

If there is a recession, GDP in each sector changes by $d\log GDP_0^C = -\theta^C(\sigma-\eta^C)d\tau$ *and* $d\log GDP_0^X = -\theta^X(\gamma-\eta^X)d\tau$*, and prices change by* $d\log P_0^C = \theta^C d\tau$ *and* $d\log P_0^X = \theta^X d\tau$.

We see that in each sector, if there is an overall recession, the GDP change depends on the gap between the relevant demand elasticity (σ or γ) and import substitution elasticity (η^C or η^X). This is scaled by the share of imports in the production function (θ^C or θ^X), which also governs the price effect.

The recession condition (36) then scales the sectoral GDP changes by $(1-\alpha)(1-\theta^C)$ and $\alpha(1-\theta^X)$, which are proportional to each sector's GDP share.[24] When $\theta^C = \theta^X = \alpha$ and $\eta^C = \eta^X \equiv \eta$, it reduces to our original condition (1).

In the original Gali and Monacelli (2005) case where exports are not produced using imported inputs at all, (36) becomes $\sigma > \eta^C \equiv \eta$. This is closely related to the condition in Guerrieri et al. (2022), as well as the condition for natural output in Monacelli (2025).

Alternatively, starting from our baseline model with $\theta^C = \theta^X = \alpha$, raising θ^X increases the importance of the export sector in the condition (36). For instance, if we suppose that exports are twice as import-intensive as consumption, while keeping $\alpha = 1/9$ and a single import substitution elasticity η, then $\theta^X = 1/5$ and $\theta^C = 1/10$, and (36) can be written as $0.82\sigma + 0.18\gamma > \eta$, rather than our original $0.89\sigma + 0.11\gamma > \eta$.

4.5 Durables

A crucial elasticity in our recession condition (20) is the intertemporal elasticity of substitution σ, which measures the willingness of consumers to postpone purchases in the face of higher prices. A realistic model of intertemporal substitution includes durable goods. We describe the extension of our model to durable goods in more detail in section 6.2, but

[24] Interestingly, the condition features a non-monotonicity: the weight on a sector in (36) is low either if its import share θ is close to 0 (because then it is unaffected by tariffs) or if its import share θ is close to 1 (because then it contributes little to GDP).

here we explain why this setup effectively delivers an intertemporal substitution elasticity that is much larger than the typically modeled nondurable intertemporal substitution elasticity.

The extension considers a model where households try to smooth both nondurable consumption and the stock of durables over time, with durables subject to quadratic adjustment costs. Durables and nondurables are produced by the same domestic production technology. We denote by ϵ_D the elasticity of durable expenditure to the marginal value Q of the durable stock. Now consider a purely transitory shock to the price of durables $d \log P_0$, with the nominal interest rate unchanged. Durable expenditure is

$$d \log C_0^D = \epsilon_D d \log Q_1.$$

Taking the limit of an arbitrarily short period, we show in appendix E.4 that $d \log Q_1 \simeq -d \log P_0$. Hence, ϵ_D is also the elasticity of durable expenditure to a transitory decline in the durable price. Since for nondurable expenditure we have $d \log C_0^{ND} = -\sigma d \log P_0$, where σ is the nondurable elasticity of intertemporal substitution, and since aggregate consumer spending is the sum $C_0 = C_0^{ND} + C_0^D$, we conclude that

$$d \log C_0 \simeq -\left((1-\omega)\,\sigma + \omega\epsilon_D\right) d \log P_0, \tag{37}$$

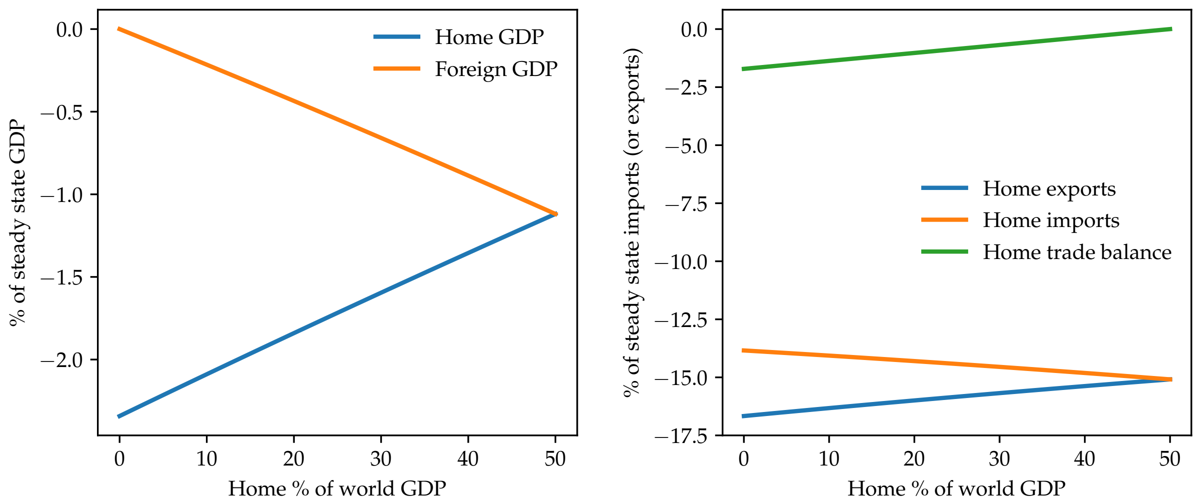
where $\omega \equiv C^D/(C^{ND} + C^D)$ is the steady-state share of durables in consumption.

Consumption behaves just like before, except with an effective elasticity of intertemporal substitution equal to $(1-\omega)\,\sigma + \omega\epsilon_D$ instead of just σ. Since estimates of ϵ_D are generally much larger than the nondurable elasticity, on the order of 8 to 12 (see, e.g. Baker et al. 2019 and McKay and Wieland 2021), this suggests that the σ in our recession condition (1) should also be thought of as being significantly greater than the standard nondurable elasticity (which is often calibrated to 1).

4.6 Nonlinearities from large tariffs

Our main results use a first-order approximation of the model. In appendix figure 16 we plot a nonlinear solution of the model, varying τ_0 from 0 to 50%, for our baseline calibration. We see some nonlinearities, especially for trade flows. In levels, the sensitivity of imports and exports to tariffs declines with larger tariffs. This is because larger tariffs compress trade volumes, leaving a smaller base for additional tariffs to influence. The sensitivity of GDP and welfare, on the other hand, does not decline in the same way. This is because the distortionary cost grows quadratically in the size of the tariff, as we discuss

Figure 6: Large open economy with retaliation



further in section 5.2.

4.7 Large open economy

Our baseline model assumes a small open economy. In this section, we extend our analysis to a large open economy. We sketch the main pieces of this extension and relegate the details to the appendix. We take the world economy to consist of a large open home economy, with a share λ of world output, and a mass of small open economies that make up the remaining $1-\lambda$ share of world output. Our previous model is the special case where $\lambda \to 0$. We structure the economy so that it corresponds to world economy described in Gali and Monacelli (2005), except that a mass λ of regions in the world makes up the single large economy.

We assume that all economies continue to produce using domestic labor and intermediate goods, similar to (4). Intermediate goods are a CES bundle of all countries' products, with weights proportional to their output shares and elasticity of substitution γ.[25] For example, the large home economy's imports are given by

$$M_t = \left((1-\lambda)^{-1/\gamma} \int_\lambda^1 m_{it}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}},$$

[25]For the large home economy, because it has a share λ of world output, a steady-state share λ of the CES bundle is its own goods, while the remaining $1-\lambda$ are imports.

where m_{it} are imports from country i. An individual foreign country i's imports are

$$M_{it} = \left(\lambda^{1/\gamma} X_{it}^{\frac{\gamma-1}{\gamma}} + (1-\lambda)^{\frac{1}{\gamma}} \int_{\lambda}^{1} m_{ijt}^{\frac{\gamma-1}{\gamma}} dj \right)^{\frac{\gamma}{\gamma-1}},$$

where m_{ijt} are imports from country j and X_{it} are imports from the home economy (i.e. exports of the home economy to country i). Since the home economy is large in the import basket of all other countries, an import tariff shock that reduces home imports from the rest of the world will measurably reduce the rest of the world's exports.

In figure 6 we solve the large open economy model with a tariff shock of 10%, varying the size of the home economy from 0% (the small open economy limit) to 50% of world GDP. We focus on the case with retaliation here. We see in panel (a) that a larger home economy is itself less affected by a trade war, while the rest of the world is affected more strongly. If the home economy makes up half of the world economy, the GDP decline is symmetric across countries. Panel (b) shows that the trade balance deterioration we found in section 3 is always present, as long as the home economy is less than half of the world economy. For reference, in nominal terms the U.S. accounts for approximately 25% of world GDP.

These results suggest that size is power for a temporary trade war: whoever is larger, the home economy or the retaliating rest of the world, takes less damage from a trade war and sees its own trade balance improve.

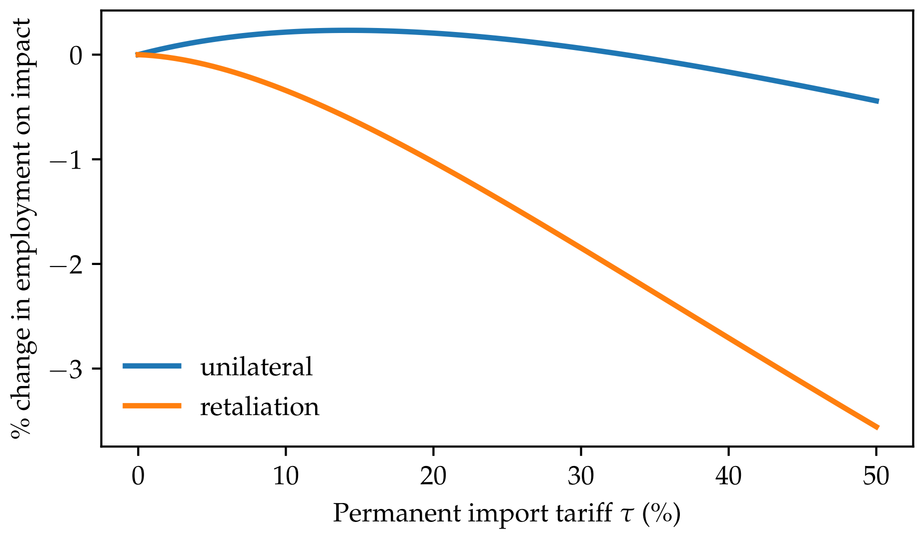
4.8 Recession from permanent tariffs

So far, we have focused on temporary tariff shocks. In the model described in section 2, permanent tariffs do not cause a recession, as the economy immediately adjusts to its new steady state (proposition 1).

Such a rapid adjustment, however, seems unrealistic, especially in light of the distinction between short-run and long-run elasticities highlighted in section 2.3. We now modify the model to take this distinction into account (see appendix C.7 for details). In particular, we assume that the short-run γ and η in period 0 are calibrated as in table 1, but that from period 1 onward these elasticities instead take the higher long-run values $\overline{\gamma}$ and $\overline{\eta}$, where $\gamma = (3/8) \cdot \overline{\gamma}$ and $\eta = (3/8) \cdot \overline{\eta}$ following Boehm et al. (2023), as discussed in section 2.3.

With $\eta < \overline{\eta}$, the nonlinear effect of a large import tariff on domestic prices P_t in (5) is larger in the short run ($t = 0$) than in the long run ($t \geq 1$). This captures the notion that firms may not be able to immediately re-shore their supply chains in the short run, and

Figure 7: Recessions from sudden permanent tariff surprises



are only able to substitute toward domestic inputs after some time. With domestic output temporarily more expensive, both domestic consumption and exports suffer.

Meanwhile, the first-order effect of $\eta < \overline{\eta}$ is to reduce import substitution in the short run, which also reduces demand for domestic labor. At the same time, $\gamma < \overline{\gamma}$ means that foreign firms substitute away from domestic goods by less in the short run. This supports short-run demand.

Figure 7 simulates permanent tariff surprises of different sizes in the two cases of unilateral tariffs and tariffs with symmetric retaliation. We see that the forces supporting demand, and thus employment, in the short run dominate for small unilateral import tariffs.[26] As the tariff gets larger, however, the nonlinear effect described above dominates, and the economy experiences a recession as it adjusts to the permanently higher tariff. Meanwhile, in the retaliation case, a recession occurs for any size of the tariff.

5 Welfare

We now consider the welfare effects of a tariff shock for the home economy.

[26]Here, to make figure 7 cleaner, we assume that there is also some nominal rigidity on the upside, so that a slight increase in employment is possible. Note also that here, we display employment as an indicator of the output gap; in appendix C.7, we augment the graph with GDP, which declines by more in the short run for large τ due to the cost of distortions.

5.1 First-order welfare effects

We start with a general result for the first-order effect of any tariff shock—possibly persistent or permanent. We will use the notation $PV(x_t) \equiv \sum_{t=0}^{\infty} \beta^t x_t$ to denote the present discounted value of any sequence $\{x_t\}$.

Proposition 10. *Starting from the steady state, let $\{d\tau_t\}_{t=0}^{\infty}$ be a tariff shock, and let $\{d\tau_t^r\}_{t=0}^{\infty}$ be the accompanying retaliation shock. Then the first-order effect on the utility of the domestic household, normalized by $u'(C)C$ to put in units of steady-state consumption, is:*

$$\underbrace{\frac{\alpha}{1-\alpha}\frac{\eta PV(d\tau_t)-(1-\alpha)\gamma PV(d\tau_t^r)}{(1-\alpha)(\gamma-1)+\eta}}_{\text{terms-of-trade effect}}+\underbrace{\left(1-\alpha\frac{1}{(1-\alpha)(\gamma-1)+\eta}\right)PV(d\log GDP_t)}_{\text{output-gap effect}}. \tag{38}$$

Proof. See appendix D.1. □

In (38), the first-order welfare effect has two components.

First, the traditional *terms-of-trade effect* of tariffs is due to the endogenous change in export prices on international markets—which is only possible because the home economy has market power ($\gamma < \infty$). Holding GDP fixed, an increase in import tariffs $d\tau_t$ causes a decline in import demand proportional to the elasticity η. In partial equilibrium, this improves the trade balance. But since the trade balance must still be zero in the long run, the long-run exchange rate strengthens in general equilibrium—in inverse proportion to the elasticity $(1-\alpha)(\gamma-1)+\eta$ of the trade balance to exchange rates (see also (14)–(15)). Domestic exports then sell at a higher price on international markets, improving the terms of trade and ultimately the home economy's welfare. There is a similar effect, but with the opposite sign, from retaliatory tariffs.

Second, the *output-gap effect* arises from GDP possibly falling below its natural level. If the home economy lacked market power, this would have a one-for-one effect on welfare, but this effect is slightly attenuated by the endogenous strengthening of the exchange rate, which also improves the terms of trade.

Discussion and numerical illustration. Typical analyses of optimum tariffs start with the positive terms-of-trade effect of a small tariff, and then determine how high the tariff can be raised until its nonlinear distortionary effects offset this benefit. We will consider these nonlinear effects in the next section. For the first-order effect, here we make two observations.

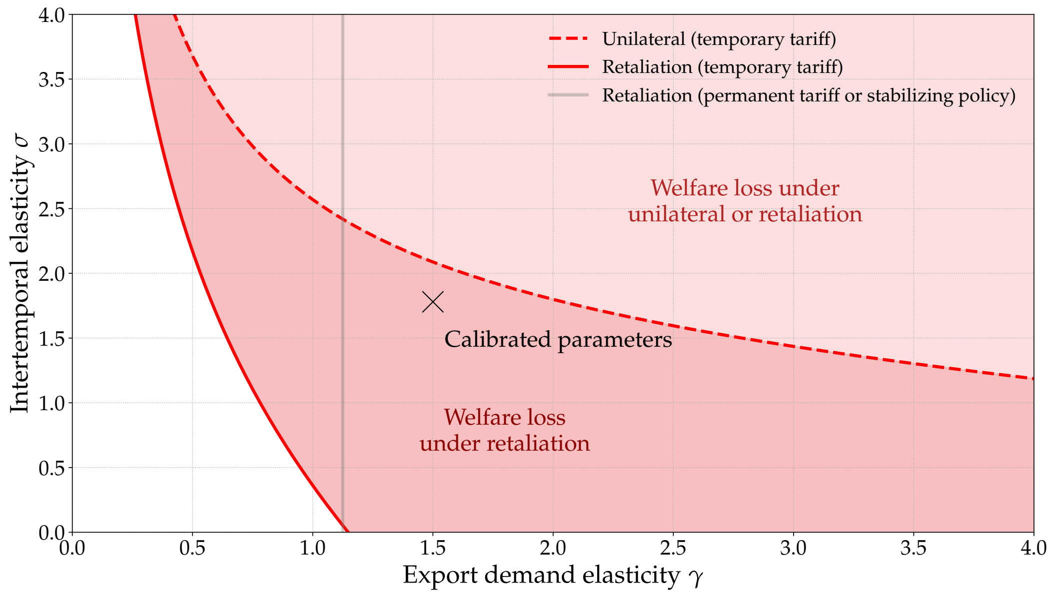


Figure 8: When does a tariff cause a first-order welfare loss?

First, with retaliation, it is quite plausible that the first-order terms-of-trade effect will be negative: this requires only that γ is mildly higher than η, so that $(1-\alpha)\gamma > \eta$. Assuming retaliation, therefore, the welfare effect of a small tariff can be negative for the home country, even in the absence of a recession.

Second, the possibility of a recession, with the output gap contributing negatively to (38), provides another source of first-order welfare losses that is missing in the usual long-run analysis.

We illustrate this numerically by revisiting the case of a temporary shock at date 0, with the same $\beta \to 1$ limit and a constant nominal rate as considered in previous sections. Here, the present values in (38) are simply the date-0 shocks: $PV(d\tau_t) = d\tau_0$, $PV(d\tau_t^r) = d\tau_0^r$, and $PV(d\log GDP_t) = d\log GDP_0$.

Figure 8 displays the results as we vary σ and γ, holding α and η fixed as in figures 3 and 5. For sufficiently high γ and σ, there is a first-order welfare loss even with a unilateral tariff, because a negative output-gap effect dominates a positive but smaller terms-of-trade effect. With retaliation $\tau_0^r = \tau_0$, however, a welfare loss is almost inevitable, except when the export elasticity γ is extremely small. This is because a recession is very likely (as in figure 5), so that a negative output-gap effects dominates, and for larger γ this is actually reinforced by a negative terms-of-trade effect.

Alternatively, in the case of either a permanent tariff—where a constant-nominal-rate policy achieves $d\log GDP_t = 0$—or a temporary tariff with stabilizing monetary policy, the output-gap effect in (38) is zero. If $\eta > 0$, the terms-of-trade effect is always positive in the unilateral case, reflecting the standard motivation for an optimal tariff.[27] But if $(1-\alpha)\gamma > \eta$, then with retaliation the terms-of-trade and thus the welfare effect is still negative, even in the absence of a recession. Figure 8 depicts this threshold in light gray.

5.2 Nonlinear welfare effects

The first-order effects in the previous section do not include the economic distortion from tariffs, since any distortionary effects are second-order starting from the steady state with zero tariffs. To study the costs of distortion, and also to investigate the robustness of our first-order analysis, we now look at the nonlinear effects of large tariff shocks. For simplicity, we will continue to focus on the short run: date-0 shocks with the limit $\beta \to 1$.

We define $\mathcal{W}(\tau)$ to be the change in total home utility from setting $\tau_0 = \tau$ vs. $\tau_0 = 0$, assuming passive monetary policy and normalizing by $u'(C)C$ as in proposition 10. We analogously define $\mathcal{W}^{stab}(\tau)$ to be the utility effect of the tariff when there is stabilizing monetary policy, which achieves full employment. Finally, we define $\mathcal{W}^{corr}(\tau)$ to be the utility effect when the Home household receives a transfer $T_t^{corr}(\tau)$ that exactly offsets any change in its foreign-currency export prices resulting from the tariff.[28] This removes any terms-of-trade effects.

We then define the nonlinear decomposition

$$\mathcal{W}(\tau) = \underbrace{\mathcal{W}(\tau) - \mathcal{W}^{stab}(\tau)}_{\text{output-gap effect}} + \underbrace{\mathcal{W}^{stab}(\tau) - \mathcal{W}^{corr}(\tau)}_{\text{terms-of-trade effect}} + \underbrace{\mathcal{W}^{corr}(\tau)}_{\text{distortion effect}} \tag{39}$$

for which we have the following result.[29]

Proposition 11. *To first order in τ, in either the unilateral case ($\tau_0 = \tau$ and $\tau_0^r = 0$) or the retaliation case ($\tau_0 = \tau_0^r = \tau$), the output-gap and terms-of-trade effects in (39) equal those defined in (38).*

The distortion effect is zero to first order, and to second order in τ is

$$\mathcal{W}^{corr}(\tau) \simeq \frac{1}{2}\frac{\alpha}{1-\alpha}\frac{d\log M_0}{d\tau}\tau^2 \tag{40}$$

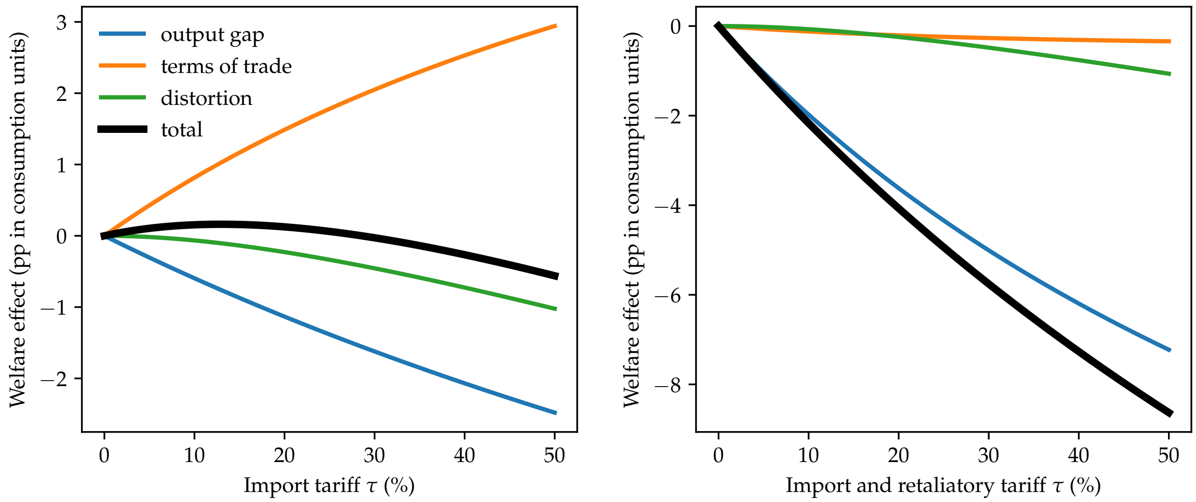
in either the unilateral or retaliation case.

[27] Here we assume that $(1-\alpha)(\gamma-1)+\eta > 0$, so that the elasticity of the trade balance to exchange rates has the right sign.

[28] This transfer is defined by the differential equation $(T_t^{corr})'(\tau) = -\frac{d(P_t(\tau)/\mathcal{E}_t(\tau))}{d\tau} \cdot X_t(\tau)$, where $P_t(\tau), \mathcal{E}_t(\tau), X_t(\tau)$ are the price, exchange rate, and exports when the time-0 tariff is τ.

[29] Here, we remove the output gap first, so that the terms-of-trade effect equals the neoclassical effect with full employment.

Figure 9: Decomposition of nonlinear welfare effects from tariff



Proof. See appendix D.2. □

To second order, therefore, the cost of the "distortion effect" in (39) is given by a Harberger triangle, which scales with the responsiveness of date-0 imports to the tariff τ. This is a standard result: at the margin, the distortionary cost of a tariff depends on the interaction between the tariff and the quantity response it induces. In the absence of terms-of-trade effects, this is the typical cost from distorting trade.

How large is the distortion effect characterized in (40) relative to the other two effects? Figure 9 plots the decomposition (39) for our baseline parameters from table 1, given tariff shocks up to $\tau = 0.5$. In the unilateral case, the terms-of-trade effect is slightly larger than the output-gap effect, making a strictly positive tariff optimal, but the distortion effect causes overall welfare to decline above $\tau = 0.15$.[30] In the retaliation case, by contrast, all three effects are negative. The output-gap effect dominates, driving an enormous welfare loss from large tariffs.

We conclude that the output-gap effect of tariffs—which is not considered in traditional, long-run trade frameworks—can easily play a major or even dominant role in welfare analysis.

[30] The terms-of-trade effect here, which implies that with stabilizing monetary policy the optimal tariff would be over 50%, is arguably too large, driven by the fact that our calibration (intended to reflect short-run responsiveness) has relatively low η and γ, and therefore overstates the exchange rate movement that is needed to achieve long-run trade balance. Appendix D.3 recalculates figure 9 with a long-run calibration of higher η and γ, finding a much smaller terms-of-trade effect and optimal tariff.

6 Quantitative exploration

We now turn to our quantitative model. We first consider an extension of our baseline model to persistent shocks and then explicitly introduce durable goods and inventories.

6.1 Quantitative version of baseline model

Phillips curve. We modify the baseline model to make the nominal wage rigidity symmetric, instead of only binding downward. We do so in two steps. First, we modify household preferences to allow for an explicit disutility from labor supply N_t. Flow utility is then given by $\frac{C_t^{1-1/\sigma}}{1-1/\sigma} - \varphi_N \frac{N_t^{1+1/\phi}}{1+1/\phi}$, where $\varphi_N > 0$ is a constant and ϕ is the Frisch elasticity of labor supply. Second, we introduce a standard New Keynesian wage Phillips curve, à la Erceg, Henderson and Levin (2000). Workers are off their labor supply curves at each time t, and belong to unions that are able to reset nominal wages on behalf of their workers with a constant Calvo probability each period. This formulation leads to a linearized Phillips curve for nominal wage inflation

$$w_t - w_{t-1} = \kappa \left(\frac{1}{\sigma} c_t + \frac{1}{\phi} n_t - w_t + p_t \right) + \beta \mathbb{E} \left[w_{t+1} - w_t \right]$$

with some slope $\kappa > 0$. Here and from now on, we write $x_t \equiv \log X_t / X$ for the log deviation of variable $X_t \in \{W_t, C_t, N_t, P_t\}$ from steady state.

Monetary rules. We consider three types of monetary policy rules. First, we consider passive monetary policy, which we now assume fixes the nominal interest rate at its pre-shock steady-state level permanently, $i_t = i$, rather than just for a single period. To ensure determinacy, we also assume that the long-run nominal exchange rate is stabilized at its original level; combined with the fixed nominal interest rate, this implies a fixed nominal exchange rate in every period. Second, we consider a rule that targets zero wage inflation at all dates and therefore implements the flexible-wage allocation (a "natural rate" rule). Third, we consider a Taylor rule that responds to wage inflation, the best measure of domestic slack in this economy, $i_t = i + \phi_\pi (w_t - w_{t-1})$.

Calibration. We start by calibrating the economy to the same parameters we have used so far: $\alpha = 0.11$, $\sigma = 1.79$, $\gamma = 1.5$, and $\eta = 1.15$. We specify a quarterly calibration frequency and set $\kappa = 0.05$ by using the standard Calvo formula with frequency of wage adjustment of 0.2 from Grigsby et al. (2021) and no real rigidity. We set standard values

Table 2: Calibration for quantitative version of the baseline model

	Description	Value		Description	Value
σ	Intertemporal elasticity	1.79	β	Discount factor	0.99875
γ	Export elasticity	1.5	ϕ_π	Taylor rule coefficient	1.5
η	Import elasticity	1.15	ρ	Persistence of tariff shock	0.75
ϕ	Frisch elasticity of labor supply	0.50	κ	Slope of wage Phillips curve	0.05
α	Import share	0.11			

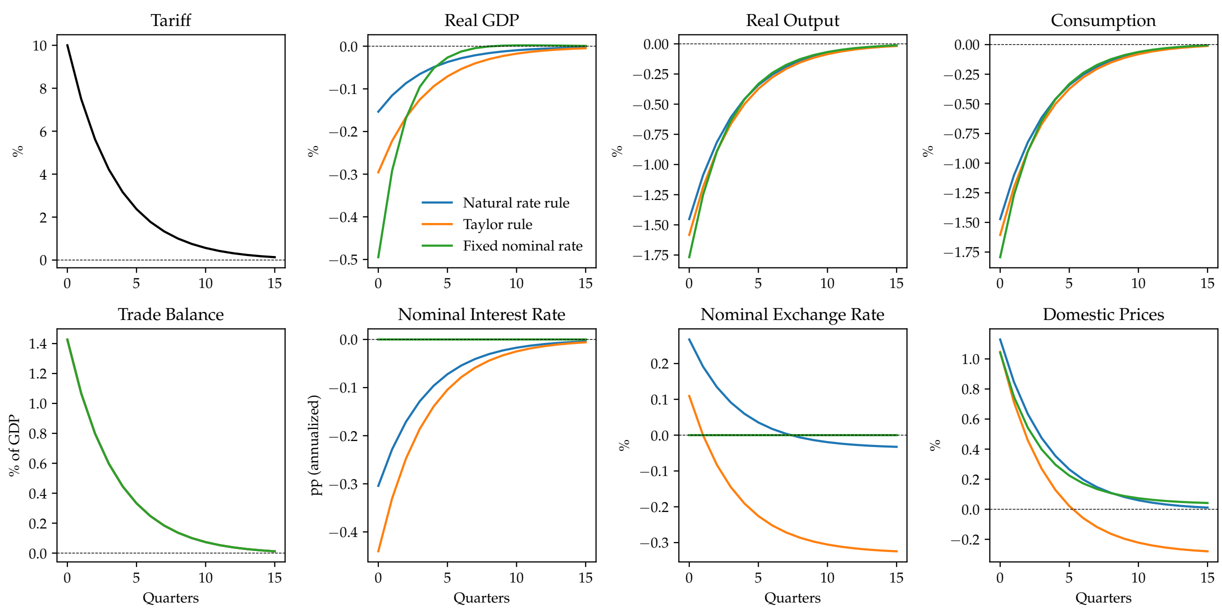


Figure 10: Impulse responses to persistent unilateral tariff shock

for the Frisch elasticity, $\phi = 0.50$, the discount factor $\beta = 0.99875$ (implying an annual steady state real interest rate of 0.5%), and the Taylor rule coefficient $\phi_\pi = 1.5$. Finally, we solve the model linearly, set the impact size of the tariff shock at our baseline of 10%, and assume that it is AR(1) with persistence of $\rho = 0.75$. This is implies that it is 1% by the end of year 2, and virtually zero by the end of year 4. Table 2 summarizes our calibration parameters.

Results. Figure 10 visualizes the impulse responses to the shock for all three monetary rules. The patterns are broadly similar to those described in the one-period analysis of section 3. Across all monetary rules, GDP, output, and domestic consumption fall. GDP falls by most with a passive rule that fixes interest and exchange rates, about three times as much as with the natural rate rule. Gross output falls by much more than GDP, due to a large reduction in imports. Since imports fall by more than exports, the trade balance improves. Consumption drops significantly in the short run due to intertemporal substi-

Table 3: Impact effects of 10% tariff, alternative scenarios

Scenario	Unilateral			Retaliation		
Outcome	Passive	Taylor rule	Natural rate	Passive	Taylor rule	Natural rate
GDP	-0.49%	-0.30%	-0.15%	-1.86%	-1.02%	-0.53%
Trade balance (of GDP)	1.43%	1.43%	1.43%	-0.22%	-0.22%	-0.23%
Nominal interest rate	0.00pp	-0.44pp	-0.30pp	0.00pp	-1.53pp	-1.06pp
Nominal exchange rate	0.00%	0.11%	0.27%	0.00%	0.51%	1.06%

tution, but recovers in the long run to a permanently higher level. Finally, the exchange rate depreciates on impact or remains stable under all three rules. The intermediate case of a Taylor rule shows how, with a plausible calibration, our model can simultaneously generate a nominal depreciation and negative output gap.

Quantitatively, the magnitudes are relatively mild. While gross output does contract by around 1.5% for all monetary rules, real GDP only contracts by 0.5% or less on impact, with a swift recovery thereafter. The annualized natural rate declines by 0.3pp, and the nominal exchange rate depreciates by less than 0.3%.

Table 3 shows the impact effects across a few key outcome variables and compares to those implied by equal retaliation from the rest of the world.[31] In the latter case, exports decline far more due to the direct effects of retaliatory tariffs; as a result, the trade balance deteriorates instead of improving, and GDP falls quite significantly. The nominal exchange rate also depreciates significantly more in this case. The signs and magnitudes are broadly similar to those we found in section 3.

6.2 Durables

In our model, the main reason why short-run unilateral tariffs are contractionary is the intertemporal substitution response. In section 4.5, we argued that in the short-run limit, the existence of durable goods implies a higher effective overall elasticity of intermporal substitution, and we used this to justify calibrating our basic model to a higher σ. We now extend the model to explicitly feature durables, and consider the dynamics that arise from both the temporary nature of new tariffs and the anticipation of future tariffs. Model details are in appendix E.

In the model with durables, households enjoy the stock of the durable good D_t in addition to the consumption of the nondurable good C_t^{ND}. Their objective function is separable with curvature $1/\sigma$ on both consumption C_t^{ND} and the stock of durables D_t,

[31] See figure 19 in the appendix for the full impulse responses under retaliation.

namely

$$\sum_{t=0}^{\infty}\beta^t\left(\frac{\left(C_t^{ND}\right)^{1-1/\sigma}}{1-1/\sigma}+\varphi_D\frac{D_{t-1}^{1-1/\sigma}}{1-1/\sigma}-\varphi_N\frac{N_t^{1+1/\phi}}{1+1/\phi}\right),$$

where $\varphi_D, \varphi_N > 0$ are constants. Durables depreciate at rate δ, and they are produced using the same technology as nondurable consumption and exports. Adjusting durables requires paying a quadratic cost $\frac{1}{2\delta\epsilon_D}\left(\frac{D_t-D_{t-1}}{D_{t-1}}\right)^2 D_{t-1}$ in units of home goods. Hence, the household budget constraint is now

$$P_tC_t^{ND}+P_tC_t^D+P_t\frac{1}{2\delta\epsilon_D}\left(\frac{D_t-D_{t-1}}{D_{t-1}}\right)^2 D_{t-1}+A_t=A_{t-1}\left(1+i_{t-1}\right)+W_tN_t+\Pi_t+T_t \tag{41}$$

where $C_t^D \equiv D_t-(1-\delta)\,D_{t-1}$ is expenditure on durables.

The Euler equation for nondurables C_t^{ND} is still (19). The first order condition for durables, however, involves dynamics that can be described using Q theory, namely

$$\frac{D_t-D_{t-1}}{D_{t-1}} = \delta\epsilon_D\left(Q_{t+1}-1\right) \tag{42}$$

$$\left(1+r_t\right)Q_t = \varphi_D\left(\frac{C_t^{ND}}{D_{t-1}}\right)^{1/\sigma}-\frac{D_t}{D_{t-1}}+1-\delta-\frac{1}{2\delta\epsilon_D}\left(\frac{D_t-D_{t-1}}{D_{t-1}}\right)^2+\frac{D_t}{D_{t-1}}Q_{t+1} \tag{43}$$

where Q_t is the marginal value of the durable stock in terms of nondurables at the beginning of period t. The market clearing condition (13) now becomes

$$Y_t = X_t + C_t^{ND} + C_t^D. \tag{44}$$

To simulate the model, we set σ to a lower, more standard value, $\sigma = 1$, and choose $\epsilon_D = 8.2$ using the evidence on durable expenditure elasticity to expected changes in sales taxes documented in Baker et al. (2019). We calibrate depreciation to 20% annually, ($\delta = 0.20/4$), which is roughly the average depreciation rate of consumer durables in the Fixed Asset Accounts, and set the share of durable to total consumption expenditure to 11% as in the 2023 National Income and Product Accounts.

Figure 11 compares the key impulse responses in the model that now explicitly includes durables (with $\sigma = 1$) to the quantitative model in the previous section (calibrated to $\sigma = 1.79$ as described in section 2.3, to implicitly reflect the durables margin). Here we assume passive monetary policy; see figure 20 for all variables and alternative policy rules.

Consumption drops by slightly less in the new model with durables than in the pre-

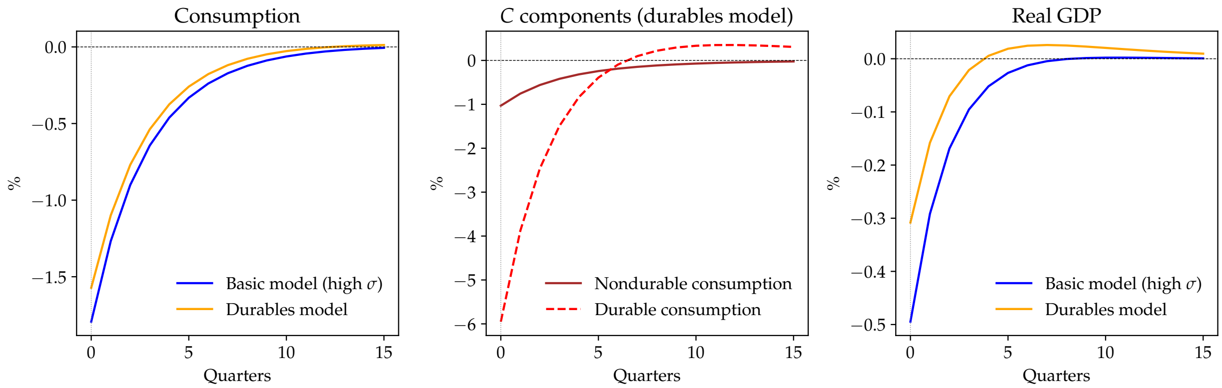


Figure 11: Role of durables

Note. This figure compares the impulse response to a unilateral tariff shock in the quantitative model with an explicit durables margin (with $\sigma = 1$) vs. the model without durables (with higher σ calibrated to implicitly reflect durables as described in section 2.3). Monetary policy is assumed to be passive, implementing a fixed exchange rate. The tariff shock is the same as that in figure 10.

vious model. This discrepancy arises because with a persistent shock, our equivalence result from section 4.5 does not exactly hold: knowing that they will continue to draw down their durables stock, households cut back a bit less to start. This smaller drop in consumption translates into a somewhat weaker recession, followed by a mild expansion.

Explicitly modeling durables has additional benefits. First, we see that the demand decline is highly concentrated in durables, with durable expenditures falling about 6% on impact, compared to only 1% in nondurables. In addition, the decline in durables eventually reverses as the tariffs decline, with durable spending above trend by year 2. This durable snap-back effect is responsible for the small boost to GDP at this horizon.

Anticipated tariffs. The high degree of intertemporal substitution in durable consumption also matters when tariff shocks are anticipated. Figure 12 shows the impulse response to the announcement of a tariff shock in three quarters, reflecting potential implementation delays or, more speculatively, limited short-run pass-through of tariffs to retail prices. This results in a boom in GDP on impact, driven entirely by durable goods as households rush to buy their durables ahead of the price increases.

6.3 Inventories

Because many imports are durable goods, they are often held in inventory before they are sold in the retail market or used in further production. Modeling inventory behavior may therefore be important to understanding the dynamics of imports in response to tariffs. We describe such a model extension next, with details in appendix E.

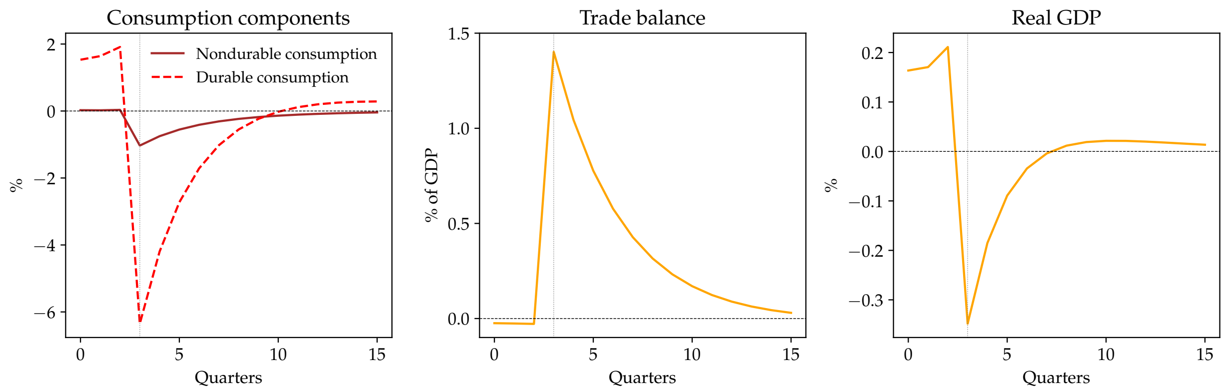


Figure 12: Anticipated tariff shock

Note. This figure analyzes a tariff shock that is anticipated three quarters in advance in a model with durables. Monetary policy is assumed to be passive, that is, it implements a fixed exchange rate. After quarter 3, the tariff shock is the same as that in figure 10.

We add inventories to the model with durables from the previous section by replacing the production function (4) with

$$Y_t = \left((1-\tilde{\alpha})^{1/\eta} N_t^{\frac{\eta-1}{\eta}} + \tilde{\alpha}^{1/\eta} G_t^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

where G_t is now a composite import good.[32] This composite import good G_t is itself produced by import retailers, using goods in their inventory $\tilde{M}_t$ as well as the inventory stock S_{t-1}.[33] The production function for G_t is also given by a CES aggregator

$$G_t = \left(\chi^{1/v} \left(\left(\beta^{-1} - 1 \right) S_{t-1} \right)^{\frac{v-1}{v}} + (1-\chi)^{1/v} \tilde{M}_t^{\frac{v-1}{v}} \right)^{\frac{v}{v-1}}$$

where $\chi > 0$ is the relative weight put on inventories. Imports M_t increase the stock of inventories, and use of inventories in production $\tilde{M}_t$ reduces it. For simplicity we abstract from depreciation, so that the inventory accumulation equation is

$$S_t = S_{t-1} + M_t - \tilde{M}_t. \tag{45}$$

Further, we assume that import retailers incur costs $\frac{1}{2\epsilon_S} \left(\frac{S_t - S_{t-1}}{S_{t-1}} \right)^2 S_{t-1}$ when adjusting

[32] We denote the cost share on G_t by $\tilde{\alpha}$ to emphasize that α is no longer the appropriate measure of openness in this economy.

[33] Having the inventory stock in the production function is a simple way to have a well-defined stock of inventories in the steady state. This proxies for the role of inventories in smoothing production and avoiding stockouts modeled more explicitly in the literature, e.g. Ramey and West (1999), Kryvtsov and Midrigan (2013), and more recently Monnery (2024).

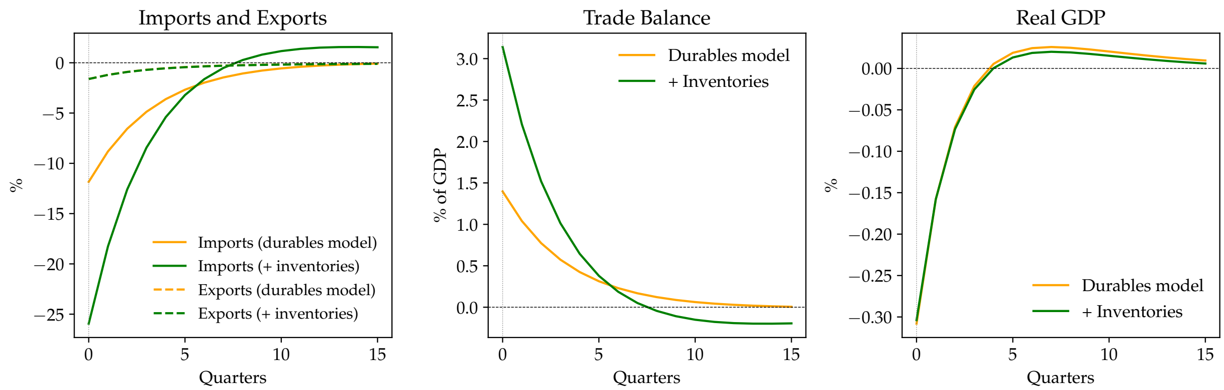


Figure 13: Unilateral tariff shock with inventories

Note. This figure analyzes an unanticipated tariff shock, comparing a model with durables to a model with durables and import inventories. Monetary policy is assumed to be passive, implementing a fixed exchange rate. The tariff shock is the same as that in figure 10.

their inventory stock. Import retailers maximize the present value of flow profits $P_t^G G_t - P_t^M \left(S_t - S_{t-1} + \tilde{M}_t + \frac{1}{2\epsilon_S} \left(\frac{S_t - S_{t-1}}{S_{t-1}} \right)^2 S_{t-1} \right)$, subject to (45).

The first-order conditions for the import retailer give $P_t^G \frac{\partial G_t}{\partial \tilde{M}_t} = P_t^M$, together with the optimal inventory dynamics

$$\frac{S_t - S_{t-1}}{S_{t-1}} = \epsilon_S \left(Q_{t+1}^S - 1 \right) \tag{46}$$

$$\frac{P_{t-1}^M}{P_t^M} (1 + i_{t-1}) Q_t^S = \frac{P_t^G}{P_t^M} \frac{\partial G_t}{\partial S_{t-1}} - \frac{S_t}{S_{t-1}} + 1 - \frac{1}{2\epsilon_S} \left(\frac{S_t - S_{t-1}}{S_{t-1}} \right)^2 + \frac{S_t}{S_{t-1}} Q_{t+1}^S \tag{47}$$

which are analogous to the Q theory equations governing durable dynamics. Real GDP is now given, to first order, by $dGDP_t = dY_t - dM_t + dS_t - dS_{t-1}$, that is, gross output net of imports and inclusive of inventory accumulation (with initial prices normalized to 1).

We set $v = 1$ so that G_t is a Cobb-Douglas aggregate in inventory outflows and inventory stock, and choose χ to hit a steady-state ratio of inventories to imports S/M of 0.33 at quarterly frequency (so that inventories are one month of sales). We calibrate the elasticity of inventory investment to Q to $\epsilon_S = 5.77$. This matches the response of inventories to an anticipated permanent tariff hike in the rich model of inventory dynamics by Alessandria, Khan and Khederlarian (2024).[34]

Figure 13 compares the impulse responses of imports, exports, the trade balance, and real GDP between the model with inventories and the model without inventories, where

[34]They find a peak response of the inventory-to-sales ratio of about 160% in response to an anticipated permanent 10% tariff hike one year out. We match this in our model after the same shock.

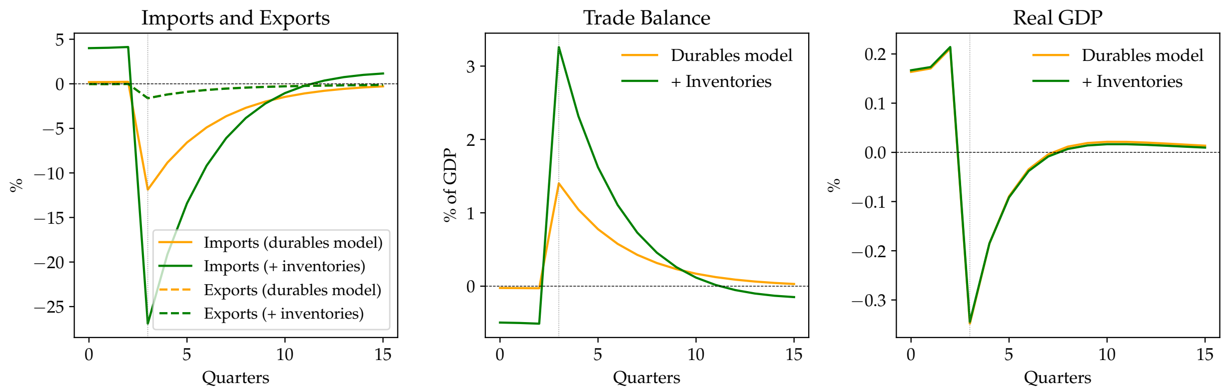


Figure 14: Anticipated tariff shock with inventories

Note. This figure analyzes a tariff shock that is anticipated three quarters in advance. It compares a model with durables to a model with durables and import inventories. Monetary policy is assumed to be passive, that is, it implements a fixed exchange rate. After quarter 3, the tariff shock is the same as that in figure 10.

both models include durable goods. In the right panel, we see that the real GDP response is very similar for both models. In fact, comparing figures 20 and 21 in the appendix reveals that this is true more generally for all variables except imports and the trade balance. The other panels in figure 13 show that, with inventories, imports are very elastic to tariff shocks, collapsing on impact before bouncing back as tariffs recede and firms replenish their inventories. This leads the trade balance to improve dramatically at first, while worsening afterwards.

In response to an anticipated tariff shock, the dynamics of trade are even starker, as shown in figure 14. Ahead of the shock, firms load up on inventories, pushing up imports and worsening the trade balance. This reverses into a drawdown of inventories, an even larger decrease in imports, and an even larger increase in the trade balance once tariffs actually hit. This is consistent with firms' recent behavior: for instance, both imports and inventory accumulation increased dramatically in 2025Q1, then reversed in 2025Q2.

In figure 15 we vary the number of periods that a tariff shock is anticipated in advance. We plot the changes in the same variables as figure 14, relative to steady state, on the date when tariffs actually hit, as a function of the anticipation horizon. We see that longer anticipation makes the ultimate response to the tariff shock more extreme.

7 Conclusion

When do temporary import tariffs lead to downturns? We provide a general analysis of this question in the context of a simple New Keynesian model. Even when the tar-

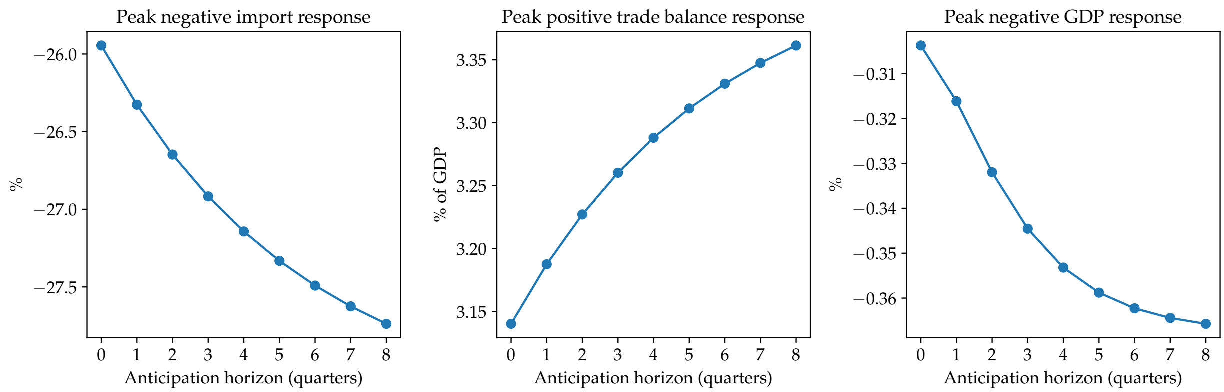


Figure 15: Varying the anticipation horizon

Note. This figure plots the peak responses of imports, the trade balance, and GDP in response to an anticipated tariff shock, varying the anticipation horizon. The model has durables and inventories. Once the shock hits, the tariff shock is the same as that in figure 10.

iffs are unilateral and monetary policy does not respond, tariffs are contractionary when $(1-\alpha)\sigma + \alpha\gamma > \eta$, i.e. when intertemporal substitution and export substitution dominate import substitution. We argue that this condition is likely satisfied in practice, at least in the short run, since durable goods have great scope for intertemporal substitution, and it is easier for foreigners to substitute between different types of exports than for domestic residents to substitute between home and foreign goods. Retaliation by other countries worsens the downturn and typically leads to a deterioration of the trade balance. The optimal tariff is significantly lower once this possibility of contraction is taken into account.

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Online Appendix

A Appendix to section 2

A.1 Proof of proposition 1

Under a permanent increase in import tariffs, the economy immediately jumps to a new steady state, still with zero NFA. We continue to denote steady state objects without t subscripts. Without loss, we assume the nominal wage is still $W = 1$, which here is simply a choice of numeraire to make nominal exchange rate well defined and comparable to our later analysis.

The nonlinear steady state equations are then given as follows. For households, we find

$$PC = 1 - \alpha + \tau \mathcal{E} M$$

For prices we find

$$P^F = (1+\tau)\,\mathcal{E} \qquad P = \left[1 - \alpha + \alpha \left(P^F\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

For exports we find

$$X = \alpha \cdot \left(\frac{P}{\mathcal{E}}\right)^{-\gamma}$$

and for output

$$C + X = Y = \left((1-\alpha) + \alpha^{1/\eta} M^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}$$

Linearizing these equations, we find for prices

$$d\log P^F = d\tau + d\log \mathcal{E} \qquad d\log P = \alpha d\tau + \alpha d\log \mathcal{E}$$

Consumption then is

$$d\log C = \frac{\alpha}{1-\alpha} \alpha d\log(1+\tau) - \alpha d\log \mathcal{E}$$

and exports are

$$d\log X = -\gamma\left(\alpha d\tau - (1-\alpha)\, d\log \mathcal{E}\right)$$

Substituting these into $d\log Y = (1-\alpha)d\log C + \alpha d\log X$ and simplifying, we have

$$d\log Y = \alpha^2 (1-\gamma)\, d\tau + \alpha(\gamma-1)(1-\alpha)\, d\log \mathcal{E}$$

Since the labor market clears at $N = 1-\alpha$ as in the original steady state without tariffs, it must be that

$$0 = d\log N = d\log Y + \alpha\eta d\log P^F$$

Evaluating the expression pins down the exchange rate,

$$d\log \mathcal{E} = -\frac{\eta - \alpha(\gamma-1)}{(\gamma-1)(1-\alpha)+\eta} d\tau$$

which is exactly (15). With this exchange rate, exports decline by

$$d\log X = -\frac{\gamma\eta}{(\gamma-1)(1-\alpha)+\eta} d\tau$$

To obtain the response of imports, notice that by (6),

$$d\log M = d\log N - \eta d\log P^F$$

Thus,

$$d\log M = -\eta\left(d\tau + d\log \mathcal{E}\right)$$

and simplifying

$$d\log M = -\frac{\eta(\gamma-1)}{(\gamma-1)(1-\alpha)+\eta} d\tau$$

Trade balance holds, as

$$\frac{dTB}{M} = d\log X + d\log P - d\log \mathcal{E} - d\log M$$

which collapses to

$$\begin{aligned}
\frac{dTB}{M} &= \frac{-\gamma\eta + \eta(\gamma-1) + (\eta - \alpha(\gamma-1))(1-\alpha) + \alpha((\gamma-1)(1-\alpha)+\eta)}{(\gamma-1)(1-\alpha)+\eta} d\tau \\
&= \frac{-\gamma\eta + \eta(\gamma-1) + \eta(1-\alpha) + \alpha\eta}{(\gamma-1)(1-\alpha)+\eta} d\tau = 0
\end{aligned}$$

The real exchange rate moves according to

$$d\log\left(\mathcal{E}/P\right) = -\left[\left(1-\alpha\right)\frac{\eta-\alpha\left(\gamma-1\right)}{\left(\gamma-1\right)\left(1-\alpha\right)+\eta}+\alpha\right]d\tau = -\frac{\eta}{\left(\gamma-1\right)\left(1-\alpha\right)+\eta}d\tau$$

A.2 Calibration of long-run η

Appendix E.2 in Auclert et al. (2024) generalizes the Gali-Monacelli model so that the final consumption good is a CES aggregate with elasticity $\tilde{\zeta}$ between tradable and nontradable goods, where the steady-state tradable share is $\tilde{\phi}$. The tradable good is then a CES bundle of foreign and home-produced tradable goods with elasticity $\tilde{\eta}$, with a steady-state home share $1-\tilde{\alpha}$ within tradables. (We add tildes to these parameters to distinguish them from our own calibration.)

In equation (A.167), Auclert et al. (2024) show that this implies an effective elasticity η between home and foreign goods of

$$\eta = \frac{(1-\tilde{\alpha})\tilde{\eta}+(1-\tilde{\phi})\tilde{\alpha}\tilde{\zeta}}{(1-\tilde{\alpha})+(1-\tilde{\phi})\tilde{\alpha}} \tag{48}$$

This is a weighted average of the elasticity $\tilde{\eta}$ between home and foreign tradables and the elasticity $\tilde{\zeta}$ between nontradable and tradable goods.

We calibrate (48) as follows. We take the steady-state tradable share $\tilde{\phi}$ to be the share of goods in total U.S. personal consumption expenditures in 2024, which was 31.5% in NIPA Table 2.3.5. We then calibrate $\tilde{\alpha} = \alpha/\tilde{\phi} = 12.5\%/31.5\% \approx 39.7\%$. This implies weights on $\tilde{\eta}$ and $\tilde{\zeta}$ in (48) of 68.9% and 31.1%, respectively.

Taking the elasticity $\tilde{\eta}$ between home and foreign tradables to be the same as our $\gamma = 4$ between-country elasticity, and assuming Cobb-Douglas $\tilde{\zeta} = 1$, this evaluates to $\eta \approx 3.07$.

B Appendix to section 3

B.1 Nonlinear solution of the model for a one-period tariff, and the $\beta \nearrow 1$ limit

Here we describe the solution of the model for a one-period import tariff shock τ_0 of arbitrary size, assuming that import tariffs are back at zero thereafter, $\tau_t = 0$ for $t > 0$. We then take the limit $\beta \nearrow 1$. For completeness, we also allow for a general retaliatory import tariff τ^r imposed by the rest of the world.

Since there is no tariff after date 0, and the NFA is the only backward looking state variable, we can characterize the allocation after date 1 as a function of the NFA entering period 1, A_0. We guess and verify that all equilibrium variables are constant after $t = 0$.

$$
\begin{aligned}
C_1 &= 1-\alpha+i^* A_0 \\
Y_1 &= \left(1-\alpha+\alpha^{1/\eta} M_1^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \\
P_1 &= \left[1-\alpha+\alpha \mathcal{E}_1^{1-\eta}\right]^{\frac{1}{1-\eta}} \\
1 &= Y_1 P_1^{\eta} \\
X_1 &= \alpha\left(\left(1+\tau^r\right) \frac{P_1}{\mathcal{E}_1}\right)^{-\gamma} \\
C_1+X_1 &= Y_1
\end{aligned}
$$

Since, after date 1, $i_t = i^* = \beta^{-1} - 1$, the households' Euler equation holds for constant consumption, and the UIP condition also holds for a constant interest rate.

In general, this system of equations has a complicated and intractable solution. In the limit $\beta \nearrow 1$, however, we also have $i^* = i \searrow 0$. This implies that the steady state solution solves the system above. Thus, in this limit, the economy returns to the steady state at date 1. This allows us to significantly reduce the complexity of our analysis.

To get at the date 0 behavior nonlinearly, we collect the following model equations, for arbitrary import tariff and monetary policy shocks:

- Euler equation

$$C_0 = C P_0^{-\sigma}\left(1+i_0\right)^{-\sigma}$$

- Pricing (5)

$$P_0=\left[(1-\alpha) W_0^{1-\eta}+\alpha\left(\mathcal{E}_0\left(1+\tau_0\right)\right)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{49}$$

- UIP (7)

$$\mathcal{E}_0=\frac{1}{1+i_0}$$

- Exports (10)

$$X_0=\alpha\left(\left(1+\tau^r\right) \frac{P_0}{\mathcal{E}_0}\right)^{-\gamma}$$

- Goods demand (13)

$$C_0+X_0=Y_0$$

- Labor and imports demand (6)

$$N_0 = (1-\alpha)\,Y_0 \left(\frac{W_0}{P_0}\right)^{-\eta} \qquad M_0 = \alpha Y_0 \left(\frac{P_0^F}{P_0}\right)^{-\eta}$$

- Downward rigidity

$$W_0 = \begin{cases} 1 & \text{if } N_0 < 1-\alpha \\ \geq 1 & \text{if } N_0 = 1-\alpha \end{cases}$$

The allocation with passive monetary policy is a solution to these equations with $i_0 = i = 1/\beta - 1$. The natural allocation is a solution in which i_0 is chosen to achieve stable employment $N_0 = N$.

B.2 Real GDP

Nominal GDP in period 0 is given by nominal value added

$$GDP_0^n = P_0 Y_0 - \mathcal{E}_0 M_0 = W_0 N_0 + \tau_0 \mathcal{E}_0 M_0 \tag{50}$$

With perfect competition in home goods production, nominal value added is equal to domestic labor income plus import tariff revenue.

A Divisia index for *real* GDP can be defined by specifying the first-order change in GDP to equal the share-weighted changes in gross output minus imports:

$$d\log GDP_0^r = \frac{P_0 Y_0}{P_0 Y_0 - \mathcal{E}_0 M_0} d\log Y_0 - \frac{\mathcal{E}_0 M_0}{P_0 Y_0 - \mathcal{E}_0 M_0} d\log M_0. \tag{51}$$

The constant-returns-to-scale and perfectly competitive production sector also implies that $d\log Y_0 = \frac{W_0 N_0}{P_0 Y_0} d\log N_0 + \frac{P_0^F M_0}{P_0 Y_0} d\log M_0$. Substituting this into (51), and using (50) to rewrite the denominator, gives

$$d\log GDP_0^r = \frac{W_0 N_0}{W_0 N_0 + \tau_0 \mathcal{E}_0 M_0} d\log N_0 + \frac{\tau_0 \mathcal{E}_0 M_0}{W_0 N_0 + \tau_0 \mathcal{E}_0 M_0} d\log M_0 \tag{52}$$

This reduces to simply $d\log GDP_0^r = d\log N_0$ when $\tau_0 = 0$. It follows that to first order starting from the zero-tariff steady state, the log change in real GDP equals the log change in labor. This is a consequence of labor being the only domestic factor of production, and the economy initially being undistorted. This equivalence allows us to treat changes in labor and real GDP synonymously throughout most of the paper, where we consider only first-order effects starting from the zero-tariff steady state.

If $\tau_0 > 0$, on the other hand, (52) shows that the change in real GDP also depends positively on the change in imports. The intuition is that the import tariff is a domestic distortion away from imports; conditional on labor, therefore, substituting away from this distorted input is inefficient and lowers real GDP. It follows that to *second order*, an increase in τ_0 starting from the zero-tariff steady state leads to a wedge between log real GDP and labor.[35]

Nonlinear calculation. To nonlinearly compute real GDP for a date-0 tariff shock of arbitrary magnitude, as in section 4.6, we index all date-0 quantities and prices by τ. We then can use either (51) or (52) to calculate the derivative of real GDP with respect to τ,

$$\begin{aligned}\frac{d\log GDP^r(\tau)}{d\tau} &= \frac{P(\tau)Y(\tau)}{GDP^n(\tau)}\frac{d\log Y(\tau)}{d\tau} - \frac{\mathcal{E}(\tau)M(\tau)}{GDP^n(\tau)}\frac{d\log M(\tau)}{d\tau} \\ &= \frac{W(\tau)N(\tau)}{GDP^n(\tau)}\frac{d\log N(\tau)}{d\tau} + \frac{\tau\mathcal{E}(\tau)M(\tau)}{GDP^n(\tau)}\frac{d\log M(\tau)}{d\tau},\end{aligned} \tag{53}$$

and then integrate to obtain the overall change in chained real GDP,

$$\log\frac{GDP^r(\tau)}{GDP^r(0)} = \int_0^\tau \frac{d\log GDP^r(\tau')}{d\tau'}d\tau'.$$

B.3 Proof of proposition 2

The result for GDP follows directly from the steps preceding proposition 2. Exports follow directly from (18). Log-linearizing (6), we find for imports

$$d\log M_0 = d\log N_0 - \eta d\log P_0^F$$

Solving this,

$$d\log M_0 = -\left((1-\alpha)\eta + \alpha\left((1-\alpha)\sigma + \alpha\gamma\right)\right)d\tau$$

The trade balance (22) is given by

$$\frac{dTB_0}{M} = d\log P_0 + d\log X_0 - d\log M_0$$

[35]We thank Javier Bianchi for alerting us to the difference between real GDP and labor to higher order in τ.

which we can simplify to obtain

$$\frac{dTB_0}{M} = (\alpha + (1-\alpha)\,\eta + \alpha\,(1-\alpha)\,(\sigma - \gamma))\,d\tau$$

which is (22).

B.4 Proof of proposition 3

B.4.1 General derivations

To prove proposition 3, we first derive the linearized solution of the model for arbitrary import tariff shocks $d\tau$ and interest rate responses $d\log(1+i_0)$. Then, we solve for the natural allocation.

First we derive expressions for the exchange rate and prices. By the UIP condition (7), the exchange rate moves inversely to interest rates,

$$d\log\mathcal{E}_0 = -d\log(1+i_0)$$

The price of foreign goods (8) is then given by

$$d\log P_0^F = d\tau + d\log\mathcal{E}_0 = d\tau - d\log(1+i_0)$$

and the CPI P_0 by

$$d\log P_0 = \alpha\,(d\tau + d\log\mathcal{E}_0) = \alpha\,(d\tau - d\log(1+i_0))$$

Linearizing (10) and (19), we find for exports and consumption

$$\begin{aligned} d\log X_0 &= -\gamma d\log(P_0/\mathcal{E}_0) = -\gamma\,(\alpha d\tau + (1-\alpha)\,d\log(1+i_0)) \\ d\log C_0 &= -\sigma\,(1-\alpha)\,d\log(1+i_0) - \sigma\alpha d\tau \end{aligned} \quad (54)$$

From the goods market clearing condition (13), we then derive total goods demand as in (17)

$$d\log Y_0 = -(1-\alpha)\,(\sigma\,(1-\alpha) + \alpha\gamma)\,d\log(1+i_0) - \alpha\,((1-\alpha)\,\sigma + \alpha\gamma)\,d\tau$$

With this, we can evaluate total labor demand linearizing (6)

$$d\log N_0 = -\left(\left(1-\alpha\right)\left(\sigma\left(1-\alpha\right)+\alpha\gamma\right)+\eta\alpha\right)d\log\left(1+i_0\right) \\ +\alpha\left(\eta-\left(\left(1-\alpha\right)\sigma+\alpha\gamma\right)\right)d\tau \quad (55)$$

For imports, we find

$$d\log M_0 = -\left(1-\alpha\right)\left(\sigma\left(1-\alpha\right)+\alpha\gamma-\eta\right)d\log\left(1+i_0\right) \\ -\left(\left(1-\alpha\right)\eta+\alpha\left(\left(1-\alpha\right)\sigma+\alpha\gamma\right)\right)d\tau \quad (56)$$

and for the trade balance we find (after some algebra)

$$\frac{dTB_0}{M} = \left(1-\alpha\right)\left(\sigma\left(1-\alpha\right)+\alpha\gamma-\eta+\left(1-\gamma\right)\right)d\log\left(1+i_0\right) \\ +\left(\left(1-\gamma\right)\alpha+\left(1-\alpha\right)\eta+\alpha\left(\left(1-\alpha\right)\sigma+\alpha\gamma\right)\right)d\tau \quad (57)$$

B.4.2 Check: proposition 2

For proposition 2, we assume a passive monetary policy, $i_0 = i$. Thus, (55) simply becomes

$$d\log N_0 = \alpha\left(\eta-\left(\left(1-\alpha\right)\sigma+\alpha\gamma\right)\right)d\tau$$

identical to (21). It immediately follows that there is a recession if (20) holds. (54) becomes

$$d\log X_0 = -\gamma\alpha d\tau$$

For imports, from (56), we obtain

$$d\log M_0 = -\left(\left(1-\alpha\right)\eta+\alpha\left(\left(1-\alpha\right)\sigma+\alpha\gamma\right)\right)d\tau$$

and the trade balance, expressed relative to GDP, becomes

$$\frac{dTB_0}{M} = \left(\left(1-\gamma\right)\alpha+\left(1-\alpha\right)\eta+\alpha\left(\left(1-\alpha\right)\sigma+\alpha\gamma\right)\right)d\tau$$

which can be rearranged to (22).

B.4.3 Proof of proposition 3

To obtain the natural interest rate, we back out from (55) the interest rate response $d\log\left(1+i_0\right)$ that leaves labor demand unchanged. After some algebra, we obtain (26). Substituting this interest rate $d\log\left(1+i_0\right)$ into the trade balance equation (57), we obtain (27).

B.5 Proof of proposition 4

The direct effects of the tax, (28) and (29), follow immediately from the calculations preceding proposition 4. We can find the natural interest rate by combining the direct effect of the export tax on GDP,

$$d\log N_0 = -\alpha\gamma d\tau$$

with the effect of monetary policy on GDP from (55),

$$d\log N_0 = -\left(\left(1-\alpha\right)\left(\sigma\left(1-\alpha\right)+\alpha\gamma\right)+\eta\alpha\right)d\log\left(1+i_0\right)$$

Combining those two equations, we find that an interest rate reduction as in (30) is needed to undo the effect of the export tax on GDP.

B.6 Proof of proposition 5

The GDP response to retaliation with passive monetary policy is simply the sum of what happens under unilateral tariffs and what happens with an export tax. The reason for this is that the additional tax revenue is irrelevant for date 0 spending in the limit $\beta \nearrow 1$. Thus, the sum of (21) and (28) gives us (32). For the trade balance, we start from (29). However, with a foreign import tariff, the price at the border changes (while it did not for a domestic export tax). Thus, the direct effect of retaliation is given by

$$\frac{dTB_0}{GDP} = -\left(1-\alpha\right)\gamma d\tau$$

Combining this equation with the effect of a unilateral import tariff on the trade balance, (22), we find (33). Finally, since the retaliation itself is contractionary, it necessarily lowers the natural interest rate (on its own). This must mean that the natural rate falls by more in response to import tariffs if they are being retaliated against than if they are not.

C Appendix for section 4

C.1 Initial trade deficit and proof of proposition 6

In the steady state (where we normalize all prices to 1), the household's budget constraint implies that $X + D = M$, so that the trade balance is $TB = -D$.

The derivation of proposition 2 goes through mostly unchanged. The log-linearization in (17) now has $\alpha^E \equiv \frac{X}{Y}$ as the weight on $d\log X_0$, which becomes the weight on γ in the recession condition, but the change in the CPI is $d\log P_0 = \frac{M}{Y} d\log P_0^F + \frac{WN}{Y} d\log W_0 = \alpha^I d\tau$, which then scales $d\log X_0$ and $d\log C_0$, and thus the magnitude of the GDP change, via (18) and (19).

C.2 Hand-to-mouth agents and proof of proposition 7

Since the domestic representative agent in our baseline steady state also consumes its labor income in every period, there is no change to the steady state from replacing a fraction of its mass with hand-to-mouth households.

For dynamics, denote the consumption of the hand-to-mouth and "Ricardian" (unconstrained) households by C_t^{HTM} and C_t^R. Hand-to-mouth households' date-0 consumption is given by $C_0^{HTM} = \frac{W_0 N_0}{P_0}$. Assuming fixed W_0, $d\log P_0 = \alpha d\tau$ is unchanged, and to first order this implies $d\log C_0^{HTM} = d\log N_0 - d\log P_0 = d\log N_0 - \alpha d\tau$. Meanwhile, Ricardian households behave just as before, with $d\log C_0^R = -\sigma\alpha d\tau$. Replacing the $-\sigma d\tau$ in our previous derivation with $-\alpha\left((1-\mu)\sigma + \mu\right)d\tau + \mu d\log N_0$, the equation for change in GDP ($d\log GDP_0 = d\log N_0$) becomes

$$d\log GDP_0 = -\alpha\left((1-\alpha)\left((1-\mu)\sigma + \mu\right) + \alpha\gamma - \eta\right)d\tau + \mu(1-\alpha)d\log GDP_0$$

which solves out to give the desired formula (35). This is consistent with a decline in GDP if the inner expression $(1-\alpha)\left((1-\mu)\sigma + \mu\right) + \alpha\gamma - \eta$ is positive, consistent with condition (34).

C.3 Incomplete pass-through and proof of proposition 8

To model incomplete pass-through, we assume that imported goods are purchased at price $\mathcal{E}_t\left(1 + \tau_t\right)$ abroad, and sold domestically by a mass 1 of monopolistically competitive importers, labelled by k. Goods imported by importer k are denoted by m_{kt} and enter a CES aggregate

$$M_t = \left(\int_0^1 m_{kt}^{\frac{\xi-1}{\xi}} dk \right)^{\frac{\xi}{\xi-1}}$$

Importers optimally set their price equal to a constant markup over marginal cost,

$$p_{kt}^M = \frac{\xi}{\xi - 1} \mathcal{E}_t \left(1 + \tau_t\right)$$

We assume that a fraction $1 - \psi_M$ of importers are required to set their prices one period in advance. Thus, in period 0, we have

$$P_0^M = \frac{\xi}{\xi - 1} \left(\psi_M \left(\mathcal{E}_0 \left(1 + \tau_0\right)\right)^{1-\xi} + 1 - \psi_M \right)^{\frac{1}{1-\xi}}$$

Since we are not interested in the importer monopoly distortion, we focus on the limit $\xi \to \infty$. In that limit, to first order, we have

$$d \log P_0^M = \psi_M (d\tau_t + d \log \mathcal{E}_t)$$

From this, it immediately follows that, absent a monetary policy response, any import tariff shock of size $d\tau_t$ is effectively now smaller by a factor ψ_M. Proposition 8 follows directly from this argument.

C.4 Multiple production technologies and proof of proposition 9

We generalize (4) by writing a consumption-specific technology

$$C_t = \left((1 - \theta^C)^{1/\eta^C} (N_t^C)^{\frac{\eta^C - 1}{\eta^C}} + (\theta^C)^{1/\eta^C} (M_t^C)^{\frac{\eta^C - 1}{\eta^C}} \right)^{\frac{\eta^C}{\eta^C - 1}}$$

and an analogous technology for exports. We continue to normalize all steady-state prices to 1, so that steady-state import shares for consumption and exports are θ^C and θ^X. Given a date-0 tariff shock $d\tau$ and passive monetary policy, if there is a recession it follows immediately from constant wages and exchange rates that $d \log P_0^C = \theta^C d\tau$ and $d \log P_0^X = \theta^X d\tau$, reflecting the direct effect of tariffs on costs.

We then observe that (using $GDP_t^C = N_t^C$, $GDP_t^X = N_t^X$)

$$\begin{aligned} d\log GDP_0^C &= \frac{d\log C_0 - \theta^C d\log M_0^C}{1-\theta^C} = d\log C_0 + \frac{\theta^C}{1-\theta^C}\eta^C(d\tau - d\log P_0^C) \\ &= d\log C_0 + \frac{\theta^C}{1-\theta^C}\eta^C(1-\theta^C)d\tau = d\log C_0 + \theta^C\eta^C d\tau \end{aligned}$$

and similarly $d\log GDP_0^X = d\log X_0 + \theta^X\eta^X d\tau$. Like before, with constant rates we have $d\log C_0 = -\sigma d\log P_0^C = -\theta^C\sigma d\tau$ and $d\log X_0 = -\theta^X\gamma d\tau$, so overall we have $d\log GDP_0^C = -\theta^C(\sigma - \eta^C)d\tau$ and $d\log GDP_0^X = -\theta^X(\gamma - \eta^X)d\tau$.

Finally, noting that steady-state GDP weights on C and X are proportional to $(1-\alpha)(1-\theta^C)$ and $\alpha(1-\theta^X)$, the condition (36) for a decline in GDP follows from aggregating $d\log GDP_0^C$ and $d\log GDP_0^X$.

C.5 Nonlinearities from large tariffs

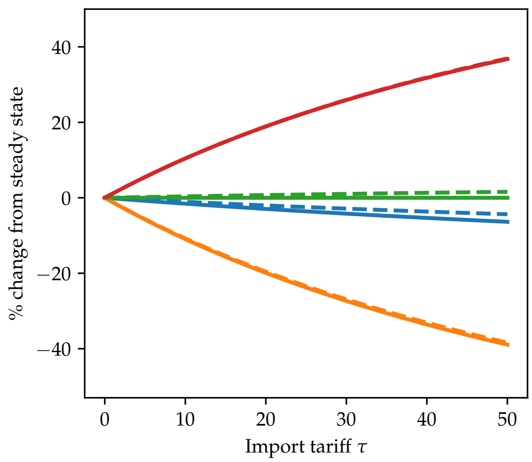
Figure 16 shows the effect on trade flows, the exchange rate and GDP, under passive monetary policy and in the natural allocation, and under unilateral tariffs and retaliation, from large tariffs of up to 50%. The first-order approximations given in the main text hold up well for tariffs of up to 10%, but the effects from large tariffs tend to be smaller. The equations for this analysis are in appendix B.1.

C.6 Large open economy

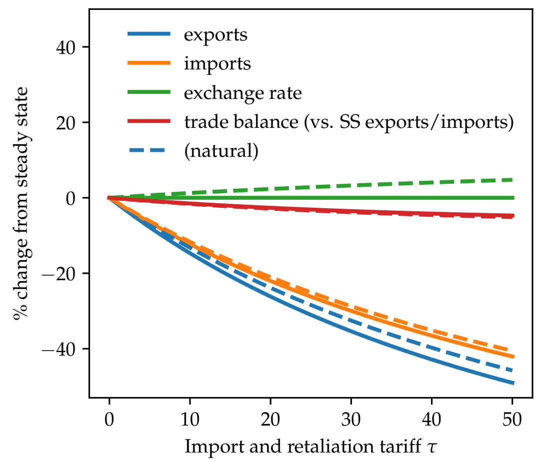
This appendix section derives the equations used to simulate a version of our model in which the home country is a large, instead of a small, open economy. These equations are used to produce figure 6.

The structure of the world economy is similar to that in Gali and Monacelli (2005), except we assume a mass λ of continuum of economies in Gali and Monacelli (2005) makes up a single large open economy, the home country. We assume that the home country accounts for a share λ of world output and is surrounded by a mass $1-\lambda$ of symmetric small open economies. Our previous setup of a small open home economy can be recovered in the limit $\lambda \to 0$.

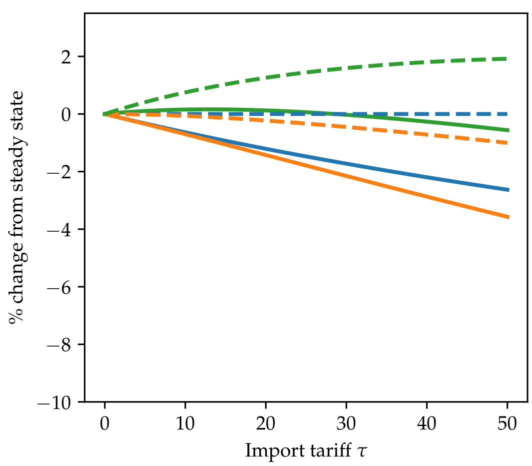
Each economy produces its own good. We label each of the small open economies' goods by $i \in [\lambda, 1]$. The home good has no further index, as before. We denote the nominal interest rate at home by i_t as before, and the nominal interest rate in country i by i_t^*. We assume that i_t^* is the same in all foreign countries. Without loss of generality, all prices are then identical among those countries. The nominal exchange rate between any



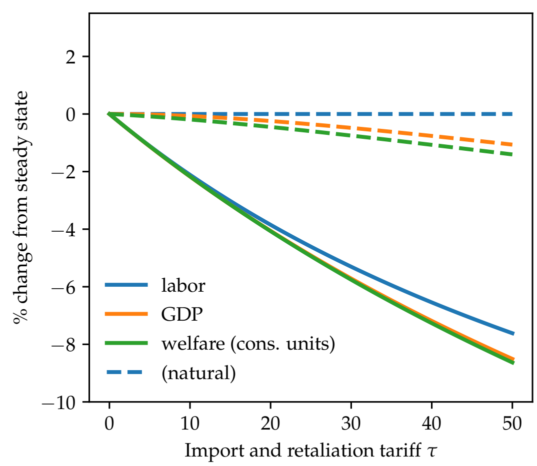
(a) Unilateral tariff: Trade



(b) Retaliation: Trade



(c) Unilateral tariff: GDP, welfare



(d) Retaliation: GDP, welfare

Figure 16: Large tariff shocks

Note. Reference calibration from table 1. y axis in % from initial steady state values, except trade balance which is in pp. of steady state GDP.

of them and the home economy is denoted by $\mathcal{E}_t$ and determined by (7),

$$\mathcal{E}_t = \frac{1+i_t^*}{1+i_t}\mathcal{E}_{t+1} \tag{58}$$

C.6.1 Goods and prices

Home goods are now produced with production function,

$$Y_t = \left((1-\alpha)^{1/\eta} N_t^{\frac{\eta-1}{\eta}} + \alpha^{1/\eta} \overline{M}_t^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

where the intermediate input $\overline{M}_t$ is an aggregate between imports M_t and a domestic intermediate good Q_t,

$$\overline{M}_t = \left(\lambda^{1/\gamma} Q_t^{\frac{\gamma-1}{\gamma}} + (1-\lambda)^{1/\gamma} M_t^{\frac{\gamma-1}{\gamma}} \right)^{\frac{\gamma}{\gamma-1}}$$

where m_{it} reflects goods imported by the home economy from economy i and imports are given by

$$M_t = \left((1-\lambda)^{-1/\gamma} \int_\lambda^1 m_{it}^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}}$$

The home good trades at domestic price P_t and at foreign price

$$P_t^* = \mathcal{E}_t^{-1} (1+\tau_t^*) P_t \tag{59}$$

The intermediate input is priced at

$$\overline{P}_t = \left(\lambda P_t^{1-\gamma} + (1-\lambda) \left(P_t^F \right)^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \tag{60}$$

Small open economy i produces foreign good i using production function

$$Y_{it}^{F*} = \left((1-\alpha)^{1/\eta} (N_{it}^*)^{\frac{\eta-1}{\eta}} + \alpha^{1/\eta} M_{it}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}$$

where L_{it}^{F*} denotes labor in economy i and M_{it} are imports from the rest of the world, given by

$$M_{it} = \left(\lambda^{1/\gamma} X_{it}^{\frac{\gamma-1}{\gamma}} + (1-\lambda)^{\frac{1}{\gamma}} \int_\lambda^1 m_{ijt}^{\frac{\gamma-1}{\gamma}} dj \right)^{\frac{\gamma}{\gamma-1}}$$

Variable	Quantities	Price (home)	Price (foreign)
Home good	Y, C, X, X_i, Q	P	P^*
Home labor	N	W	—
Home intermediate input	$\overline{M}$	$\overline{P}$	—
Home import bundle	M	P^F	—
Foreign good i	$Y_i^{F*}, C_i^*, m_i, m_{ji}$	P_i^F	P_i^{F*}
Foreign labor i	N_i^*	—	W_i^*
Foreign import bundle i	M_i	—	P_i^M

Table 4: Overview of goods in large open economy model

X_{it} are exports of the home economy to economy i, and m_{ijt} are imports from economy j to economy i. The price of foreign good i is denoted by P_{it}^{F*} in the small open economies and given by

$$P_{it}^{F*} = \left((1-\alpha) \left(W_{it}^*\right)^{1-\eta} + \alpha \left(P_{it}^M\right)^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{61}$$

where P_{it}^M is the price of foreign country i's import bundle,

$$P_{it}^M = \left(\lambda \left(P_t^*\right)^{1-\gamma} + \int_\lambda^1 \left(P_{jt}^{F*}\right)^{1-\gamma} \right)^{\frac{1}{1-\gamma}} \tag{62}$$

The price is

$$P_{it}^F = \mathcal{E}_t \left(1+\tau_t\right) P_{it}^{F*} \tag{63}$$

in the home economy. Table 4 has an overview of the variables used in this model.

C.6.2 Euler equations

The Euler equation of the home economy reads

$$\frac{C_t^{-1/\sigma}}{P_t} = \beta \left(1+i_t\right) \frac{C_{t+1}^{-1/\sigma}}{P_{t+1}} \tag{64}$$

The one of foreign economy i reads

$$\frac{\left(C_{it}^*\right)^{-1/\sigma}}{P_{it}^{F*}} = \beta \left(1+i_t^*\right) \frac{\left(C_{it+1}^*\right)^{-1/\sigma}}{P_{it+1}^{F*}} \tag{65}$$

where we already assumed that interest rates are equal and unchanged, $i_t = i_t^* = i^*$.

C.6.3 Market clearing conditions

Market clearing for home goods requires that

$$Y_t = C_t + Q_t + \int_\lambda^1 X_{it} di \tag{66}$$

Market clearing for foreign good i requires that

$$Y_{it}^{F*} = C_{it}^* + \int_\lambda^1 m_{jit} dj + m_{it} \tag{67}$$

C.6.4 Steady state

We again start from a steady state in which all prices are normalized to 1. We normalize world output $Y + \int Y_i^{F*} di$ to 1. Domestic output Y is then equal to $Y = \lambda$ as the domestic economy makes up a share λ of world output. Foreign country i's output is equal to $Y_i^{F*} = 1$.

Home GDP and domestic consumption are $C = N = (1 - \alpha)\lambda$, while total intermediate inputs are $\overline{M} = \alpha\lambda$. Of that, $\alpha\lambda\lambda$ is domestically sourced while $\alpha\lambda(1 - \lambda)$ is imported. Hence, total imports and total exports are $X = M = \lambda(1 - \lambda)\alpha$. This means that home imports from and exports to each small open economy are given by $m_i = X_i = \lambda\alpha$.

Foreign country i has GDP $C_i^* = N_i^* = 1 - \alpha$ and imports $M_i = \alpha$ overall, with $X_i = \alpha\lambda$ from the home economy and $m_{ij} = \alpha$ from every other foreign economy j.

C.6.5 Tariff shock

Just like before, we feed in a first-order one-period tariff shock, $d\tau_0 = d\tau$ and $d\tau_0^r = d\tau^r$. Since the foreign economies act symmetrically, all quantities are independent of any i and j subscripts in the following. Again, we focus on the limit of a discount factor approaching 1, $\beta \nearrow 1$.

In that case, we collect the following system of linearized equations. For worldwide prices, we have seven equations for seven unknowns:

a) The exchange rate is determined by the UIP condition (58),

$$d \log \mathcal{E}_0 = d \log (1 + i_0^*) - d \log (1 + i_0)$$

b) The price of the foreign goods bundle at home is determined by (63) and symmetry. Log-linearized, we have:

$$d\log P_0^F = d\log P_{i0}^F = d\log \mathcal{E}_0 + d\tau + d\log P_{i0}^{F*}$$

c) The intermediate input bundle price (60) gives us:

$$d\log \overline{P}_t = \lambda d\log P_0 + (1-\lambda)\, d\log P_0^F$$

d) From the price index for home goods (5), we have:

$$d\log P_0 = \alpha d\log \overline{P}_t$$

e) The home goods price abroad is determined via (59):

$$d\log P_0^* = -d\log \mathcal{E}_0 + d\tau^r + d\log P_0$$

f) The price of foreign country i's import bundle (62),

$$d\log P_{i0}^M = \lambda d\log P_0^* + (1-\lambda)\, d\log P_{i0}^{F*}$$

g) Finally, the price of foreign good i abroad is determined via the price index (61),

$$d\log P_{i0}^{F*} = \alpha d\log P_{i0}^M$$

For quantities of the home economy, we have six more equations:

a) The Euler equation of home households (64),

$$d\log C_0 = -\sigma d\log(1+i_0) - \sigma d\log P_0$$

b) The home goods market clearing condition (66)

$$d\log Y_0 = (1-\lambda)\,\alpha d\log X_0 + (1-\alpha)\, d\log C_0 + \alpha\lambda d\log Q_0$$

c) Optimal demand for domestic labor (6)

$$d\log N_0 = d\log Y_0 + \eta d\log P_0$$

d) Optimal demand for intermediate inputs

$$d\log \overline{M}_0 = d\log N_0 - \eta d\log \overline{P}_0$$

e) Optimal demand for imports (6)

$$d\log M_0 = d\log \overline{M}_0 + \gamma d\log \overline{P}_0 - \gamma d\log P_0^F$$

f) Optimal demand for domestic intermediate inputs

$$d\log Q_0 = d\log \overline{M}_0 + \gamma d\log \overline{P}_0 - \gamma d\log P_0$$

For quantities of the foreign economy, we also have six equations:

a) Euler equation of foreign households (65)

$$d\log C_{i0}^* = -\sigma d\log\left(1+i_0^*\right) - \sigma d\log P_{i0}^{F*}$$

b) Market clearing of foreign good i, (67)

$$d\log Y_{i0}^{F*} = (1-\lambda)\,\alpha d\log m_{ij0} + (1-\alpha)\,d\log C_{i0}^* + \lambda\alpha \underbrace{d\log m_i}_{=d\log M_0}$$

c) Optimal demand for foreign economy i's labor, $N_{it}^* = (1-\alpha)\,Y_{it}^{F*}\left(W_i^*/P_{it}^{F*}\right)^{-\eta}$, is log-linearized

$$d\log N_{i0}^* = d\log Y_{i0}^{F*} + \eta d\log P_{i0}^{F*}$$

d) Optimal demand for foreign economy i's import's bundle, $M_{it} = \alpha Y_{it}^{F*}\left(P_{it}^M/P_{it}^{F*}\right)^{-\eta}$ is log-linearized

$$d\log M_{i0} = d\log Y_{i0}^{F*} + \eta d\log P_{i0}^{F*} - \eta d\log P_{i0}^M$$

e) Similarly, i's optimal import demand from j,

$$d\log m_{ij0} = d\log M_{i0} + \gamma d\log P_{i0}^M - \gamma d\log P_{i0}^{F*}$$

f) And finally i's optimal import demand from the home economy,

$$d\log X_{i0} = d\log M_{i0} + \gamma d\log P_{i0}^{M} - \gamma d\log P_{0}^{*}$$

For any given set of trade policies $d\tau, d\tau^{r}$ and monetary policy $d\log\left(1+i_0\right), d\log\left(1+i_0^{*}\right)$, these 19 linear equations characterize all 19 unknowns. Based on these unknowns, we can also compute home's trade balance, as a share of initial imports

$$\frac{dTB_0}{M_0} = d\log P_0 - d\log \mathcal{E}_0 + d\log X_{i0} - d\log M_0 - d\log P_{i0}^{F*}$$

C.7 Recession from permanent tariffs

Analytics. Denote by $\overline{\gamma}$ and $\overline{\eta}$ the long-run trade elasticities, in periods $t \geq 1$. Since the tariff shock is permanent, the economy will be at the new long-run steady state immediately starting in $t = 1$. We can use the formulae in appendix A.1 to describe the new long-run allocation, consisting of five unknowns C, P, X, M, Y, determined by the following equations:

- Equation for consumption from the household budget constraint,

$$PC = 1 - \alpha + \tau \mathcal{E} M \tag{68}$$

- CPI price index

$$P = \left[1 - \alpha + \alpha\left(\left(1+\tau\right)\mathcal{E}\right)^{1-\overline{\eta}}\right]^{\frac{1}{1-\overline{\eta}}} \tag{69}$$

- Exports and imports

$$X = \alpha \cdot \left(\frac{P}{\mathcal{E}}\right)^{-\overline{\gamma}} \qquad M = \alpha \cdot \left(\frac{\left(1+\tau\right)\mathcal{E}}{P}\right)^{-\overline{\eta}} \tag{70}$$

- Output

$$C + X = Y = \left(\left(1-\alpha\right) + \alpha^{1/\overline{\eta}} M^{\frac{\overline{\eta}-1}{\overline{\eta}}}\right)^{\frac{\overline{\eta}}{\overline{\eta}-1}} \tag{71}$$

Next, consider period 0. With passive monetary policy, $i_0 = 0$ and $\mathcal{E}_0 = \mathcal{E}$. From the Euler equation, we find consumption

$$C_0 = C\left(\frac{P_0}{P}\right)^{-\sigma} \tag{72}$$

where period 0's price level is determined by

$$P_0 = \left[1 - \alpha + \alpha\left((1+\tau)\,\mathcal{E}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{73}$$

which is different from P precisely because the short-run elasticity is different from the long-run elasticity, $\eta \neq \overline{\eta}$. Export demand is given by

$$X_0 = \alpha\left(\frac{P_0}{\mathcal{E}}\right)^{-\gamma} \tag{74}$$

which again differs from long run exports X because $\gamma \neq \overline{\gamma}$. Together, consumption and exports determine output,

$$C_0 + X_0 = Y_0 \tag{75}$$

and that ultimately determines employment,

$$N_0 = (1-\alpha)\,Y_0\left(\frac{1}{P_0}\right)^{-\eta} \tag{76}$$

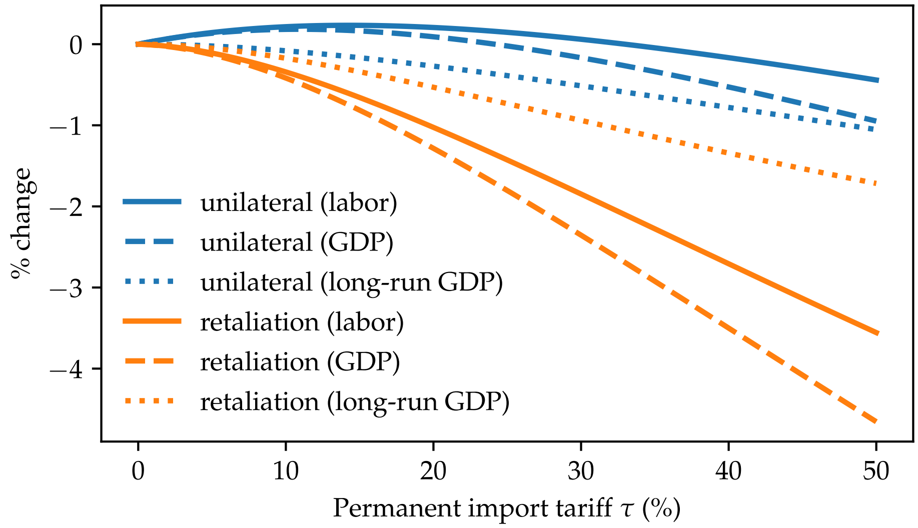
To solve this economy, we thus first solve the long-run allocation (68)–(71), then the date-0 allocation (72)–(76).

Results including GDP effects. In figure 17, we display an augmented version of figure 7, which adds information on the behavior of short-run GDP (dashed) and long-run GDP (dotted). We see that to first order, short-run GDP behaves the same as labor, but that for larger tariffs, GDP declines by more, due to the additional distortionary effects of tariffs.

Interestingly, long-run GDP declines by more than short-run GDP in the unilateral case, but less in the retaliation case. This is because in the long run, there is no employment effect (because we assume a return to the natural allocation), so the only source of GDP decline is the distortionary effect from tariffs, which is larger in the long run due to the higher trade elasticities.[36] In the retaliation case, where the short-run contractionary effects are large, this is not enough to outweigh the short-run downturn in GDP; but in the unilateral case, at least for the range of τ displayed in figure 17, it does.

[36] See the second-order approximation in (40) for an illustration of how the distortionary effect of tariffs scales in the elasticity of imports.

Figure 17: Recessions from sudden permanent tariff surprises



C.8 Natural output

In this section, we characterize the effect of an import tariff in a version of our section 2 economy with flexible labor supply. We modify preferences (2) to include separable disutility,

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-1/\sigma}}{1-1/\sigma} - \varphi_N \frac{N_t^{1+1/\phi}}{1+1/\phi} \right),$$

similar to the preferences we use in section 6. We follow the same approach as in section 3.2, but ask instead what the response is of the natural level of N_0 to a one-time tariff shock at date 0.

For a given interest rate response $d \log (1+i_0)$, prices, consumption and exports are still determined by (23), (24), and (25). Aggregate output is still determined by (17), and labor demand by (16). Combining these equations, we find labor demand to be

$$\begin{aligned} d \log N_0 = &- \left((1-\alpha) \left(\sigma (1-\alpha) + \alpha \gamma \right) + \eta \alpha \right) d \log (1+i_0) \\ &+ \alpha \left(\eta - \left((1-\alpha) \sigma + \alpha \gamma \right) \right) d\tau \end{aligned} \tag{77}$$

as in (55). Labor supply, different from before, is determined by its first order condition

$$\frac{1}{\phi} d \log N_0 = -\frac{1}{\sigma} d \log C_0 + d \log \frac{W_0}{P_0} = -\frac{1}{\sigma} d \log C_0 - d \log P_0$$

Here, consumption and prices are

$$d\log C_0 = -\sigma(1-\alpha)\, d\log(1+i_0) - \sigma\alpha d\tau$$

and

$$d\log P_0 = \alpha\left(d\tau - d\log(1+i_0)\right)$$

so that labor supply is

$$\frac{1}{\phi} d\log N_0 = d\log(1+i_0) \tag{78}$$

Without having used the labor demand equation 77, this already suggests that the key force moving labor supply in this economy is the natural interest rate. With a rising natural interest rate, intertemporal substitution will call for rising labor supply; with a falling natural interest rate, labor supply will fall, as well.

Combining (77) and (78) and solving for the interest rate, we find

$$d\log(1+i_0) = \frac{\alpha\left(\eta - \left((1-\alpha)\sigma + \alpha\gamma\right)\right)}{(1-\alpha)\left(\sigma(1-\alpha) + \alpha\gamma\right) + \eta\alpha + \phi} d\tau$$

$$d\log(1+i_0) = \frac{\alpha}{1-\alpha} \frac{\eta - \left((1-\alpha)\sigma + \alpha\gamma\right)}{\left(\sigma(1-\alpha) + \alpha\gamma\right) + \frac{\alpha}{1-\alpha}\eta + \frac{1}{1-\alpha}\phi} d\tau$$

very similar to (26). The natural rate, and thus the natural level of labor supply (or GDP), falls if and only if

$$(1-\alpha)\sigma + \alpha\gamma > \eta$$

which is just (1).

D Appendix to section 5

D.1 Proof of proposition 10

We can write the optimization problem for the Home representative agent as

$$\max \sum_{t=0}^{\infty} \beta^t u(C_t)$$

$$\frac{P_t C_t - W_t N_t}{\mathcal{E}_t} = (1+i^*)\tilde{A}_{t-1} - \tilde{A}_t + \frac{T_t}{\mathcal{E}_t} \tag{79}$$

where we have divided by $\mathcal{E}_t$ to rewrite the budget constraint (3) in terms of foreign currency, defining $\tilde{A}_t \equiv A_t/\mathcal{E}_t$. The current-value Lagrange multiplier on the constraint is $\lambda_t = u'(C_t)\frac{\mathcal{E}_t}{P_t}$, and it follows from the envelope theorem that given first-order changes $\{dP_t, dW_t, dN_t, d\mathcal{E}_t, dT_t\}$, the first-order effect on the objective is the discounted sum of

$$\frac{P_tC_t}{\mathcal{E}_t} d\log P_t - \frac{W_tN_t}{\mathcal{E}_t}(d\log W_t + d\log N_t) - \frac{dT_t}{\mathcal{E}_t} - \frac{P_tC_t - W_tN_t - T_t}{\mathcal{E}_t} d\log \mathcal{E}_t \tag{80}$$

times $-\lambda_t$.

First-order effect starting from steady state. Starting from the steady state, we can remove the t subscripts on $P_tC_t/\mathcal{E}_t$, etc., in (80). Multiplying by $-\lambda = u'(C)\frac{\mathcal{E}}{P}$, but dividing by $u'(C)C$ to put in units of steady-state consumption, (80) becomes

$$-d\log P_t + d\log N_t + \frac{dT_t}{PC} \tag{81}$$

where we use that in steady state, $PC = WN$ and $T = 0$, and also use $d\log W_t = 0$. We then have $d\log P_t = \alpha(d\log \mathcal{E}_t + d\tau_t)$ and $\frac{dT_t}{PC} = \frac{\alpha}{1-\alpha}d\tau_t$, so that (81) becomes just

$$d\log N_t - \alpha d\log \mathcal{E}_t + \frac{\alpha^2}{1-\alpha}d\tau \tag{82}$$

where $d\log N_t$ is the direct effect of any change in labor, and the other two terms correspond to changes in the terms of trade.

Exchange rate effects and first-order welfare. Next, we characterize the endogenous $-\alpha d\log \mathcal{E}_t$ term in (82), allowing for the possibility of retaliatory tariffs. First, note that

$$\begin{aligned} P_tC_t - W_tN_t - T_t &= P_tY_t - W_tN_t - P_tX_t - T_t \\ &= (1+\tau_t)\mathcal{E}_tM_t - P_tX_t - \tau_t\mathcal{E}_tM_t = \mathcal{E}_tM_t - P_tX_t. \end{aligned}$$

Noting that $1 + i^* = \beta^{-1}$, it follows that we can combine (79) into the single present-value budget constraint

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{P_tX_t}{\mathcal{E}_t} - M_t \right) = 0.$$

Log-linearizing around the steady-state with balanced trade, this implies

$$\sum_{t=0}^{\infty} \beta^t \left(d\log P_t - d\log \mathcal{E}_t + d\log X_t - d\log M_t \right) = 0. \tag{83}$$

We also have $d\log X_t = -\gamma(d\log P_t + d\tau_t^r - d\log \mathcal{E}_t)$ and $d\log M_t = d\log Y_t - \eta(d\log \mathcal{E}_t - d\log P_t) = (1-\alpha)d\log N_t + \alpha d\log M_t - \eta(d\log \mathcal{E}_t - d\log P_t)$, which can be simplified to $d\log M_t = d\log N_t - (1-\alpha)^{-1}\eta(d\log \mathcal{E}_t + d\tau_t - d\log P_t)$. Plugging these into (83), we get

$$\sum_{t=0}^{\infty} \beta^t \left((1-\gamma-(1-\alpha)^{-1}\eta)(d\log P_t - d\log \mathcal{E}_t) + (1-\alpha)^{-1}\eta d\tau_t - \gamma d\tau_t^r - d\log N_t \right) = 0$$

We further observe that $d\log P_t - d\log \mathcal{E}_t = -(1-\alpha)d\log \mathcal{E}_t + \alpha d\tau_t$. Using PV notation to denote discounted sums (i.e. $PV(Z_t) \equiv \sum_{t=0}^{\infty} \beta^t Z_t$ for any $\{Z_t\}$), this becomes

$$\begin{aligned} ((1-\alpha)(\gamma-1)+\eta) \left(PV(d\log \mathcal{E}_t) - \frac{\alpha}{1-\alpha} PV(d\tau_t) \right) \\ = -(1-\alpha)^{-1}\eta PV(d\tau_t) + \gamma PV(d\tau_t^r) + PV(d\log N_t) \end{aligned}$$

and we can solve to obtain

$$PV(d\log \mathcal{E}_t) - \frac{\alpha}{1-\alpha} PV(d\tau_t) = \frac{-(1-\alpha)^{-1}\eta PV(d\tau_t) + \gamma PV(d\tau_t^r) + PV(d\log N_t)}{(1-\alpha)(\gamma-1)+\eta} \tag{84}$$

The overall first-order welfare effect is the present value of (82). Substituting (84) into this, and using $d\log GDP_t = d\log N_t$, we have a first-order welfare effect of

$$\frac{\alpha}{1-\alpha} \frac{\eta PV(d\tau_t) - (1-\alpha)\gamma PV(d\tau_t^r)}{(1-\alpha)(\gamma-1)+\eta} + \left(1 - \alpha \frac{1}{(1-\alpha)(\gamma-1)+\eta}\right) PV(d\log GDP_t)$$

which is exactly the first-order result (38) in proposition 10.

D.2 Proof of proposition 11

The first-order equivalence of the output-gap effect in (39) with (38) follows immediately, since full-employment monetary policy in response to a tariff sets $d\log GDP_t = 0$ and thus the output gap to zero in (38), while leaving the other term unchanged.

We now turn to the other two terms.

Starting from any point, the terms-of-trade correction adds $dT_t^{corr} = d\left(\frac{P_t}{\mathcal{E}_t}\right) X_t = \frac{P_t X_t}{\mathcal{E}_t}(d\log P_t - d\log \mathcal{E}_t)$ to (80). Given monetary policy, such that $d\log N_t = 0$, and also $d\log W_t$, (80) becomes

$$\frac{P_t C_t}{\mathcal{E}_t} d\log P_t - \frac{dT_t}{\mathcal{E}_t} - \frac{P_t C_t - W_t N_t - T_t}{\mathcal{E}_t} d\log \mathcal{E}_t + \frac{P_t X_t}{\mathcal{E}_t}(d\log P_t - d\log \mathcal{E}_t).$$

Noting that $P_t X_t + P_t C_t = P_t Y_t$ and also that $P_t Y_t - W_t N_t - T_t = P_t^F M_t - T_t = \mathcal{E}_t M_t$, we can add $\frac{P_t X_t}{\mathcal{E}_t} d \log P_t$ from the last term to the first term, and similarly $-\frac{P_t X_t}{\mathcal{E}_t} d \log \mathcal{E}_t$ from the rightmost term to the third term, and obtain the simplification

$$\frac{P_t Y_t}{\mathcal{E}_t} d \log P_t - \frac{dT_t}{\mathcal{E}_t} - M_t d \log \mathcal{E}_t. \tag{85}$$

Next, we observe that $d \log P_t = \frac{(1+\tau_t)\mathcal{E}_t M_t}{P_t Y_t} d \log \mathcal{E}_t + \frac{\mathcal{E}_t M_t}{P_t Y_t} d\tau_t$, so that the first term above simplifies to $(1 + \tau_t) M_t d \log \mathcal{E}_t + M_t d\tau_t$. Finally, $\frac{dT_t}{\mathcal{E}_t} = M_t d\tau_t + \tau_t dM_t + \tau_t M_t d \log \mathcal{E}_t$. All terms in (85) then cancel except $-\tau_t dM_t$.

Multiplying by $-\lambda_t = -u'(C_t)\frac{\mathcal{E}_t}{P_t}$, this becomes

$$\frac{u'(C_t)}{P_t} \cdot (\tau_t \mathcal{E}_t dM_t) \tag{86}$$

i.e. the revenue effect of changing imports at the current tariff, converted into current consumption units.

Starting from the steady state with zero tariffs, (86) is zero, so that $\mathcal{W}^{corr}(\tau)$ is zero to first order in τ. It follows that $\mathcal{W}^{fe}(\tau) - \mathcal{W}^{corr}(\tau)$ must be, to first order, the remaining term in (38), namely the terms-of-trade effect.

Second-order characterization of distortion effect. If the only tariff change is $\tau_0 = \tau$ at date 0, (86) implies that $(\mathcal{W}^{corr})'(\tau) = \frac{1}{u'(C)C}\frac{u'(C_0)}{P_0} \cdot (\tau \mathcal{E}_0 M_0'(\tau))$.

We have already observed that this is zero when $\tau = 0$. Expanding $\mathcal{W}^{corr}(\tau)$ to *second order* around $\tau = 0$, the only surviving term is therefore

$$\frac{1}{2}\frac{1}{u'(C)C}\frac{u'(C)}{P}\tau\mathcal{E}\frac{dM_0}{d\tau}\tau = \frac{1}{2}\frac{1}{PC}\mathcal{E}\frac{dM_0}{d\tau}\tau^2.$$

Finally, if we write $\frac{1}{PC}\mathcal{E} dM_0 = \frac{\mathcal{E}M}{PC} d \log M_0 = \frac{\alpha}{1-\alpha} d \log M_0$, this simplifies to just

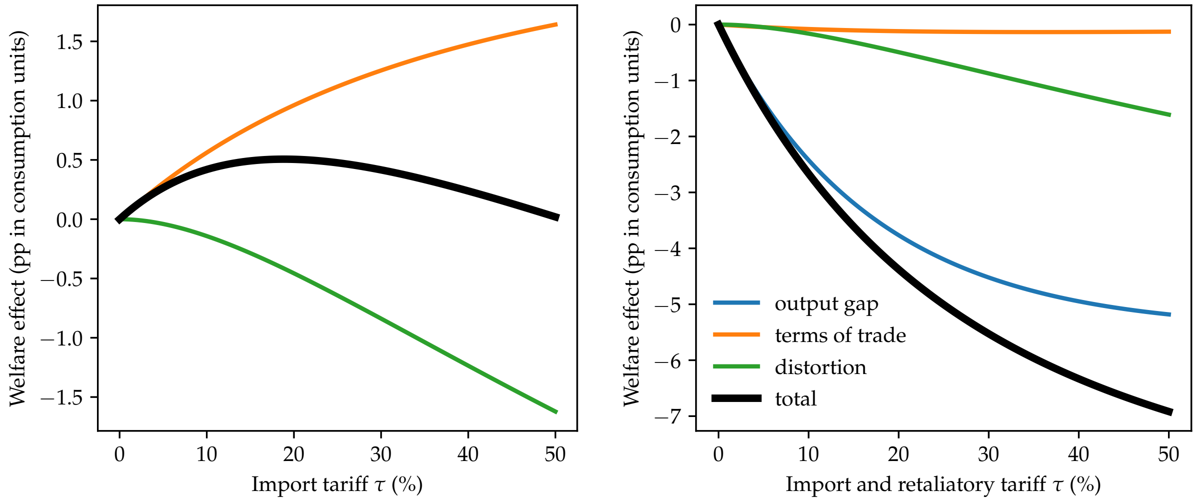
$$\frac{1}{2}\frac{\alpha}{1-\alpha}\frac{d \log M_0}{d\tau}\tau^2. \tag{87}$$

which is our final second-order expression in (40).

D.3 Analysis with long-run elasticities

Figure 18 redoes figure 9, replacing our calibrated values of $\eta = 1.15$ and $\gamma = 1.5$ with long-run values of $\eta = 3.07$ and $\gamma = 4$. (As discussed in section 2.3, the latter are more

Figure 18: Decomposition of nonlinear welfare effects from tariff (long-run trade elasticities)



plausible long-run values, which we convert to short-run values by multiplying by 3/8, in line with Boehm et al. (2023).)

We see that in the unilateral case, there is no output-gap effect, since our recession condition (20) no longer holds with these elasticities. The first-order terms-of-trade effect initially dominates the distortion effect, but the latter grows quickly enough to imply an optimal tariff below 20%.

In the retaliation case, all three effects are still negative (although the terms-of-trade effect is small), implying large costs from tariffs.

E Appendix to section 6

E.1 Quantitative model with durables and inventories

We begin describing our full quantitative model, with durables and inventories. We split the economy in several blocks, going over each block in turn.

Households. The utility function of the representative household is given by

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{\left(C_t^{ND}\right)^{1-1/\sigma}}{1-1/\sigma} + \varphi_D \frac{D_{t-1}^{1-1/\sigma}}{1-1/\sigma} - \varphi_N \frac{N_t^{1+1/\phi}}{1+1/\phi} \right) \tag{88}$$

where σ is both the intertemporal elasticity of substitution as well as the intratemporal one between non-durable consumption C_t^{ND} and the stock of durables D_t. ϕ is the Frisch elasticity of labor supply. $\varphi_D \geq 0$ is the weight on durables, $\varphi_N > 0$ the weight on the disutility of labor supply.

The stock of durables depreciates at rate δ but increases with durable expenditure C_t^D,

$$D_t = (1-\delta)\, D_{t-1} + C_t^D \tag{89}$$

Any adjustment in the durables stock is assumed to incur quadratic adjustment costs,

$$\frac{1}{2\delta\epsilon_D}\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)^2 D_{t-1}$$

The adjustment costs as well as durable expenditure C_t^D are in units of final goods. The latter can be viewed as assuming that durables and non-durable goods are produced with an identical production function, namely the one we introduce below for final goods.

The representative household accumulates nominal assets A_t, paying nominal interest i_t, and earns income from three distinct sources: labor income, $W_t N_t$, where W_t is the nominal wage; nominal profits Π_t from importers (see below); nominal transfers T_t from tariff revenue.

Putting everything together, the household budget constraint is then given by

$$P_t C_t^{ND} + P_t C_t^D + P_t \frac{1}{2\delta\epsilon_D}\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)^2 D_{t-1} + A_t = A_{t-1}\left(1 + i_{t-1}\right) + W_t N_t + \Pi_t + T_t \tag{90}$$

In the special case where the representative household does not consume durables, $\varphi_D = 0$, we also write $C_t = C_t^{ND}$ for nondurable consumption.

Final goods production. There is a representative final goods producer that employs labor N_t and uses intermediate inputs G_t to produce final goods with a production function

$$Y_t = \left(\left(1-\tilde{\alpha}\right)^{1/\eta} N_t^{\frac{\eta-1}{\eta}} + \tilde{\alpha}^{1/\eta} G_t^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{91}$$

The price level of the final good is equal to the CPI P_t. Labor is paid wage W_t and the price of intermediate goods is equal to P_t^G. For reasons that will become clear below, we denote the CES weight on intermediates by $\tilde{\alpha}$, not α.

Import sector. There is an import sector that imports goods M_t from abroad, at price P_t^M, and produces intermediate goods G_t. The reason we separate imported goods from intermediate goods is to allow for a role of inventories S_t. Specifically, we assume that the production function of intermediates is given by

$$G_t = \left(\chi^{1/v} \left(\left(\beta^{-1} - 1 \right) S_{t-1} \right)^{\frac{v-1}{v}} + (1-\chi)^{1/v} \tilde{M}_t^{\frac{v-1}{v}} \right)^{\frac{v}{v-1}} \tag{92}$$

where the stock of inventories evolves according to

$$S_t = S_{t-1} + M_t - \tilde{M}_t - \frac{1}{2\epsilon_S} \left(\frac{S_t - S_{t-1}}{S_{t-1}} \right)^2 S_{t-1} \tag{93}$$

Intermediate goods are produced as a CES aggregate of the stock of inventories S_{t-1} and the amount by which inventories are drawn down, $\tilde{M}_t$. We allow S_{t-1} to enter here such that the import sector finds it optimal to hold a positive steady state quantity of inventories. The $\left(\beta^{-1} - 1\right)$ term in (92) is without loss of generality and helps us simplify steady state expressions below.

Any inventory adjustments incur an adjustment cost, symmetric to that of durables,

$$\frac{1}{2\epsilon_S} \left(\frac{S_t - S_{t-1}}{S_{t-1}} \right)^2 S_{t-1}$$

which is paid in terms of imports, which is why it shows up in the law of motion (93).

The price paid by the import sector includes the tariff τ_t,

$$P_t^M = (1 + \tau_t) \mathcal{E}_t \tag{94}$$

where we normalized the price of foreign goods abroad to 1. $\mathcal{E}_t$ is the nominal exchange rate.

Export demand. The price of domestically produced goods abroad is given by

$$P_t^* = \frac{P_t}{\mathcal{E}_t} (1 + \tau_t^*)$$

Here, we allow for a retaliatory tariff of τ_t^*. The quantity of exports is then determined as

$$X_t = \alpha \left(P_t^* \right)^{-\gamma} \tag{95}$$

Exchange rate. The nominal exchange rate is determined by the UIP condition,

$$(1+i_t)\,\mathcal{E}_t = (1+i^*)\,\mathcal{E}_{t+1} \tag{96}$$

The foreign interest rate is constant and given by $1+i^* = \beta^{-1}$.

Trade balance and net foreign asset position. The trade balance of the economy (in foreign currency) is the difference between the value of exports and imports

$$TB_t = \frac{P_t}{\mathcal{E}_t} X_t - M_t \tag{97}$$

Even though the inventory adjustment cost will be zero to first order, we include it here as part of imports for completeness.

The net foreign asset position is the value of household assets in foreign currency,

$$NFA_t = \frac{A_t}{\mathcal{E}_t} \tag{98}$$

Phillips curve. We assume a standard wage rigidity as in Erceg et al. (2000). To first order, this gives the following wage Phillips curve

$$\pi_t^w = \kappa\left(\frac{1}{\phi} d\log N_t + \frac{1}{\sigma} d\log C_t^{ND} - d\log W_t + d\log P_t\right) + \beta \mathbb{E}_t \pi_{t+1}^w \tag{99}$$

where wage inflation is $\pi_t^w = d\log W_t - d\log W_{t-1}$.

Government. The fiscal authority pays out tariff revenue as lump-sum transfer

$$T_t = \tau_t \mathcal{E}_t M_t \tag{100}$$

We consider three types of monetary policy rules. First, a "passive monetary policy" rule that is simply a fixed nominal interest rate,

$$i_t = i$$

made determinate by a long-run nominal anchor for the nominal exchange rate. Second, we consider a rule that targets zero wage inflation at all dates and therefore implements the flexible-wage allocation (henceforth "natural rate rule"). And finally, we consider a

Taylor rule that responds to domestic wage inflation

$$i_t = \phi_\pi \pi_t^w$$

where ϕ_π is the Taylor rule coefficient (henceforth "Taylor rule").

Real GDP. Steady state GDP is given by

$$GDP = PY - P^M M$$

where all variables without subscript are meant to denote steady state values. We compute changes in real GDP using a standard Divisia index, as

$$dGDP_t = PdY_t - P^M dM_t + P^M (dS_t - dS_{t-1})$$

Log changes are then simply $d \log GDP_t = dGDP_t / GDP$.

E.2 Characterizing equilibrium

We define competitive equilibrium in our economy as follows.

Definition. A *competitive equilibrium* in the quantitative model consists of quantities and prices such that:

- The representative household chooses $\{C_t^{ND}, C_t^D, D_t, A_t\}$ to maximize utility (88) subject to (90).
- Final goods production (91) is optimal given prices $\{P_t, W_t, P_t^G\}$.
- Intermediate goods production (92) is optimal subject to inventories (93) given prices $\{P_t^G, P_t^M\}$.
- Export demand is given by (95); the exchange rate is consistent with (96); trade balance and net foreign assets are as in (97) and (98); inflation is consistent with (99); the transfer is as in (100).
- The goods market clears,

$$C_t^{ND} + C_t^D + \frac{1}{2\delta\epsilon_D}\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)^2 D_{t-1} + X_t = Y_t \tag{101}$$

- The balance of payments holds

$$NFA_t = NFA_{t-1}(1+i^*) + TB_t \tag{102}$$

We next derive the first-order optimality conditions for this economy.

Household optimality. It will be more intuitive to derive the household optimality conditions from a recursive Bellman equation. The Bellman equation that corresponds to (88) is

$$V_t(D_{t-1}, A_{t-1}) = \max_{D_t, A_t} \left\{ \frac{\left(C_t^{ND}\right)^{1-1/\sigma}}{1-1/\sigma} + \varphi_D \frac{D_{t-1}^{1-1/\sigma}}{1-1/\sigma} - \varphi_N \frac{N_t^{1+1/\phi}}{1+1/\phi} + \beta V_{t+1}(D_t, A_t) \right\}$$

subject to the consolidated budget constraint

$$P_t C_t^{ND} + P_t(D_t - (1-\delta)D_{t-1}) + P_t \frac{1}{2\delta\epsilon_D}\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)^2 D_{t-1} + A_t = A_{t-1}(1+i_{t-1}) + W_t N_t + \Pi_t + T_t$$

We find the following first order conditions (after some algebra):

- The standard Euler equation for nondurables

$$\left(C_t^{ND}\right)^{-1/\sigma} = \beta(1+r_{t+1})\left(C_{t+1}^{ND}\right)^{-1/\sigma} \tag{103}$$

  where the real rate is

$$1 + r_{t+1} = \frac{1+i_t}{1+\pi_{t+1}}$$

- Two conditions for durables. The first is the first order condition with respect to D_t

$$\beta \frac{\partial V_{t+1}}{\partial D_t} = \left(C_t^{ND}\right)^{-1/\sigma}\left[1 + \frac{1}{\delta\epsilon_D}\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)\right] \tag{104}$$

  The second is the Envelope condition

$$\begin{aligned}\frac{\partial V_t}{\partial D_{t-1}} &= \varphi_D D_{t-1}^{-1/\sigma} + \left(C_t^{ND}\right)^{-1/\sigma}(1-\delta) \\ &\quad - \left(C_t^{ND}\right)^{-1/\sigma}\frac{1}{2\delta\epsilon_D}\left\{\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)^2 - 2\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)\frac{D_t}{D_{t-1}}\right\}\end{aligned} \tag{105}$$

We define the value of an additional marginal unit of durables D_t in terms of nondurables as

$$Q_{t+1} \equiv \beta \left(C_t^{ND} \right)^{1/\sigma} \frac{\partial V_{t+1}}{\partial D_t}$$

We rewrite (104) in terms of Q_{t+1}

$$\delta \epsilon_D \left(Q_{t+1} - 1 \right) = \frac{D_t - D_{t-1}}{D_{t-1}} \tag{106}$$

The household invests in durables precisely when the marginal value of durables Q_{t+1} exceeds one. The sensitivity of durables investment to Q_{t+1} is governed by $\delta \epsilon_D$.

We also substitute Q_t into (105). The left hand side can be expressed as

$$\frac{\partial V_t}{\partial D_{t-1}} = Q_t \beta^{-1} \left(C_{t-1}^{ND} \right)^{-1/\sigma} = Q_t \left(1 + r_t \right) \left(C_t^{ND} \right)^{-1/\sigma}$$

Thus, (105) is equivalent to

$$\left(1 + r_t \right) Q_t = \varphi_D \left(\frac{C_t^{ND}}{D_{t-1}} \right)^{1/\sigma} - \frac{D_t}{D_{t-1}} + 1 - \delta - \frac{1}{2\delta \epsilon_D} \left(\frac{D_t - D_{t-1}}{D_{t-1}} \right)^2 + \frac{D_t}{D_{t-1}} Q_{t+1} \tag{107}$$

This gives us three optimality conditions, (103), (106), and (107).

Optimality of the final goods producer. Optimal labor demand of the representative final goods producer is equal to

$$N_t = \left(1 - \tilde{\alpha} \right) Y_t \left(W_t / P_t \right)^{-\eta} \tag{108}$$

and optimal demand for intermediates is equal to

$$G_t = \tilde{\alpha} Y_t \left(P_t^G / P_t \right)^{-\eta} \tag{109}$$

The price level is a CES aggregate of the input prices

$$P_t = \left(\left(1 - \tilde{\alpha} \right) \left(W_t \right)^{1-\eta} + \tilde{\alpha} \left(P_t^G \right)^{1-\eta} \right)^{\frac{1}{1-\eta}}$$

Optimality of the import sector. The import sector solves the Bellman equation

$$V_t(S_{t-1}) = \max_{M_t, \tilde{M}_t, S_t} \left\{ P_t^G G_t - P_t^M \left(S_t - S_{t-1} + \tilde{M}_t + \tfrac{1}{2\epsilon_S} \left(\tfrac{S_t - S_{t-1}}{S_{t-1}} \right)^2 S_{t-1} \right) + \frac{1}{1 + i_t} V_{t+1}(S_t) \right\}$$

From the first order conditions for $\tilde{M}_t$ we immediately see that

$$P_t^G \frac{\partial G_t}{\partial \tilde{M}_t} = (1-\chi)^{1/v} P_t^G \left(\frac{G_t}{\tilde{M}_t}\right)^{1/v} = P_t^M$$

and so the optimal drawdown of inventories is given by

$$\tilde{M}_t = (1-\chi) G_t \left(\frac{P_t^G}{P_t^M}\right)^v \tag{110}$$

The first order condition for inventories is given by

$$P_t^M + P_t^M \tfrac{1}{\epsilon_S}\left(\tfrac{S_t - S_{t-1}}{S_{t-1}}\right) = \frac{1}{1+i_t} V'_{t+1}(S_t) \tag{111}$$

and the Envelope condition is

$$V'_t(S_{t-1}) = P_t^G \frac{\partial G_t}{\partial S_{t-1}} + P_t^M + P_t^M \tfrac{1}{\epsilon_S} \tfrac{S_t - S_{t-1}}{S_{t-1}} \frac{S_t}{S_{t-1}} - P_t^M \tfrac{1}{2\epsilon_S} \left(\tfrac{S_t - S_{t-1}}{S_{t-1}}\right)^2 \tag{112}$$

with

$$\frac{\partial G_t}{\partial S_{t-1}} = \chi^{1/v}\left(\beta^{-1} - 1\right)\left(\frac{G_t}{(\beta^{-1}-1) S_{t-1}}\right)^{1/v}$$

Defining the marginal value of one more unit of inventory in terms of today's imports as

$$Q_{t+1}^S \equiv \frac{1}{P_t^M} \frac{1}{1+i_t} V'_{t+1}(S_t)$$

we can rewrite (111) as

$$\epsilon_S \left(Q_{t+1}^S - 1\right) = \frac{S_t - S_{t-1}}{S_{t-1}} \tag{113}$$

and (112) as

$$\frac{P_{t-1}^M}{P_t^M} (1+i_{t-1}) Q_t^S = \frac{P_t^G}{P_t^M} \frac{\partial G_t}{\partial S_{t-1}} - \frac{S_t}{S_{t-1}} + 1 - \tfrac{1}{2\epsilon_S}\left(\tfrac{S_t - S_{t-1}}{S_{t-1}}\right)^2 + \frac{S_t}{S_{t-1}} Q_{t+1}^S \tag{114}$$

E.3 Steady state

We denote steady state quantities by omitting the subscript "t". As before, we normalize all steady state prices to 1, $P = P^G = P^M = \mathcal{E} = 1$. We further normalize steady-state output to 1, $Y = 1$. From (108) and (109), we find

$$N = 1 - \tilde{\alpha} \qquad \text{and} \qquad G = \tilde{\alpha}$$

Further, (110) and (93) imply that

$$M = \tilde{M} = (1 - \chi)\,\tilde{\alpha}$$

(113) and (114) boil down to

$$Q^S = 1$$

and

$$\frac{\partial G}{\partial S} = \chi^{1/v}\left(\beta^{-1} - 1\right)\left(\frac{G}{\left(\beta^{-1} - 1\right)S}\right)^{1/v} = r$$

With $r = \beta^{-1} - 1$, this reduces to

$$rS = \chi\tilde{\alpha}$$

The equilibrium inventory to sales ratio is given by

$$\frac{S}{G} = \frac{\chi}{r}$$

From the investment condition for durables (106), we find

$$Q = 1$$

which we substitute into the valuation condition (107) to obtain

$$r + \delta = \varphi_D \left(\frac{C^{ND}}{D}\right)^{1/\sigma}$$

Labor supply optimality in the steady state is

$$\varphi_N \left(C^{ND}\right)^{1/\sigma} N^{1/\phi} = 1$$

and so

$$\varphi_N \left(C^{ND}\right)^{1/\sigma} (1 - \tilde{\alpha})^{1/\phi} = 1$$

and the budget constraint with $A = 0$ gives

$$C^{ND} + \delta D = 1 - \tilde{\alpha} + \chi\tilde{\alpha}$$

where $C^D = \delta D$. Let ω denote the share of durables in total spending,

$$\omega \equiv \frac{\delta D}{\delta D + C^{ND}}$$

Given ω, we have

$$\delta D = \omega \left(1 - \tilde{\alpha} + \chi \tilde{\alpha}\right) \qquad \text{and} \qquad C^{ND} = (1 - \omega) \left(1 - \tilde{\alpha} + \chi \tilde{\alpha}\right)$$

Any given ω maps into a preference parameter φ_D in steady state,

$$\varphi_D = (r + \delta) \left(\delta \frac{1 - \omega}{\omega}\right)^{-1/\sigma}$$

We can also pin down the preference parameter on labor supply given ω,

$$\varphi_N = \left((1 - \omega) \left(1 - \tilde{\alpha} + \chi \tilde{\alpha}\right)\right)^{-1/\sigma} (1 - \tilde{\alpha})^{-1/\phi}$$

From the goods market clearing condition (101), we extract exports X

$$C^{ND} + C^D + X = 1$$

and so

$$X = (1 - \chi) \tilde{\alpha}$$

The trade balance is then zero,

$$TB = X - M = 0$$

which fits the balance of payments (102) since the NFA is also zero. Observe that the openness of the economy here is given by

$$\alpha \equiv (1 - \chi) \tilde{\alpha}$$

and is not simply equal to the coefficient $\tilde{\alpha}$ on intermediate goods in final goods production (91).

E.4 Transitory shock limit

In this subsection we show that the durable goods block of the quantitative model reproduces the reduced-form elasticity used in Section 4.5.

We (i) shut down inventories by setting $\chi = 0$, so that only nondurables and durables matter, and (ii) consider the same transitory-shock experiment as in the main text: a one-time unexpected first-order increase in import tariffs $d\tau$, leading to an increase in the domestic price level $d\log P_0$, no further shocks for $t \geq 1$, and the limit $\beta \to 1$, $r \to 0$, $\delta \to 0$, with constant durables expenditure $\delta D = C^D = const$ (via adjusting D and ϕ_D). This corresponds to the length of a time period taken to be arbitrarily small. The key optimality conditions from above are:

$$\left(C_t^{ND}\right)^{-1/\sigma} = \beta(1+r_{t+1})\left(C_{t+1}^{ND}\right)^{-1/\sigma}, \tag{115}$$

$$D_t = (1-\delta)\, D_{t-1} + C_t^D \tag{116}$$

$$\delta\epsilon_D\left(Q_{t+1}-1\right) = \frac{D_t - D_{t-1}}{D_{t-1}}, \tag{117}$$

$$(1+r_t)Q_t = \phi_D\left(\frac{C_t^{ND}}{D_{t-1}}\right)^{1/\sigma} - \frac{D_t}{D_{t-1}} + 1 - \delta - \frac{1}{2}\delta\epsilon_D\left(\frac{D_t - D_{t-1}}{D_{t-1}}\right)^2 + \frac{D_t}{D_{t-1}}Q_{t+1}. \tag{118}$$

These are equations (103), (89), (106), and (107) in the main appendix. As in the main text, we focus here on the case of a stable nominal interest rate at date 0, that is,

$$1 + r_1 = (1+i)\,\frac{P_0}{P_1} \tag{119}$$

which, in our limit, becomes $1 + r_1 = P_0$, as $i \to 0$ and $P_1 \to 1$.

Conjecture. We conjecture that the following is the first-order solution $\{d\log C_t^{ND}, d\log C_t^D, d\log D_t, d$ to the system (115)–(118), once our transitory shock limit is applied:

$$d\log C_t^{ND} = \begin{cases} -\sigma\, d\log P_0 & t = 0 \\ 0 & t > 0 \end{cases} \tag{120}$$

and

$$d\log C_t^D = \begin{cases} -\epsilon_D\, d\log P_0 & t = 0 \\ 0 & t > 0 \end{cases}$$

and

$$d\log D_t = 0$$

and

$$d\log Q_t = \begin{cases} -d\log P_0 & t = 1 \\ 0 & t > 1 \end{cases}$$

We verify each of the equations (115)–(118) above.

Equation (115). Linearizing (115), we have

$$-\frac{1}{\sigma}d\log C_t^{ND} = d\log\left(1+r_{t+1}\right) - \frac{1}{\sigma}d\log C_{t+1}^{ND}$$

Substituting in our guess (120), together with

$$d\log\left(1+r_1\right) = d\log P_0$$

in our limit, verifies (115).

Equation (116). Linearizing the law of motion (116), we obtain

$$d\log D_t = \left(1-\delta\right)d\log D_{t-1} + \delta d\log C_t^D$$

which in our limit, simplifies to $d\log D_t = \left(1-\delta\right)d\log D_{t-1}$. This is clearly satisfied by our guess that $d\log D_t = 0$.

Equation (117). Substituting the law of motion (116) into (117), we find

$$\delta\epsilon_D\left(Q_{t+1}-1\right) = \frac{C_t^D}{D_{t-1}} - \delta$$

Linearizing, this becomes,

$$\delta\epsilon_D d\log Q_{t+1} = d\frac{C_t^D}{D_{t-1}} = \delta\left(d\log C_t^D - d\log D_{t-1}\right)$$

In our limit, this simplifies to

$$\epsilon_D d\log Q_{t+1} = d\log C_t^D - d\log D_{t-1}$$

Our guess clearly satisfies this equation, as both sides are zero for any period $t \neq 0$, and in period $t = 0$, we have that both sides simplify to $-\epsilon_D d\log P_0$.

Equation (118). The linearized version of (118) around the steady state is given by

$$dr_t + \left(1+r\right)d\log Q_t = \phi_D\frac{1}{\sigma}\left(\frac{C^{ND}}{D}\right)^{1/\sigma}\left(d\log C_t^{ND} - d\log D_{t-1}\right) + d\log Q_{t+1}$$

This equation is irrelevant for $t = 0$, as it only pins down dQ_0, which does not enter any other equation. For $t > 1$, both sides of the equation are equal to zero under our guess. For $t = 1$, in the transitory shock limit, the left hand side is equal to

$$d \log P_0 + d \log Q_t = 0$$

under our guess, as is the right hand side. Thus (118) is also satisfied by our guess.

Summary. We have shown that, in the transitory shock limit, durables spending is

$$d \log C_0^D = -\epsilon_D \, d \log P_0$$

while non-durable spending is

$$d \log C_0^{ND} = -\sigma \, d \log P_0.$$

Taken together, total consumer expenditure $C_t = C_t^{ND} + C_t^D$ therefore moves according to

$$d \log C_0 = -\left(\omega \epsilon_D + (1-\omega)\,\sigma\right) d \log P_0$$

where $\omega = \frac{\delta D}{\delta D + C^{ND}}$. Thus, the total elasticity of consumption is

$$\omega \epsilon_D + (1-\omega)\,\sigma$$

confirming (37)

E.5 Additional figures

E.5.1 Retaliation in baseline model

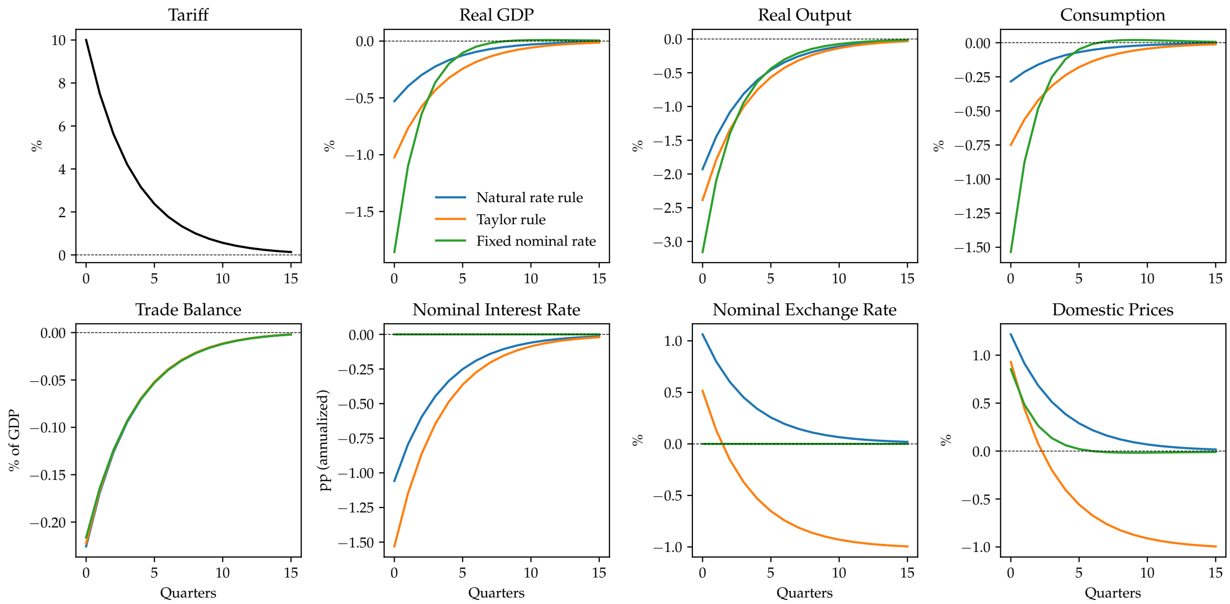


Figure 19: Persistent tariff shock with retaliation in baseline model

E.5.2 Durables

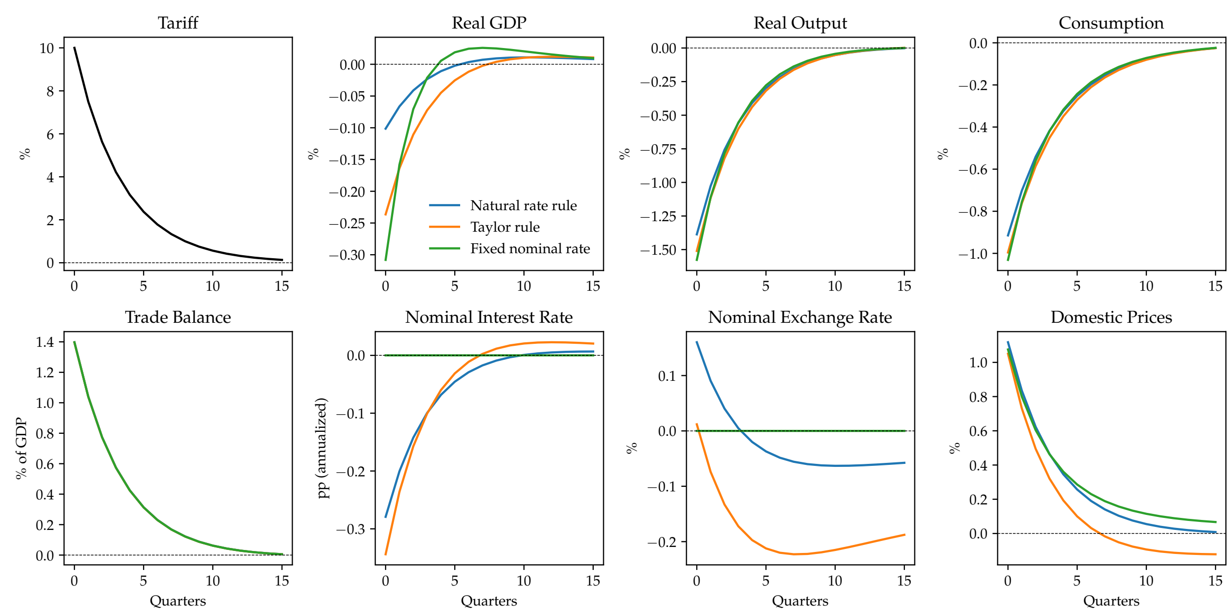


Figure 20: Persistent unilateral tariff shock: durables

E.5.3 Durables and inventories

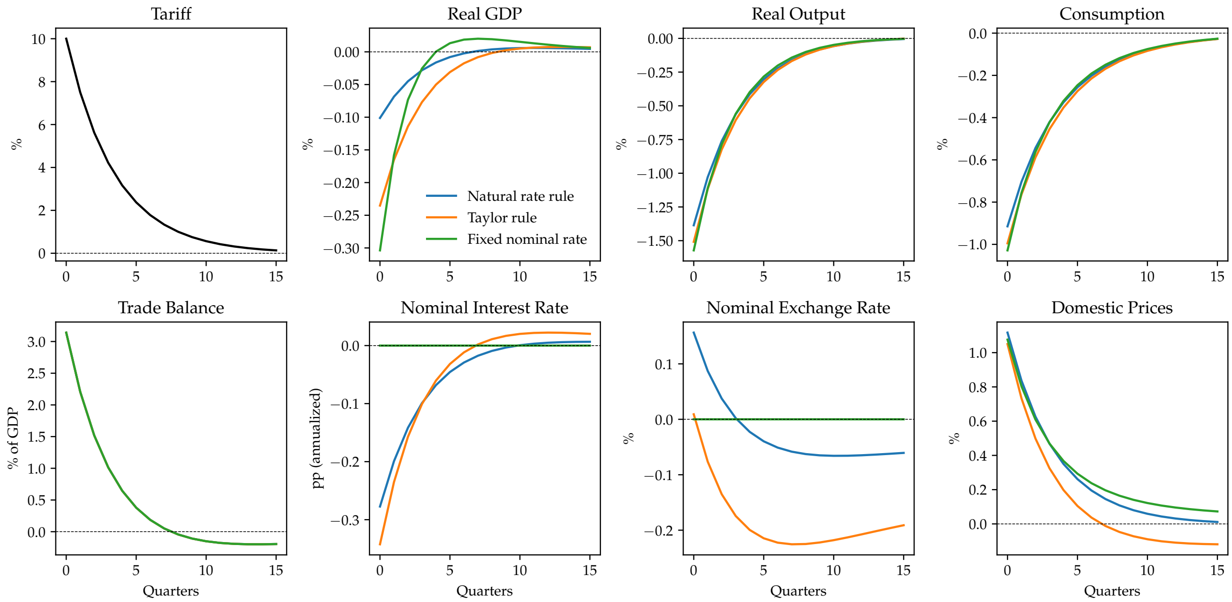


Figure 21: Persistent unilateral tariff shock: durables and inventories