Could Tariffs Provide a Stimulus? Simple Analytics of Tariffs and the Macro Economy

Jeremy Meng

June 11,2025

Abstract

This paper shows that tariffs may stimulate demand when nominal frictions are present. While tariffs in small open economies depress consumption under PPI-targeting monetary policy, tariffs can in principle stimulate demand when monetary policy accommodates producer price inflation, such as under CPI targeting, the fiscal determinacy of the price level, and inactive monetary policy. Unless production uses inputs, inflationary tariffs in the world economy depress global demand even at the world liquidity trap. Even if consumption and terms of trade achieve the first-best outcome under strict PPI targeting monetary policy, optimal monetary policy—which still needs to address input-demand inefficiency—can be either expansionary or contractionary relative to a strict PPI targeting rule, depending on input shares.

Keywords: Tariffs, roundabout production, monetary policy

*Department of Economics, UC Davis (ximeng@ucdavis.edu). The opinions expressed in this paper are solely those of the author and do not necessarily reflect the viewpoints of any other organization. Any errors in the content are the sole responsibility of the author. I am grateful to Paul Bergin and Kathryn Russ for their invaluable support and feedback. I also thank participants of the UC Davis Macroeconomics Lunchtime Talk for providing insightful comments and suggestions.

1. Introduction

Protectionism has re-emerged repeatedly since the very beginning of global trade. Even though countries impose import tariffs with different objectives, stimulating domestic demand has been one of them. Could tariffs ever stimulate demand in the short run, and how could this happen? While Neoclassical trade models on long-term effects generally say no, model-based analyses on tariffs in a sticky-price environment have mainly focused on *output*. This paper answers this question within a general class of open-economy New Keynesian models and shows that the short-run impact of tariffs on domestic demand—a key determinant of welfare—depends on the degree of monetary policy accommodation to domestic producer price inflation.

Tariffs reduce consumption in a complete-market small open economy model with inputs under flexible prices and a Taylor-rule type monetary policy targeting PPI. These results hold regardless of the model parameters. The relative values of trade elasticity and the IES determine the response of output. As monetary policy becomes more accommodating to producer price inflation, consumption could, in principle, rise in response to tariffs. Under commonly calibrated values, an accommodating monetary policy—such as one that is inactive at the zero interest rate lower bound or passive when fiscal policy determines the price level—may increase domestic consumption.

This response of demand is a combination of supply- and demand-side effects. A higher *level* of tariffs creates (expected) inflation by depressing domestic producer prices and hence lowering markups. The expectation of ending tariffs directly increases the consumption-based real interest rate as households postpone consumption in anticipation of lower future tariffs. Inputs in production flatten the Phillips curve, allowing tariffs to generate more inflation. While having inputs does not change any qualitative effects of tariffs on demand, inputs play a crucial role in determining the impact of tariffs on global aggregate demand. Without inputs in production, even if the world economy faces the zero lower interest rate bound, making monetary policy ineffective, tariffs remain a force that depresses global demand, even though they generate inflation.

Inputs also have a direct implication for the optimal monetary policy response to tariff shocks. Even though the flexible-price competitive equilibrium has consumption and terms of trade responses identical to those in the first best, firms do not internalize the choice of inputs in production within the country's budget constraint, which creates an input-demand inefficiency. In other words, the competitive equilibrium does not operate at the production frontier like the frictionless first best. Tariff shocks enlarge the gap between the production frontiers. I illustrate this point by analyzing the optimal monetary policy response to tariff shocks under unitary trade elasticity and the intertemporal elasticity of substitution (IES). Monetary policy strictly targeting producer price inflation completely eliminates the wedges of consumption and terms of trade. However, monetary policy faces a trade-off between stabilizing the terms of trade and mitigating input-demand inefficiency. Depending on the share of inputs used in production, the terms of trade wedge may rise or fall, even though tariffs under the optimal monetary policy are always inflationary. Moreover, consumption under the optimal monetary policy may be higher or lower than under strict PPI targeting.

This paper contributes to recent works on the positive and normative analyses of short-run effects of trade policy. On the positive side, the central question this paper focuses on is the response of consumption to tariff shocks. This complements recent works analyzing output responses (Monacelli, 2025; Kalemli-Ozcan et al., 2025). It also contributes to understanding the role of inputs in analyzing short-run effects of trade policy (Bergin and Corsetti, 2023; Auray et al., 2024; Bianchi and Coulibaly, 2025). The paper contributes to these studies by showing how inputs shape the positive effects of tariffs on global demand in a global liquidity trap, in contrast to predominantly negative effects in existing studies (Jeanne, 2021; Barattieri et al., 2021; Auray et al., 2024). This paper also argues that inputs create an inefficiency in the competitive equilibrium, such that the optimal monetary response to tariffs can be either expansionary or recessionary compared to the benchmark of strict PPI targeting—similar to results for large countries by Bergin and Corsetti (2023) but in contrast to expansionary results by Bianchi and Coulibaly (2025) and Monacelli (2025).

This paper starts with a baseline model in Section 2, followed by a discussion of the propagation of tariffs under different monetary policy accommodations to inflation in Section 3. Section 4 shows two implications of inputs in analyzing tariffs, and Section 5 concludes. The online appendix describes the model environments in greater detail and includes derivations.

2. The propagation of tariffs under nominal frictions

2.1 Baseline model

This section lays out a small-open economy model with complete asset markets, inputs in production, and tariff shocks. Relative to the textbook treatment in Galí (2015), the last two elements are additional ingredients in this paper. Tariff shocks, the only shocks in the model, follow an AR(1) process. The exception is the addition of preference shocks and the consideration that both shocks follow a two-state process during the discussion of inactive monetary policy at the zero interest rate lower bound in Sections 3.3 and 4.1.

Demand Households maximize lifetime utility by choosing consumption C_t, labor supply N_t, and state-contingent assets D_t.

$$\max_{\{C_t,N_t,D_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \quad \text{s.t. } P_tC_t + \mathbb{E}_t(Q_{t,t+1}D_{t+1}) = D_t + W_tN_t + T_t + \Pi_t$$

The parameterized utility function is $U(C_t, N_t) = log(C_t) - \frac{N_t^{1+\varphi}}{1+\varphi}$ for a unitary IES $\sigma = 1$ and $U(C_t, N_t) = \frac{C^{1-\sigma}-1}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$ for $\sigma \neq 1$. When the inverse of the Frisch elasticity, φ, is zero, the model features a perfectly elastic labor supply.

Home-biased final consumption, C_t, consists of home $C_{H,}$ and foreign consumption goods $C_{F,t}$ bundled using a CES aggregator as $C_t = \left((1-\nu)^{\frac{1}{\eta}} C_{H,t}^{\frac{1-\eta}{\eta}} + \nu^{\frac{1}{\eta}} C_{F,t}^{\frac{1-\eta}{\eta}}\right)^{\frac{\eta}{\eta-1}}$, with the degree of home bias $\nu \in (0, 0.5)$ and trade elasticity $\eta > 0$[1]. Home consumption goods come from bundling differentiated varieties, $Y(i)_t$, produced at home, where the elasticity of substitution among varieties is ϵ, as $C_{H,t} = (\int Y(i)_t^{\frac{\epsilon-1}{\epsilon}} di)^{\frac{\epsilon}{\epsilon-1}}$. Home importers pay a uniform tariff τ_t on

[1]When $\eta = 1$, $C_t = C_{H,t}^{1-\nu} C_{F,t}^{\nu}$

foreign-produced consumption goods $C_{F,t}$ and inputs $X_{F,t}$. Tariff revenues T_t are transferred to households as lump-sum payments.

Households save in state-contingent bonds D_{t+1}. $Q_{t,t+1}$ is the stochastic discount factor for one-period-ahead nominal payoffs. From the households' optimal labor supply choice, $C_t^\sigma N_t^\varphi = \frac{W_t}{P_t}$, where W_t/P_t is the real wage. Given the consumption level in the rest of the world, C_t^*, the risk sharing condition under complete markets is

$$C_t = \zeta_{RS} C_t^* (\frac{\mathcal{E}_t P_t^*}{P_t})^{\frac{1}{\sigma}} = \zeta_{RS} C_t^* (\frac{P_{F,t}}{P_t})^{\frac{1}{\sigma}} \quad (1)$$

where ζ_{RS} depends on the initial holdings of assets. The nominal exchange rate is $\mathcal{E}_t$ (an increase in $\mathcal{E}_t$ means that the home currency depreciates). The second equality uses the Law of One Price, $\mathcal{E}_t P_t^* = P_{F,t}$, to express the real exchange rate, $\frac{\mathcal{E}_t P_t^*}{P_t}$, as (tariff-exclusive) import prices relative to domestic consumer prices, $\frac{P_{F,t}}{P_t}$.

Production Monopolistically competitive firms indexed by $i \in [0, 1]$ produce differentiated variety i and employ labor and use inputs $X(i)_t$ according to $Y(i)_t = N(i)_t^{1-\alpha} X(i)_t^\alpha$ with $0 \le \alpha \le 1$. These inputs are produced by combining home and foreign final output using the same aggregation function as consumption bundles. Therefore, the price of inputs is the same as that of final consumption goods. Firms also face Calvo-type nominal frictions. They reset their optimal prices with a probability $1 - \theta$ each period. Firm i's optimal labor demand is $W_t N_t(i) = (1 - \alpha) MC_t Y_t(i)$, and the optimal demand for inputs is $P_t X_t(i) = \alpha MC_t Y_t(i)$. The real marginal cost is given by $\frac{MC_t}{P_t} = \frac{(W_t/P_t)^{1-\alpha}}{\bar{\omega}}$, where $\bar{\omega} = \alpha^\alpha (1-\alpha)^{1-\alpha}$. After aggregating across factor demand and using the definition of the aggregate factor demand ($N_t = \int N(i)_t di$ and $X_t = \int X(i)_t di$) and the demand for differentiated good $Y(i)_t = (\frac{P_{H,t}(i)}{P_{H,t}})^{-\epsilon} Y_t$, factor demands become $W_t N_t = (1 - \alpha) MC_t Y_t d_t$ and $P_t X_t = \alpha MC_t Y_t d_t$, where the price dispersion $d_t = \int (\frac{P_{H,t}(i)}{P_{H,t}})^{-\epsilon} di$.

Market clearing and the steady state The goods market clearing condition is $Y_t = C_{H,t} + X_{H,t} + C_{F,t} + X_{F,t}$. Let the tariff-exclusive terms of trade be the relative prices of home-produced consumption goods to foreign-produced consumption goods, $S_t = P_{H,t}/P_{F,t}$. Throughout the paper, I focus on a zero-inflation non-stochastic steady state. I assume that countries are symmetric in the steady state and that a subsidy is applied to eliminate the markup. Moreover, tariffs are zero in the steady state.

Log-linearized model Let variables in lower cases denote deviations from the non-stochastic steady state. The log-linearized labor supply condition is

$$\sigma c_t + \varphi n_t = w_t = \frac{mc_t}{1-\alpha} \tag{2}$$

where w_t is the real wage and mc_t is the real marginal cost. The log-linearized labor demand from the production-side is $n_t = y_t - \alpha w_t$. Labor demand can be expressed in terms of output and domestic demand using the definition of the real wage in equation (2).

$$(1+\varphi\alpha)n_t = y_t - \alpha\sigma c_t \tag{3}$$

The CES aggregator implies the price index $(1-\nu)p_{H,t} = -\nu(p_{F,t} + \tau_t)$. τ_t is the tariff imposed by the home country on foreign goods. $p_{H,t}$ is the log of the domestic producer price relative to the consumer price, $\frac{P_{H,t}}{P_t}$, and $p_{F,t}$ is the log of the tariff-exclusive price of imported goods in local currency relative to consumer price, $\frac{P_{F,t}}{P_t}$. Domestic producer prices can be expressed in relation to the terms of trade and tariffs.

$$p_{H,t} = \nu s_t - \nu\tau_t \tag{4}$$

The log-linearized risk-sharing condition expressed using the terms of trade is

$$\sigma c_t = -(1-\nu)s_t - \nu\tau_t \tag{5}$$

The two expressions above provide insight into the difference between the propagation of terms of trade and tariff shocks on the demand side. Negative terms of trade and positive tariff shocks have identical direct effects on domestic producer prices. However, the risk sharing condition in equation (5) indicates that the two shocks have opposite direct effects on consumption.

Moreover, applying the definitions of producer price and consumer price inflation yields their relationships.

$$\pi_{H,t} = \pi_t - \Delta p_{H,t} = \pi_t - (\nu \Delta s_t - \nu \Delta \tau_t) \tag{6}$$

The log-linearized households' Euler equation is

$$c_t = \mathbb{E}_t(c_{t+1}) - \frac{1}{\sigma}(i_t - \mathbb{E}_t(\pi_{t+1})) \tag{7}$$

After combining households' labor supply and marginal cost, the log-linearized goods market clearing condition is

$$\kappa_y y_t = -\kappa_s s_t + \kappa_c c_t + \kappa_\tau \tau_t \tag{8}$$

where $\kappa_y = 1 - (1-\nu)\alpha \frac{1+\varphi}{1+\alpha\varphi}$, $\kappa_s = \eta\nu(2-\nu)$, $\kappa_\tau = \eta\nu(1-\nu)$ and $\kappa_c = (1-\nu)(1-\alpha) + \frac{(1-\nu)\alpha(1-\alpha)\sigma}{1+\alpha\varphi}$. Finally, the Phillips curve is

$$\pi_{H,t} = \beta \mathbb{E}_t(\pi_{H,t+1}) + \lambda(mc_t - p_{H,t}) \tag{9}$$

The log-linearized competitive equilibrium consists of prices $\{mc_t, s_t, p_{H,t}, \pi_t, \pi_{H,t}\}$ and quantities $\{c_t, n_t, y_t\}$. Given the nominal interest rate i_t and tariffs τ_t, equations (2)-(9) characterize the equilibrium.

From the definition of the price index and the expression for tariff revenues, $T_t = \tau_t P_{F,t}(C_{F,t} + X_{F,t})$, the households' budget constraint yields the balance of payment equation and trade balances defined below.

$$\frac{NX_t}{P_t} = \frac{P_{H,t}}{P_t}(X^*_{H,t} + C^*_{H,t}) - \frac{P_{F,t}}{P_t}(C_{F,t} + X_{F,t})$$

The first-order approximation of trade balance, normalized by steady-state output, is

$$nx_t = \nu(1 - 2\eta + \nu\eta)s_t + \eta\nu(1-\nu)\tau_t - \nu(1-\alpha)c_t - \nu\alpha x_t \tag{10}$$

where $x_t = \frac{1+\varphi}{1+\alpha\varphi} y_t + \frac{(1-\alpha)\sigma}{1+\alpha\varphi} c_t$.

2.2 Tariffs in a Neoclassical model

The competitive equilibrium in the Neoclassical model consists of prices $\{p_{H,t}, mc_t, s_t\}$ and quantities $\{c_t, n_t, y_t\}$. Given the process for tariffs τ_t, equations (2), (3), (8), (5), (4), and firms' optimal pricing $p_{H,t} = mc_t$ jointly characterize the equilibrium.

Substituting equations (2), (3), and (4) into firms' optimal pricing yields a relationship between consumption, output, terms of trade and tariff: $\frac{(1-\alpha)\sigma}{1+\alpha\varphi} c_t + \frac{(1-\alpha)\varphi}{1+\alpha\varphi} y_t - \nu s_t + \nu \tau_t = 0$. Further substituting out y_t and s_t using the risk sharing (equation (5)) and the market clearing (equation (8)) yields the equilibrium effects of tariffs on consumption: $\frac{dc_t}{d\tau_t} < 0$. Tariffs depress consumption. The reason for this is that domestic producer prices (relative to consumer prices) fall. In a competitive factor market, firms demand less labor, so the wage rate falls. Labor supply optimality implies that consumption falls in response to reduced income.

Output response under no inputs The response of output is ambiguous. To illustrate this, I consider the baseline model without inputs in production by setting $\alpha = 0$. The response of output depends on trade elasticity and the IES.

$$y_t = \Phi \times (\eta - \frac{1}{\sigma})\tau_t, \quad \Phi = \frac{\nu(1-\nu)}{1 + \varphi(\eta\nu(2-\nu) + \frac{(1-\nu)^2}{\sigma})} \tag{11}$$

The response of output to tariffs depends on changes in expenditure levels and the reallocation of consumption between home and foreign goods driven by the terms of trade, the so-called expenditure switching effect. When the trade elasticity is greater than the IES, the expenditure switching effect dominates, and output rises.

The trade balance is $nx_t = \nu(1 - 2\eta + \nu\eta)s_t - \nu c_t + \eta\nu(1-\nu)\tau_t$, and trade balances rise in equilibrium. Similar to the ambiguous response of output, terms of trade fall under a high trade elasticity. The terms of trade have a directly negative impact on the trade balance, as higher domestic price discourages exports. However, lower import quantities caused by falling domestic consumption levels are the dominant force.

Output response under perfectly elastic labor supply I illustrate the role of inputs under perfectly elastic labor supply, $\varphi = 0$. The optimal labor supply choice $(1-\alpha)\sigma c_t = \nu s_t - \nu \tau_t$ and the risk sharing condition (equation (5)) pin down the equilibrium. $c_t = -\frac{\nu}{\sigma(1-(1-\nu)\alpha)}\tau_t$ and $s_t = \frac{\nu\alpha}{(1-(1-\nu)\alpha)}\tau_t$. Without inputs, the terms of trade do not respond to tariffs. With inputs, the terms of trade improve. The output response is

$$y_t = \frac{\nu}{(1-(1-\nu)\alpha)^2}\left[(1-\nu-\alpha)\eta - (1-\alpha)(1-\nu)(\frac{1}{\sigma}+\alpha)\right]\tau_t \tag{12}$$

2.3 The implication of market incompleteness

The Neoclassical model so far assumes perfect risk sharing. This section shows that considering market incompleteness breaks the stark result of falling consumption, but under unrealistic parameters. I further assume no intermediate goods in production and a perfectly elastic labor supply ($\alpha = \varphi = 0$). Moreover, the international financial market is fully segmented and a risk-averse financial intermediary domiciled outside the home country arbitrages local-currency bonds issued by the small-open economy and the rest of the world. The setup is identical to Itskhoki and Mukhin (2023), except that there are no noisy traders. Having a risk-averse arbitrageur ensures stationarity. The following three equations summarize the equilibrium.

$$\sigma c_t = \nu s_t - \nu \tau_t \tag{13}$$

$$b_t^* - \frac{1}{\beta}b_{t-1}^* = \underbrace{\frac{1}{\beta}\left(\nu(1-2\eta+\nu\eta) - \frac{\nu^2}{\sigma}\right)}_{\hat{\kappa}_s} s_t + \underbrace{\frac{1}{\beta}\left(\frac{\nu^2}{\sigma} + \eta\nu(1-\nu)\right)}_{\hat{\kappa}_\tau}\tau_t \tag{14}$$

$$\mathbb{E}_t\left(\sigma\Delta c_{t+1} + (1-\nu)\Delta s_{t+1} + \nu\Delta\tau_{t+1}\right) = -\omega b_t^* \tag{15}$$

where b_t^* is the home country's net foreign asset position, and ω summarizes both the risk aversion parameter of the financial intermediary engaged in carry trade and the volatility of the exchange rate. ω is the product of $\breve{\omega}\sigma_t^2$, where $\sigma_t^2 = \text{var}_t(\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}})$, using the fact that the equilibrium value of σ_t^2 is well-defined. $\breve{\omega}$ is the risk aversion. This log-linearized version of the risk sharing is identical to the one derived from portfolio adjustment cost when steady-state bond holding is zero.

Combining the real marginal cost (equation (2)) and firms' optimal pricing $p_{H,t} = mc_t$ yields equation (13). Equation (14) is the first-order approximation of the balance of payments, and equation (15) is the risk sharing condition. The equilibrium terms of trade s_t follow an ARMA(2,1) process:

$$s_t = (\rho + \mu_{in,1})s_{t-1} - \rho\mu_{in,1}s_{t-2} + \hat{\chi}_1\epsilon_{\tau,t} - \hat{\chi}_1\mu_{in,1}\rho\epsilon_{\tau,t-1} \tag{16}$$

where $0 < \mu_{in,1} = \frac{1}{2}[(1 - \omega\hat{\kappa}_s + \frac{1}{\beta}) - \sqrt{(1 - \omega\hat{\kappa}_s + \frac{1}{\beta})^2 - \frac{4}{\beta}}] \leq 1$, provided that $\omega \geq 0$ and $\hat{\kappa}_s < 0$, with the equality at $\omega = 0$. ρ is the autoregressive coefficient of tariffs τ_t, $\epsilon_{\tau,t}$ is the tariff shock, and $\hat{\chi}_1 = -\frac{\hat{\kappa}_\tau}{\hat{\kappa}_s}\frac{1-\beta\mu_{in,1}}{1-\beta\mu_{in,1}\rho}$. The response of consumption on impact of the shock depends on the sign of $\hat{\chi}_1 - 1$, which can be re-written as the difference between two terms.

$$\sigma(1-\eta) - (\nu + \eta\sigma(1-\nu))\frac{\beta\mu_{in,1}(1-\rho)}{1-\beta\mu_{in,1}\rho} \tag{17}$$

Since the second term is strictly positive and the first term is negative when $\eta > 1$, consumption falls as in the previous complete market model. When $\eta < 1$, consumption may rise. For example, for $\eta = 0.9$, $\nu = 0.4$, $\beta = 0.99$ and a large IES $\sigma = 0.5$, $\mu_{in,1} = 1$ as ω approaches zero, the sign of the above expression is positive when tariff shocks are persistent enough, for example $\rho = 0.9$.

The bond holdings can be written as

$$b_t^* = \mu_{in,1}b_{t-1}^* + \underbrace{\left(\frac{\hat{\kappa}_\tau}{1-\beta\mu_{in,1}\rho}\beta\mu_{in,1}(1-\rho)\right)}_{>0}\tau_t \tag{18}$$

The impact effect of tariffs on trade balance is positive as long as the restriction of the parameters satisfying $\hat{\kappa}_s < 0$, even though consumption may fall. The reason is that $\hat{\chi}_1 < 0$ given that $\hat{\kappa}_s < 0$, and the terms of trade in equation (16) are depressed upon the impact of tariffs.

2.4 Tariffs under a PPI-targeting monetary policy rule

Tariffs in the baseline complete-market Neoclassical model reduce consumption. This section shows that this result carries over in the presence of nominal frictions and an interest rate rule targeting PPI. PPI targeting is often found to be close to the optimal monetary policy in an open economy. The nominal interest rate i_t is expressed as the deviation from the real interest rate, $r^n = -log(\beta)$, in the zero-inflation steady state. Under PPI targeting, $i_t = \max(-r^n, \phi_\pi \pi_{H,t})$, that is the nominal interest rate is non-negative. I illustrate the propagation first under a perfectly elastic labor supply before turning to the generalized case.

A special case: perfectly elastic labor supply The log-linearized model around the steady state can be summarized by the open-economy New Keynesian Phillips curve, the IS curve, and a monetary policy rule targeting domestic producer price inflation. Given exogenous tariffs τ_t, equations 19-21 define the equilibrium dynamics of consumption c_t, producer price inflation $\pi_{H,t}$, and the nominal interest rate i_t. Once consumption is pinned down, equation (8) determines the response of output. Given the main focus on consumption, the IS curve is expressed using consumption instead of output.

$$\pi_{H,t} = \beta \mathbb{E}_t(\pi_{H,t+1}) + \lambda \left(\sigma(\frac{1}{1-\nu} - \alpha)c_t + \frac{\nu}{1-\nu}\tau_t \right) \tag{19}$$

$$c_t = \mathbb{E}_t(c_{t+1}) - \frac{1-\nu}{\sigma}\big(i_t - \mathbb{E}_t(\pi_{H,t+1}) - \frac{\nu}{1-\nu}\mathbb{E}_t(\Delta\tau_{t+1})\big) \tag{20}$$

$$i_t = \max\{-r^n, \phi_\pi \pi_{H,t}\} \tag{21}$$

where λ comes from Calvo sticky prices and governs the slope of the Phillips curve. ϕ_π governs the response of monetary policy to domestic producer price inflation.

Two competing forces generated by tariff shocks influence inflation through the New Keynesian

Phillips and IS curves. Unlike many shocks that affect only the supply side or only the demand side, the current tariff level enters the New Keynesian Phillips curve (equation (19)), whereas expected tariffs enter the IS curve (equation (20)).

On the demand side, tariffs are expected to return to a lower value in the steady state. This expectation lowers expected consumer price inflation and thereby raises the consumption-based natural real interest rate, which depresses current consumption.

On the supply side, tariffs directly raise inflation. When firms adjust prices infrequently and anticipate gradually lower domestic producer prices as other firms adjust prices, they undershoot when cutting prices. This compresses the firms' markups, thus generating inflation because producer price inflation moves inversely with markups.

In general equilibrium, tariffs generate inflation, despite the decline in consumption. Domestic producer price inflation is

$$\frac{d\pi_{H,t}}{d\tau_t} = \frac{\nu\lambda(1-\rho)\alpha}{\mathcal{M}}, \text{ where } \mathcal{M} = (1-\beta\rho)(1-\rho) + \lambda(\phi_\pi - \rho)(1-\alpha(1-\nu)) > 0$$

Tariffs necessarily increase the real interest rate and depress consumption on the demand side, and the extent to which this generates deflation depends on the slope of the Phillips curve. The Phillips curve is flattened as the share of inputs in production increases.

The response of consumption to tariffs in general equilibrium is

$$\frac{dc_t}{d\tau_t} = -\frac{\nu\sigma^{-1}}{\mathcal{M}}\left\{\lambda(\phi_\pi - \rho) + (1-\rho)(1-\beta\rho)\right\} < 0 \tag{22}$$

Tariffs always depress consumption as $\phi_\pi > 1$ is required for a stable equilibrium.

The direct response of consumption to anticipated lower tariffs is the dominant force and is independent of household inter-temporal consumption motives (i.e. σ does not affect the sign of the response of consumption to tariffs). This result occurs because any small IES would imply a small direct response of current consumption on the demand side, but a small IES also implies a large substitution between consumption and labor supply, which leads to a steeper Phillips curve and larger expected deflation from tariffs. In general equilibrium, the supply- and demand-side effects from household intertemporal consumption smoothing motives cancel out. Therefore, σ does not affect the sign of equation 22.

Moreover, monetary policy responds to domestic producer price inflation, reducing expected inflation from tariffs and further amplifying the negative effects of tariffs on consumption. Due to the simplifying assumption of perfectly elastic labor supply, the impact of tariffs on output depends on aggregate consumption, the expenditure switching effect from terms of trade, and the direct response of tariffs, as shown by

$$\begin{aligned} y_t &= \frac{1}{1-(1-\nu)\alpha}\left[(1-\nu)(1-\alpha)(1+\alpha\sigma)c_t - \nu\eta(2-\nu)s_t + \nu\eta(1-\nu)\tau_t\right] \\ &= \frac{1}{1-(1-\nu)\alpha}\left[((1-\nu)(1-\alpha)(1+\sigma\alpha) + \frac{\eta\nu(2-\nu)\sigma}{1-\nu})c_t + \frac{\nu\eta}{1-\nu}\tau_t\right] \end{aligned}$$

Tariffs improve the terms of trade, and hence the expenditure switching effect directly from tariffs is the only source of rising output.

Depressed consumption under PPI-targeting generalized With an upward-sloping labor supply for $\varphi > 0$, the Phillips curve can be written as

$$\pi_{H,t} = \beta\mathbb{E}_t(\pi_{H,t+1}) + \lambda_c c_t + \lambda_\tau \tau_t \tag{23}$$

where $\lambda_\tau > 0$ and $\lambda_c > 0$. The response of consumption is then given by

$$\frac{dc_t}{d\tau_t} = -\frac{(1-\beta\rho)(1-\rho)\frac{\nu}{\sigma} + \frac{1-\nu}{\sigma}(\phi_\pi - \rho)\lambda_\tau}{(1-\beta\rho)(1-\rho) + \frac{1-\nu}{\sigma}(\phi_\pi - \rho)\lambda_c} < 0 \tag{24}$$

The above results of depressed consumption can be generalized for monetary policy rules targeting domestic output along with targeting PPI. Proposition 1 below summarizes the result.

Proposition 1 *Tariffs depress consumption in the baseline model for flexible PPI-targeting rules, $i_t = \max(-r^n, \phi_\pi\pi_{H,t} + \phi_y y_t)$ for $\phi_y > 0$ and $\phi_\pi > 1$ (See Appendix A.1.2 for the proof).*

In sum, whenever monetary policy targets PPI[2], the inflationary effects directly from tariffs and hence the rising nominal interest rate dominate any countervailing channels, increasing the real interest rate, and further reducing consumption.

3. Alternative monetary policy rules and demand-stimulating tariffs

Previous results show that tariffs increase the equilibrium consumption-based real interest rate and depress consumption when the monetary policy rule targets producer price inflation. This section shows that tariffs may stimulate demand under alternative monetary policy rules: CPI targeting, passive monetary policy under the fiscal theory of the price level, and inactive monetary policy—for example, at the zero interest rate lower bound. Throughout this section, the slope of the labor supply curve does not influence the argument of demand-stimulating tariffs qualitatively. Therefore, to simplify the exposition and focusing on the mechanism, I assume perfectly elastic labor supply, $\varphi = 0$.

3.1 Alternative inflation target

When consumer price inflation enters a Taylor-rule type monetary policy, using the relationship between consumer price and producer price inflation in equation 6, the IS curve becomes

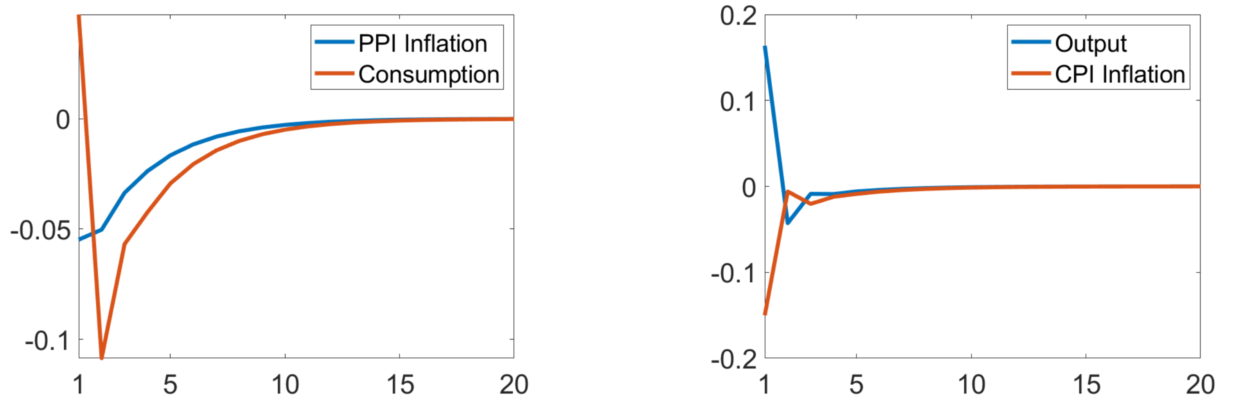
$$\mathbb{E}_t(c_{t+1})+\frac{1-\nu}{\sigma}\mathbb{E}_t(\pi_{H,t+1})+(\frac{\nu\phi_\pi}{\sigma}-\frac{\nu}{\sigma}(1-\rho))\tau_t = \frac{1-\nu}{\sigma}\phi_\pi\pi_{H,t}+(1-\nu\phi_\pi)c_t+\nu\phi_\pi c_{t-1}+\frac{\phi_\pi\nu}{\sigma}\tau_{t-1}$$

Combined with the Phillips curve in equation (9), the unique stationary equilibrium can be solved numerically using the Blanchard-Khan method. I illustrate the possibility of rising consumption by assigning parameters within reasonable calibrations. The impulse response of consumption in

[2] Under strict PPI targeting, consumption falls. Setting $\pi_{H,t} = \mathbb{E}_t(\pi_{H,t}) = 0$ in equation (23) implies $c_t = -\frac{\lambda_\tau}{\lambda_c}\tau_t < 0$.

Figure 1 to persistent tariff shocks shows an increase in consumption on impact.

Figure 1: Impulse response to tariff shocks under CPI-targeting monetary policy



(a) (b)

Notes: This figure illustrates the possibility that home tariffs can increase consumption. The baseline key parameters are $\beta = 0.99$, $\varphi = \alpha = 0$, $\nu = 0.1$, $\sigma = \eta = 1$. In addition, $\phi_\pi = 1.5$ $\rho = 0.7$ $\lambda = 0.0858$.

This rising consumption does not generally occur under strict CPI targeting. From $\mathbb{E}_t(\pi_{t+1}) = \mathbb{E}_t(\pi_{H,t+1}) + \nu\mathbb{E}_t(\Delta s_{t+1} - \Delta\tau_{t+1})$ implied by equation (6), the Phillips curve can be written as

$$\frac{\beta\mathbb{E}_t(\pi_{t+1}) - \pi_t}{\beta\nu\sigma(1-\nu)^{-1}} + c_{t+1} = \underbrace{\frac{\nu\beta + \nu - \lambda(1-\alpha(1-\nu))}{\nu\beta}}_{B_{11}} c_t - \frac{1}{\beta}c_{t-1} + \frac{1-\lambda+\beta(1-\rho)}{\beta\sigma}\tau_t - \frac{1}{\beta\sigma}\tau_{t-1}$$

After setting $\pi_t = \mathbb{E}_t(\pi_{t+1}) = 0$ implied by strict CPI targeting and denoting $m_t = c_{t-1}$, the Phillips curve in state-space form is $\mathbb{E}_t\left(\begin{smallmatrix} c_{t+1} \\ m_{t+1} \end{smallmatrix}\right) = \begin{pmatrix} B_{11} & -\frac{1}{\beta} \\ 1 & 0 \end{pmatrix}\left(\begin{smallmatrix} c_t \\ m_t \end{smallmatrix}\right) +$ other terms. A unique stationary solution for consumption requires that one of the two eigenvalues $\mu_{cpi} = \frac{1}{2}[B_{11} \pm \sqrt{B_{11}^2 - \frac{4}{\beta}}]$ lie outside the unit circle. Standard parameter values imply $B_{11}^2 - \frac{4}{\beta} < 0$—the two eigenvalues are complex conjugates and lie either both inside or both outside the unit circle. However, unrealistically low trade openness can produce a unique solution. In that case, the impact effect of tariff shocks is

$$c_0 = \mu_{cpi,1}c_{-1} - \tau_0\frac{\mu_{cpi,1}}{\sigma(1-\beta\rho\mu_{cpi,1})}(1+\beta(1-\rho) - \lambda - \beta\mu_{cpi,1}) \tag{25}$$

For example, for $\nu = 0.02$, $\beta = 0.99$, $\sigma = 1$, $\lambda = 0.0858$, and $\alpha = 0$, I obtain $\mu_{cpi,1} = \frac{1}{2}[B_{11} + \sqrt{B_{11}^2 - \frac{4}{\beta}}] = -0.048$, and hence consumption $c_0 > 0$.

3.2 Passive monetary policy under the fiscal theory of the price level

The previous results highlight that the effect of trade policy on domestic demand depends on how monetary policy accommodates inflation. This section analyzes the case of price determination under fiscal policy rules and a passive monetary policy regime. In addition to the small open-economy complete market setup with $\alpha = 0$, the government's lump-sum taxes $\mathcal{T}_t^G$ levied on households follow the rule

$$\frac{\widetilde{\mathcal{T}}_t^G}{\widetilde{\mathcal{T}}^G} = \left(\frac{D_{t-1}^G}{D^G}\right)^{\gamma_d}$$

where the "real value" of taxes is normalized by the domestic producer price level, $\widetilde{\mathcal{T}}_t^G = \frac{\mathcal{T}_t^G}{P_{H,t}/P_t}$, and the outstanding debt D_t^G is the debt payment B_t^G normalized by the domestic producer price level $P_{H,t}/P_t$. The government faces the budget constraint

$$\frac{B_t^G}{R_t} + \mathcal{T}_t^G = B_{t-1}^G$$

Equilibrium inflation and consumption depend on the debt process implied by the first-order approximation of the government budget constraint.

$$d_t^G = \frac{1-(1-\beta)\gamma_d}{\beta} d_{t-1}^G + (\phi_\pi - \frac{1}{\beta})\pi_{H,t} \tag{26}$$

Since there are two forward-looking variables ($\pi_{H,t}$ and c_t) and one predetermined variable, a unique equilibrium of passive monetary policy requires $0 < \gamma_d < 1$ and $0 < \phi_\pi < 1$. I make a parametric assumption that the slope of the Phillips curve and discount factor such that $\lambda + \beta > 1$. Normal calibrations always satisfy this assumption.

Proposition 2 *When $\lambda + \beta > 1$, consumption rises in the initial response to tariff shocks, $\frac{dc_0}{d\tau_0} > 0$ (See Appendix Section A.2 for the proof).*

The intuition behind this is the real fiscal balance is a state variable implied by the fiscal policy rule, and the stability of the forward looking producer price inflation and consumption requires either the fiscal policy or the monetary policy have large reaction to tariff shocks. In a passive monetary policy regime, equation (26) shows that the real value of debt has an auto-regressive coefficient greater than 1, ensuring stability. Moreover, the expected lower tariff rate reducing the real interest rate is the dominant channel under the passive monetary policy.

Another special case where monetary policy is passive is the strict currency peg— monetary policy adjusts inflation to maintain $e_t = 0$. From the law of one price, $e_t = -s_t - p_{H,t} = 0$. From the risk sharing condition, $c_t = 0$ under peg, implying $s_t > 0$ and $y_t > 0$. Therefore, under a currency peg, tariffs do not affect consumption but improve output. Under this strict peg, from $e_t = p_{H,t} - s_t$, tariffs do not affect consumption ($c_t = 0$).

3.3 Inactive monetary policy at the zero lower bound

This section examines the case in which the nominal interest rate in the economy is fixed regardless of trade policy. This occurs when the economy experiences a large negative preference shock, such that the monetary authority lowers the nominal interest rate but is constrained by the zero interest rate lower bound. With the preference shock Z_t, the modified preference is given by $\mathrm{Z}_t U(C_t, N_t)$, where Z_t equals one in the non-stochastic steady-state.

I adopt the two-state approach used by Woodford (2011) to study the fiscal spending multiplier under the zero lower bound. The one-time preference shock, $\mathrm{Z}_t = \mathrm{Z}_L$ remains in place once hit and with a probability $1-\rho$ of returning to the steady-state value. The economy is anticipated to escape the zero lower bound with a probability $1-\rho > 0$ when the preference shock disappears. Whenever the economy is under the zero lower bound (i.e. when $i_t = -r^n$), tariffs τ_L are imposed. I assume that tariffs do not lift the economy out of the constrained monetary regime. Once monetary policy is no longer constrained, tariffs return to zero. Denote $\zeta_L = log(\mathrm{Z}_L)$. After setting $i = -r^n$ and applying the method of undetermined coefficients to equations (20) and (19), adjusted for preference shocks, the equilibrium response of consumption is

$$c_L = -\frac{\nu}{\sigma}\frac{(1-\beta\rho)(1-\rho)-\lambda\rho}{\mathcal{N}}\tau_L - \frac{(1-\nu)(1-\beta\rho)}{\mathcal{N}}(-r^n - (1-\rho)(1+\nu)\zeta_L) \tag{27}$$

The stability condition requires that $\mathcal{N} = (1-\beta\rho)(1-\rho) - \lambda\rho(1-\alpha(1-\nu)) > 0$. There is an upper bound $\bar{\rho} < 1$ such that the stability condition requires $\rho < \bar{\rho}$. In addition, there exists a value of ρ such that consumption rises because the term in the denominator $1-\alpha(1-\nu)$, is less than 1 and the numerator becomes negative as ρ approaches $\bar{\rho}$.

Tariffs increase consumption by directly generating expected inflation and lowering the natural real interest rate in equilibrium. Since monetary policy is inactive, a high probability of tariffs remaining in place is required to generate enough expected inflation to offset the negative effects of anticipated future lower tariffs (expected deflation).

Although consumption no longer responds to tariffs when the input share approaches zero under a perfectly elastic labor supply, the input share is not a determinant of the stimulus effect of tariffs here. To see this, I consider no inputs and an unitary Frisch labor supply elasticity ($\alpha = 0$ and $\varphi = 1$). Assume that the zero interest rate lower bound still binds with tariffs, the consumption response to tariffs is

$$\frac{dc_L}{d\tau_L} = -\frac{\nu}{\sigma}\frac{(1-\rho)(1-\beta\rho) - \frac{1-\nu}{\sigma}\lambda\rho\chi_{L,2}}{(1-\rho)(1-\beta\rho) - \frac{1-\nu}{\sigma}\lambda\rho\chi_{L,1}}$$

where $\chi_{L,1} = \sigma + 1 - \nu + \frac{\sigma\nu}{1-\nu}(1+\eta(2-\nu))$ and $\chi_{L,2} = \frac{\nu}{1-\nu}(\eta+1)$. Consumption may rise when $\chi_{L,2} > \chi_{L,1}$, which requires $\nu\eta(1-\sigma(2-\nu)) > (1-\nu)^2 + \sigma - \nu$. This is only possible when $\sigma < 1$, for example $\sigma = 0.5$, $\nu = 0.4$, and $\eta > 5.75$.

4. Inputs in production and the propagation of trade policy

Previous sections show that inputs in production amplify the inflationary effect of tariffs by flattening the slope of the Phillips curve in equation (19). Inputs do not change the key qualitative argument that tariffs stimulate demand depending on monetary policy accommodation to producer price inflation in small open economies. This section shows two central roles of inputs in analyzing the impact of tariffs on global demand and the optimal monetary policy in response to tariff shocks.

4.1 Inputs: a necessary condition for stimulus

Macroeconomic policies generating inflation are often expansionary when monetary policy is inactive, for example due to the zero interest rate lower bound. Regardless of the intensity of inputs in production, tariffs potentially stimulate demand at the zero lower bound for small open economies. This section shows that having inputs in production is a necessary condition for the demand-stimulating effects when central banks around the world are constrained by the zero lower bound.

I extend the complete-market small open economy model with preference shocks in Section 3.3 to a two-country model. I assume the two countries are symmetric and both impose tariffs on imports. The previous small-open economy can be viewed as one of these large countries except that it faces an exogenous export demand. The superscript W denotes variables in the world aggregate.

In a Neoclassical two-country model, the world's labor market and goods market clearing conditions pin down world aggregate consumption c_t^W and output y_t^W: $y_t^W = (1 + \varphi\alpha + \sigma\alpha)c_t^W$ and $c_t^W = -\frac{\nu}{(1-\alpha)(\sigma+\varphi)}\tau_t^W$. An increase in world tariffs reduces global consumption (output) due to lower producer prices relative to consumer prices and hence lower real wages. This result is identical to the small open economy case analyzed above.

With nominal frictions and a monetary policy rule targeting PPI, the world's Phillips curve and the IS curve, along with a monetary policy rule, $i_t^W = \max\{-r^W, \phi_\pi \pi_t^W\}$ with $i_t^W = i_t + i_t^*$, $r^W = 2r^n$ and $\pi_t^W = \pi_{H,t} + \pi_{F,t}^*$, characterize the equilibrium.

$$\pi_t^W = \beta \mathbb{E}_t(\pi_{t+1}^W) + \lambda((\sigma + \varphi)(1 - \alpha)c_t^W + \nu\tau_t^W)$$

$$c_t^W = \mathbb{E}_t(c_{t+1}^W) - \frac{1}{\sigma}(i_t^W - \mathbb{E}_t(\pi_{t+1}^W) - \nu(\rho-1)\tau_t^W))$$

Similar to the small open economy case, tariff shocks enter both the New Keynesian Phillips curve and the IS curve. Tariffs increase current and expected producer price inflation worldwide, and hence exert downward pressure on the natural real interest rate, boosting current consumption. However, monetary policy reacts to a rise in current inflation under flexible-PPI targeting, offsetting the expansionary effect of tariffs. Moreover, any trade policy that elicits an expectation of lower future tariffs increases the natural real interest rate and depresses current consumption. In equilibrium, tariffs reduce global consumption, as in $\frac{dc_t^W}{d\tau_t^W} = -\nu\sigma^{-1}\frac{(1-\rho)(1-\beta\rho)+\lambda(\phi_\pi-\rho)}{\mathcal{M}^W} < 0$, where $\mathcal{M}^W = (1-\rho)(1-\beta\rho) + \lambda(\phi_\pi - \rho)\frac{(\sigma+\varphi)(1-\alpha)}{\sigma}$. However, tariffs may or may not create producer price inflation in equilibrium, $\frac{d\pi_t^W}{d\tau_t^W} = (\frac{\alpha}{1-\alpha}\sigma - \varphi) \times \frac{(1-\rho)(1-\beta\rho)\frac{\lambda\nu(1-\alpha)}{\sigma}}{\mathcal{M}^W}$, as the sign of the key term $\frac{\alpha}{1-\alpha}\sigma - \varphi$ is ambiguous.

I extend the previous two-state model with preference shocks for the small-open economy to the two-country model. I consider that the nominal interest rate in the world economy is at the zero lower bound due to large preference shocks. The preference shock and tariffs are expected to reverse back to the steady state levels with a probability of $1-\rho$. Moreover, tariffs are small enough such that monetary policy around the world remains constrained. The effect of tariffs on global consumption is

$$\frac{dc_L^W}{d\tau_L^W} = -\frac{\nu}{\sigma} \times \frac{(1-\rho)(1-\beta\rho) - \lambda\rho}{(1-\rho)(1-\beta\rho) - \lambda\rho\frac{(\sigma+\varphi)(1-\alpha)}{\sigma}} \tag{28}$$

where the existence of a solution requires $(1-\rho)(1-\beta\rho) - \lambda\rho\frac{(\sigma+\varphi)(1-\alpha)}{\sigma} > 0$. There is an upper bound $\bar{\rho} < 1$ that satisfies this condition. The term $\lambda\rho\frac{(\sigma+\varphi)(1-\alpha)}{\sigma}$ governs expected inflation from tariffs, while the term $(1-\rho)(1-\beta\rho)$ governs expected deflation from anticipated lower tariffs once the economy returns to the steady state. Without intermediate inputs in production $\alpha = 0$, whenever the stability condition holds, the numerator $(1-\rho)(1-\beta\rho) - \lambda\rho$ is positive because $(1+\frac{\varphi}{\sigma}) > 1$ in the denominator. In other words, world demand *falls* when monetary policy in both countries is constrained by the zero lower bound.

With inputs in production ($\alpha > 0$), there exists $\rho < \bar{\rho}$ such that tariffs potentially raise global consumption and output. This occurs when ρ approaches $\bar{\rho}$ so that the stability condition holds while the numerator $(1-\rho)(1-\beta\rho) - \lambda\rho$ is negative because $\frac{(\sigma+\varphi)(1-\alpha)}{\sigma}$ in the denominator may be smaller than one. Households expect tariffs to be lower once preference shocks end, and anticipated lower future tariffs depress current consumption and generate expected deflation through the Phillips curve. However, when the Phillips curve is flat, expected deflation is small. Thus, tariffs increase global demand by reducing the world's real rate.

4.2 Input demand inefficiency and the optimal monetary policy response to tariff shocks

This section illustrates the implication of inputs in production on the Ramsey optimal monetary policy with commitment in response to tariff shocks. I build on the complete-market small-open economy model used in the previous positive analysis in Section 2.1. The key insight is that the optimal monetary policy may be contractionary or expansionary relative to the real natural interest rate depending on the share of inputs in production.

To clearly isolate the channels underlying this result, I restrict parameters to a perfectly elastic labor supply ($\varphi = 0$) and unitary trade elasticity and the IES ($\sigma = \eta = 1$). Under these parameters, the responses of consumption and the terms of trade to tariff shocks in the flex-price CE (competitive equilibrium) with appropriate subsidies coincide with the FB (first best). This implies that strict PPI targeting achieves efficient consumption in the presence of nominal frictions. Here, the consumption under strict PPI targeting is also consistent with the real natural interest rate. In other words, the key result is that consumption under the optimal monetary policy may be higher or lower than under strict PPI targeting.

Throughout the welfare analysis, I use $\sim$ to denote variables under the frictionless FB and $\wedge$ to denote the wedge between CE and FB. Lowercase letters represent log deviations from the non-stochastic steady state, as in the positive analysis.

Frictionless first best The social planner's problem (FB) under the first best is subject to the constraints of the production frontier and the perfect risk sharing condition. The social planner maximizes utility by choosing the terms of trade and factors, $\tilde{X}_t$ and $\tilde{N}_t$, so that the production $\tilde{N}_t^{1-\alpha}\tilde{X}_t^{\alpha} = \tilde{Y}_t$ equals to the demand for home goods.

First Best (FB)

$$\max_{\tilde{C}_t,\tilde{N}_t,\tilde{X}_t,\tilde{S}_t} \log(\tilde{C}_t) - \tilde{N}_t$$

$$\text{s.t.}\tilde{C}_t = C^*\tilde{S}_t^{-(1-\nu)}(1+\tau_t)^{-\nu}$$

$$\tilde{Y}_t = (1-\nu)\frac{(1+\tau_t)^{\nu}}{\tilde{S}_t^{\nu}}(\tilde{C}_t+\tilde{X}_t) + \nu\frac{Y^*}{\tilde{S}_t}$$

$$\tilde{N}_t^{1-\alpha}\tilde{X}_t^{\alpha} = \tilde{Y}_t \tag{FB-1}$$

Flexible-price CE (CE)

$$(1+\psi_p)\frac{S_t^{\nu}}{(1+\tau_t)^{\nu}} = \frac{\bar{\omega}C_t^{1-\alpha}}{(1+\psi_x)^{\alpha}} \tag{CE-0}$$

$$C_t = C^*S_t^{-(1-\nu)}(1+\tau_t)^{-\nu}$$

$$Y_t = (1-\nu)\frac{(1+\tau_t)^{\nu}}{S_t^{\nu}}(C_t+X_t) + \nu\frac{Y^*}{S_t}$$

$$\bar{\omega}N_tC_t^{\alpha}(1+\psi_x)^{-\alpha} = (1-\alpha)Y_t \tag{CE-1}$$

$$\bar{\omega}X_tC_t^{-(1-\alpha)}(1+\psi_x)^{1-\alpha} = \alpha Y_t \tag{CE-2}$$

Using the first order condition of inputs, (FB) can be re-written as the problem of choosing the optimal terms of trade.

$$\max_{\tilde{S}_t} -(1-\nu)log(\tilde{S}_t) - \nu log(1+\tau_t) - N\tilde{S}_t^{-1-\frac{\nu\alpha}{1-\alpha}}(1+\tau_t)^{\frac{\nu\alpha}{1-\alpha}} \tag{31}$$

where the non-stochastic steady-state labor supply is $N = (\bar{\omega})^{-\frac{1}{1-\alpha}}(1-\nu)^{\frac{\alpha}{1-\alpha}}((1-\nu)C^*+\nu Y^*)$.

Tariffs reduce welfare in (FB). From the first-order condition, the social planner improves the terms of trade. I further assume that in the non-stochastic steady state with zero tariffs, countries are symmetric such that $Y = Y^* = C^* + X^*$. The steady-state consumption is $C = C^* = \frac{(1-\alpha)(\frac{\alpha}{1-\nu})^{\frac{\alpha}{1-\alpha}}}{1-\alpha(1-\nu)}(1-\alpha-\nu)$ (under the parametric restriction that $1-\nu-\alpha>0$). Applying the steady-state value to C^*, the optimal response of the terms of trade can be characterized as $\tilde{S}_t = (1+\tau_t)^{\frac{\nu\alpha}{1-\alpha(1-\nu)}}$. This expression further means that the planner does not react to tariff shocks when production does not use inputs.

Competitive equilibrium In addition to the risk sharing condition and the country's market clearing condition, the planning problem in the flexible price competitive equilibrium (CE) is subject to firms' optimal pricing (CE-0) and factor demands, (CE-1) and (CE-2). There exist additional sales subsidies $1 + \psi_p$ and input purchase subsidies $1 + \psi_x$ so that the steady state under flex-price CE is identical to the FB. Moreover, the terms of trade and consumption are efficient, $S_t = \tilde{S}_t$ and $C_t = \tilde{C}_t$. However, factors—from equations (CE-1) and (CE-2)—are not efficient. In fact, these two equations imply the aggregate production function in equation (FB-1), but not its equivalence. When this small open economy approaches an autarkic limit as $\nu \to 0$, CE does indeed approach the first best. The size of the input subsidy illustrates this equivalence: $1+\psi_x = C(1-\nu)^{\frac{1}{1-\alpha}}\alpha^{-\frac{\alpha}{1-\alpha}}(1-\alpha)^{-1} \to 1$ as $\nu \to 0$. Non-equivalence of the production frontiers in (FB) and (CE) occurs because firms do not internalize the consequence of their input choices on the country's production frontier. The source of this inefficiency is the home bias in inputs. For comparison, New Keynesian small open economy models without home bias can eliminate the terms of trade externality and factor allocation inefficiencies between the flex-price CE and the FB (Matsumura, 2022). Technically, from Jensen's inequality, aggregating firms' outputs from a concave production function cannot be greater than production using factors in aggregate.

Welfare loss and optimal monetary policy With nominal frictions and the subsidies mentioned above, Proposition 3 characterizes the welfare loss and the response of consumption and the terms of trade under the optimal monetary policy with commitment. The quadratic welfare loss consists of a price wedge $\hat{s}_t$, producer price inflation, and factor quantity wedges $\hat{n}_t$ and $\hat{x}_t$, summarized in the vector $\hat{\mathbf{q}}_t$. These terms represent the welfare loss from the terms-of-trade externality, price dispersion, and input-demand inefficiency. Without inputs, the input demand inefficiency vanishes, and the optimal monetary policy can achieve the first-best outcome by setting producer price inflation to zero. With inputs in production, the optimal monetary policy needs to correct the factor-demand inefficiency. The first constraint is derived from the Phillips curve. The second constraint describes the relationship between factor demand and the terms of trade.

Proposition 3 *The social planner's optimal policy problem is to choose the terms of trade wedge $\hat{s}_t$ and the factor demand wedge $\hat{\mathbf{q}}_t = (\hat{n}_t, \hat{x}_t)'$ that minimize the welfare loss given below.*

$$Loss = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\gamma_s \hat{s}_t^2 + + \gamma_\pi \pi_{H,t}^2 + \underbrace{2\hat{s}_t \hat{\mathbf{q}}_t' \mathbf{k}_\mathbf{x} + \hat{\mathbf{q}}_t' \Sigma \hat{\mathbf{q}}_t}_{\text{input demand inefficiency}} \right)$$

$$s.t. \pi_{H,t} = \beta \mathbb{E}_t(\pi_{H,t+1}) - \lambda(1 - \alpha(1-\nu))\hat{s}_t$$

$$\hat{\mathbf{q}}_t = \mathbf{k}_\tau \tau_t - \mathbf{k}_s \hat{s}_t$$

where $\gamma_s = \frac{1+\alpha-4\nu\alpha+\nu^2\alpha}{1-\alpha}$, $\gamma_\pi = \frac{\epsilon}{2\lambda}$, $\mathbf{k}_x = (0, -\frac{\alpha(1-\nu)}{1-\alpha})'$, $\Sigma = \begin{pmatrix} \alpha & -\alpha \\ -\alpha & 1 \end{pmatrix}$, $\mathbf{k}_\tau = (\frac{2\nu\alpha}{1-\alpha(1-\nu)}, \frac{2\nu}{1-\alpha(1-\nu)})'$, *and* $\mathbf{k}_s = (\frac{\nu}{1-\alpha} + (1-\nu)(1-2\alpha), \frac{\nu}{1-\alpha})'$.

Under the optimal monetary policy with commitment, upon the impact of tariff shocks, three results hold: 1) $\hat{s}_0 > 0$ *or* $\hat{s}_0 < 0$*; 2) consumption under the optimal monetary policy is either smaller or larger than that under strict PPI targeting; and 3)* $\pi_{H,0} > 0$ *(See Appendix C.5 for the proof).*

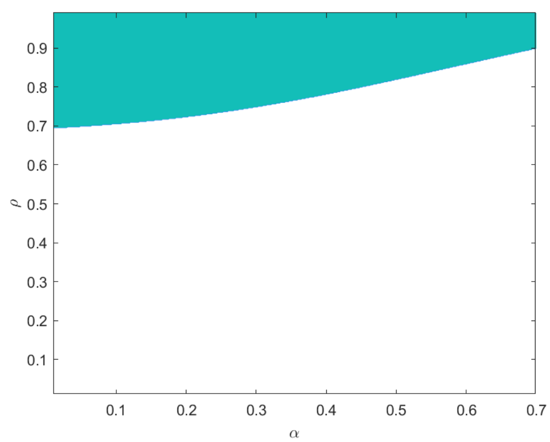
Denote τ_0 as the tariff shock in the initial period $t = 0$. The terms of trade wedge under the optimal monetary policy in the initial period is

$$\hat{s}_0 = \mu_{opt,1} \hat{s}_{-1} + \tau_0 \frac{\mu_{opt,1}}{1 - \beta\rho\mu_{opt,1}} \frac{M_\tau}{M_s} (1 - \beta(1 + \mu_{opt,1} - \rho)) \tag{32}$$

where the wedge prior to the shock is $\hat{s}_{-1} = 0$. Here, $M_\tau > 0$ and $M_s = \frac{\gamma_s - 2\mathbf{k}_s'\mathbf{k}_x + \mathbf{k}_s'\Sigma\mathbf{k}_s}{1-\alpha(1-\nu)} > 0$. $0 < \mu_{opt,1} = \frac{1}{2}[(1+\frac{1}{\beta}+\chi_{opt}) - \sqrt{(1+\frac{1}{\beta}+\chi_{opt})^2 - \frac{4}{\beta}}] < 1$, with $\chi_{opt} = \frac{\gamma_\pi \lambda^2 (1-\alpha(1-\nu))}{\beta M_s}$. Therefore, the sign of $\hat{s}_0$ depends on $1-\beta(1+\mu_{opt,1}-\rho)$, which may be greater or less than zero. Consumption under the optimal monetary policy, expressed as the log deviation from the efficient steady state, is $c_t = -(1-\nu)\hat{s}_t - \frac{\nu}{1-\alpha(1-\nu)}\tau_t = -(1-\nu)\hat{s}_t + c_t^{PPI}$, where the second equality uses the consumption under strict PPI targeting. As the sign of $\hat{s}_0$ is ambiguous, consumption under the optimal monetary policy can be greater or smaller than that under strict PPI targeting.

Figure 2 shows the combination of the input share and the persistence of tariff shocks required to generate a positive terms of trade wedge under the optimal monetary policy. In general, when persistence is high, the social planner would engineer a terms-of-trade appreciation upon the impact of tariff shocks. In turn, consumption is lower than under strict PPI targeting. Another way to view this result is that, given certain persistence of tariff shocks, a larger input share makes the optimal monetary policy relative to strict PPI targeting more expansionary.

Figure 2: Input share ($\alpha > 0$) and the persistence of tariff shocks for a positive terms of trade wedge $\hat{s}_t$ under the optimal monetary policy



Notes: Parameters are $\beta = 0.99$, $\varphi = 0$, $\nu = 0.3$, $\sigma = \eta = 1$, $\epsilon = 6$, and $\lambda = 0.0858$.

The initial producer price inflation is

$$\pi_{H,0} = \frac{M_\tau}{(1 - \beta\rho\mu_{opt,1})\lambda\gamma_\pi}(1 + \mu_{opt,1}(1 - \beta(1 + \mu_{opt,1}))) > 0 \tag{33}$$

where $1 + \mu_{opt,1}(1 - \beta(1 + \mu_{opt,1})) > 0$ because $0 < \mu_{opt,1} < 1$. Similar to flexible PPI targeting, tariffs are inflationary upon impact under the optimal monetary policy.

5. Conclusion

This paper examines the short-run impact of tariffs in a sticky-price environment. It shows analytically how trade policy interacts with monetary policy and highlights that the degree of monetary policy accommodation to producer price inflation determines the response of consumption to temporary tariff shocks. While tariffs depress consumption under a Taylor-rule type monetary policy with flexible PPI targeting, consumption may rise when monetary policy targets consumer price inflation, fiscal policy actively determines the price level, and monetary policy remains inactive due to the zero interest rate lower bound. Inputs in production flatten the Phillips curve, making tariffs potentially stimulate global demand when central banks' face the zero lower bound. Optimal monetary policy also has a role in correcting inefficient input demand caused by tariff shocks, even if the terms of trade externality is absent. This objective, in turn, may either stimulate or depress consumption under the optimal monetary policy relative to strict PPI targeting. The direct implication is that analyzing the short-run effects of trade policy should consider the reaction of monetary policy. Future quantitative and welfare analysis may enrich the model with detailed input-output linkages.

References

Auray, Stéphane, Michael B Devereux, and Aurélien Eyquem, "Trade wars, nominal rigidities, and monetary policy," *The Review of Economic Studies*, July 2024.

Barattieri, Alessandro, Matteo Cacciatore, and Fabio Ghironi, "Protectionism and the Business Cycle," *Journal of International Economics*, 2021, *129*, 103417.

Bergin, Paul R and Giancarlo Corsetti, "The macroeconomic stabilization of tariff shocks: What is the optimal monetary response?," *Journal of international economics*, July 2023, *143* (103758), 103758.

Bianchi, Javier and Louphou Coulibaly, "The Optimal Monetary Policy Response to Tariffs," Technical Report, National Bureau of Economic Research March 2025.

Galí, Jordi, *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, Princeton University Press, June 2015.

Itskhoki, Oleg and Dmitry Mukhin, "Optimal Exchange Rate Policy," Technical Report, National Bureau of Economic Research December 2023.

Jeanne, Olivier, "Currency Wars, Trade Wars, and Global Demand," Technical Report, National Bureau of Economic Research December 2021.

Kalemli-Ozcan, Sebnem, Can Soylu, and Muhammed A Yildirim, "Global Networks, Monetary Policy and Trade," Technical Report, National Bureau of Economic Research April 2025.

Matsumura, Misaki, "What price index should central banks target? An open economy analysis," *Journal of international economics*, March 2022, *135* (103554), 103554.

Monacelli, Tommaso, "Tariffs and Monetary Policy," Technical Report, CEPR Discussion Paper No. 20142 2025.

Woodford, Michael, "Simple Analytics of the Government Expenditure Multiplier," *American Economic Journal: Macroeconomics*, January 2011, *3* (1), 1–35.

Online Appendix
Could Tariffs Provide a Stimulus? Simple Analytics of Tariffs and the Macro Economy

Jeremy Meng

July 11, 2025

A. A model of small-open economy

A.1 Baseline complete market model

A.1.1 Log-linearized equilibrium

The log-linearized equilibrium of the small-open economy New Keynesian model under complete asset markets consists of an exogenous process of tariffs τ_t and a monetary policy rule for i_t. The endogenous variables are: allocations $\{c_t, y_t, n_t, x_t\}$ and prices $\{\pi_t, s_t, \pi_{H,t}, mc_t, p_{H,t}, w_t\}$. The following ten equations characterize the equilibrium.

$$c_t = \mathbb{E}_t(c_{t+1}) - \frac{1}{\sigma}(i_t - \mathbb{E}_t(\pi_{t+1}))$$

$$\pi_t = \pi_{H,t} - \Delta p_{H,t}$$

$$\pi_{H,t} = \beta\mathbb{E}_t(\pi_{H,t+1}) + \lambda(mc_t - p_{H,t})$$

$$\sigma c_t = -(1-\nu)s_t - \nu\tau_t$$

$$y_t = -\eta\nu(2-\nu)s_t + \eta\nu(1-\nu)\tau_t + (1-\nu)((1-\alpha)c_t + \alpha x_t)$$

$$\sigma c_t + \varphi n_t = w_t$$

$$mc_t = (1-\alpha)w_t$$

$$n_t + \alpha w_t = y_t$$

$$x_t - (1-\alpha)w_t = y_t$$

$$p_{H,t} = \nu s_t - \nu \tau_t$$

A.1.2

Proof of Proposition 1. Given equation (8) and using the undetermined coefficient method to solve for the equilibrium consumption under flexible-PPI targeting, the solution is

$$\frac{dc_t}{d\tau_t} = -\frac{(\phi_\pi - \rho)\lambda_\tau + (1-\beta\rho)\kappa_{app,\tau}}{\frac{\sigma}{1-\nu}(1-\rho)(1-\beta\rho) + \lambda_c(\phi_\pi - \rho) + \kappa_{app,c}(1-\beta\rho)} < 0$$

where $\kappa_{app,\tau} = \frac{\nu\frac{\kappa_s\phi_y}{\kappa_y} + \nu(1-\rho)}{1-\nu} > 0$, and $\kappa_{app,c} = \frac{\frac{\kappa_s\phi_y}{\kappa_y}\sigma + (1-\nu)\frac{\kappa_c\phi_y}{\kappa_y}}{1-\nu} > 0$.

QED.

A.2 Small-open economy extension: the fiscal theory of the price level

This section describes the small-open economy model where the determinacy of the price level may come from fiscal policy. There is no input ($\alpha = 0$), and the labor supply is perfectly elastic ($\varphi = 0$). Moreover, this model is similar to Witheridge (2024), except that the model here assumes perfect risk sharing and that the domestic producer price is used to normalize the domestic value of the debt instead of using domestic consumer prices. This normalization makes the solution tractable.

Log-linearizing the fiscal rule $\frac{\widetilde{\mathcal{T}}_t^G}{\widetilde{\mathcal{T}}^G} = \left(\frac{D_{t-1}^G}{D^G}\right)^{\gamma_d}$ with $\widetilde{\mathcal{T}}_t^G = \frac{\mathcal{T}_t^G}{P_{H,t}/P_t}$ yields $log(\frac{\widetilde{\mathcal{T}}_t^G}{\widetilde{\mathcal{T}}^G}) = \gamma_d d_{t-1}^G$. The government budget balance $\frac{B_t^G}{R_t} + \mathcal{T}_t^G = B_{t-1}^G$. $\mathcal{T}_t^G$ is the lump-sum tax and D_t^G is defined as $D_t^G = \frac{B_t^G}{P_{H,t}/P_t}$. The government budget balance can be written as

$$\frac{B_t^G/R_t}{P_{H,t}/P_t} + \frac{\mathcal{T}_t^G}{P_{H,t}/P_t} = \frac{B_{t-1}^G}{P_{H,t-1}/P_{t-1}}\frac{P_{H,t-1}/P_{t-1}}{P_{H,t}/P_t} \to \frac{D_t^G}{R_t} + \widetilde{\mathcal{T}}_t^G = D_{t-1}\pi_{H,t}^{-1}$$

Linearizing the budget balance (by using $\widetilde{\mathcal{T}}^G = D^G(1-\beta)$ in the steady state) returns equation (26).

The equilibrium under the fiscal theory of the price level consists of the real debt level d_t^G, producer price inflation $\pi_{H,t}$, and consumption c_t that satisfy

$$d_t^G = \frac{1-\gamma_d(1-\beta)}{\beta} d_{t-1}^G + (\phi_\pi - \frac{1}{\beta})\pi_{H,t}$$

$$\mathbb{E}_t(\pi_{H,t+1}) = \frac{1}{\beta}\pi_{H,t} - \frac{\lambda\sigma}{\beta(1-\nu)}c_t - \frac{\lambda\nu}{\beta(1-\nu)}\tau_t$$

$$\mathbb{E}_t(c_{t+1}) = (1+\frac{\lambda}{\beta})c_t + \frac{1-\nu}{\sigma}(\phi_\pi - \frac{1}{\beta})\pi_{H,t} + (\frac{\lambda\nu}{\beta\sigma} + \frac{\nu(1-\rho)}{1-\nu})\tau_t$$

Denote $\mathbf{X}_{g,t} = (\pi_{H,t}, c_t, d_{t-1}^G)'$. The state-space representation is $\mathbb{E}_t(\mathbf{X}_{g,t+1}) = \mathbf{M}_g\mathbf{X}_{g,t} + \mathbf{C}_g\tau_t$. Denote $\tilde{\sigma} = \frac{\sigma}{1-\nu}$, and $\tilde{\gamma}_d = \frac{1-(1-\beta)\gamma_d}{\beta}$. Then,

$$\mathbf{M}_g = \begin{bmatrix} \frac{1}{\beta} & -\frac{\lambda}{\beta}\tilde{\sigma} & 0 \\ \frac{1}{\tilde{\sigma}}(\phi_\pi - \frac{1}{\beta}) & 1+\frac{\lambda}{\beta} & 0 \\ \phi_\pi - \frac{1}{\beta} & 0 & \tilde{\gamma} \end{bmatrix} \tag{A.1}$$

$\mathbf{M}_g$ is an upper diagonal matrix with three eigenvalues, $\tilde{\gamma}_d$ and two of which come from the matrix $\mathbf{M}_{g,1} = \begin{pmatrix} \frac{1}{\beta} & -\frac{\lambda}{\beta}\tilde{\sigma} \\ \frac{1}{\tilde{\sigma}}(\phi_\pi - \frac{1}{\beta}) & 1+\frac{\lambda}{\beta} \end{pmatrix}$. It can be shown that one of the two eigenvalues $\mu_{g,1}, \mu_{g,2}$ of $\mathbf{M}_{g,1}$ is always greater than one. The necessary condition for the other eigenvalue to be greater than one is $\phi_\pi > 1$. The eigenvalue $\tilde{\gamma}_d$ of $\mathbf{M}_g$ is greater than one whenever $\gamma_d < 1$. Therefore, the active monetary policy regime, $\mu_{g,1} > 1$, $\mu_{g,2} > 1$ and $\tilde{\gamma}_d < 1$, which means $\gamma_d > 1$ and $\phi_\pi > 1$. In the passive monetary policy regime, $\mu_{g,1} < 1$, $\mu_{g,2} > 1$ and $\tilde{\gamma}_d > 1$, which means $\gamma_d < 1$ and $\phi_\pi < 1$.

In the passive monetary policy regime, the Jordan decomposition of $\mathbf{M}_g$ is $\mathbf{VJV}^{-1}$ such that the eigenvalues are ordered as $\mu_{g,2}$, $\tilde{\gamma}_d$, $\mu_{g,1}$.

$$\mathbf{V} = \begin{bmatrix} 1 & 0 & 1 \\ (\frac{1}{\beta} - \mu_{g,2})\frac{\beta}{\lambda\tilde{\sigma}} & 0 & (\frac{1}{\beta} - \mu_{g,1})\frac{\beta}{\lambda\tilde{\sigma}} \\ -(\phi_\pi - \frac{1}{\beta})\frac{1}{\tilde{\gamma}-\mu_{g,2}} & 1 & -(\phi_\pi - \frac{1}{\beta})\frac{1}{\tilde{\gamma}-\mu_{g,1}} \end{bmatrix}$$

$$\mathbf{V}^{-1} = \begin{bmatrix} \frac{\frac{1}{\beta}-\mu_{g,1}}{\mu_{g,2}-\mu_{g,1}} & -\frac{\lambda\tilde{\sigma}}{\beta}\frac{1}{\mu_{g,2}-\mu_{g,1}} & 0 \\ \frac{(\phi_\pi-\frac{1}{\beta})(\tilde{\gamma}_d-1-\frac{\lambda}{\beta})}{(\tilde{\gamma}_d-\mu_{g,1})(\tilde{\gamma}_d-\mu_{g,2})} & -\frac{\lambda\tilde{\sigma}}{\beta}\frac{\phi_\pi-\frac{1}{\beta}}{(\tilde{\gamma}_d-\mu_{g,1})(\tilde{\gamma}_d-\mu_{g,2})} & 1 \\ -\frac{\frac{1}{\beta}-\mu_{g,2}}{\mu_{g,2}-\mu_{g,1}} & \frac{\lambda\tilde{\sigma}}{\beta}\frac{1}{\mu_{g,2}-\mu_{g,1}} & 0 \end{bmatrix}$$

Under the passive monetary policy regime, $\tilde{\gamma}_d - 1 - \frac{\lambda}{\beta} < 0$. Applying the Blanchard-Khan method analytically yields the two equations below for $t = 0$.

$$(\frac{1}{\beta} - \mu_{g,1})\pi_{H,0} - \frac{\lambda\tilde{\sigma}}{\beta}c_0 = -\frac{1}{\mu_{g,2} - \rho}\left(-(\frac{1}{\beta} - \mu_{g,1})\frac{\lambda\nu}{\beta(1-\nu)} - \frac{\lambda\tilde{\sigma}}{\beta}(\frac{\lambda\nu}{\beta\sigma} + \frac{\nu(1-\rho)}{1-\nu})\right)\tau_0$$

$$(\tilde{\gamma} - 1 - \frac{\lambda}{\beta})\pi_{H,0} - \frac{\lambda\tilde{\sigma}}{\beta}c_0 = -\frac{1}{\tilde{\gamma}_d - \rho}\left(-(\tilde{\gamma}_d - 1 - \frac{\lambda}{\beta})\frac{\lambda\nu}{\beta(1-\nu)} - \frac{\lambda\tilde{\sigma}}{\beta}(\frac{\lambda\nu}{\beta\sigma} + \frac{\nu(1-\rho)}{1-\nu})\right)\tau_0$$

where $\mu_{g,2} = \frac{1+\beta+\lambda+\sqrt{(1+\beta+\lambda)^2-4\beta(\lambda\phi_\pi+1)}}{2\beta} > \frac{1}{\beta} > \tilde{\gamma}_d$ when $\beta + \lambda > 1$.

Combining these equations and applying the restrictions in the passive monetary policy regime gives the result in Proposition 2.

B. A model of large open economies

B.1 Log-linearized equilibrium and results in Section 4.1

I describe the log-linearized equilibrium and the steady state for the two country model. The results in Section 4.1 directly come from this log-linearized equilibrium.

The log-linearized two-country New Keynesian model under the Law of One Price and a complete asset market consists of exogenous variables:

1. Exogenous tariff shocks in the home and foreign countries $\{\tau_t, \tau_t^*\}$;
2. Monetary policy rules for i_t and i_t^*.

The log-linearized model consists of endogenous variables: allocations $\{c_t, c_t^*, y_t, y_t^*, n_t, n_t, x_t, x_t^*\}$, prices $\{\pi_t, \pi_t^*, \pi_{H,t}, \pi_{F,t}^*, mc_t, mc_t^*, p_{H,t}, p_{F,t}, w_t, w_t^*\}$, and home country's tariff-exclusive terms of trade (export price/import price) $\{s_t\}$ (R represents relative values (home relative to foreign countries' variables)). The following nineteen equations characterize the equilibrium.

$$\pi_{H,t} = \beta \mathbb{E}_t(\pi_{H,t+1}) + \lambda(mc_t - p_{H,t})$$

$$\pi_{F,t}^* = \beta \mathbb{E}_t(\pi_{F,t+1}^*) + \lambda(mc_t^* - p_{F,t}^*)$$

$$\sigma c_t + \varphi n_t = w_t$$

$$\sigma c_t^* + \varphi n_t^* = w_t^*$$

$$mc_t = (1-\alpha) w_t$$

$$mc_t^* = (1-\alpha) w_t^*$$

$$n_t + \alpha w_t = y_t$$

$$n_t^* + \alpha w_t^* = y_t^*$$

$$x_t - (1-\alpha) w_t = y_t$$

$$x_t^* - (1-\alpha) w_t^* = y_t^*$$

$$p_{H,t} = \nu s_t - \nu \tau_t$$

$$p^*_{F,t} - \nu s_t - \nu \tau^*_t$$

$$y_t = -2\eta\nu(1-\nu)s_t + \eta\nu(1-\nu)\tau^R_t + (1-\nu)(1-\alpha)c_t + (1-\nu)\alpha x_t + \nu(1-\alpha)c^*_t + \nu\alpha x^*_t$$

$$y^*_t = 2\eta\nu(1-\nu)s_t - \eta\nu(1-\nu)\tau^R_t + (1-\nu)(1-\alpha)c^*_t + (1-\nu)\alpha x^*_t + \nu(1-\alpha)c_t + \nu\alpha x_t$$

$$\sigma c^R_t = -s_t(1-2\nu) - \nu\tau^R_t$$

$$c_t = \mathbb{E}_t(c_{t+1}) - \frac{1}{\sigma}(i_t - \mathbb{E}_t(\pi_{t+1}))$$

$$c^*_t = \mathbb{E}_t(c^*_{t+1}) - \frac{1}{\sigma}(i^*_t - \mathbb{E}_t(\pi^*_{t+1}))$$

$$\pi_t = \pi_{H,t} - \nu\Delta s_t + \nu\Delta\tau_t$$

$$\pi^*_t = \pi^*_{F,t} + \nu\Delta s_t + \nu\Delta\tau^*_t$$

C. Welfare Analysis

To remind readers, $\sim$ denotes variables for the social planner under the first best, and $\wedge$ denotes the wedge between the competitive equilibrium (CE) and the frictionless first best (FB). The Ramsey approach to welfare analysis involves the following steps: 1) deriving the social planner's solution to tariff shocks in the FB and deriving the steady state (Section C.1); 2) writing down the competitive equilibrium and finding the subsidy to achieve an efficient non-stochastic steady state (Section C.2); 3) writing down the welfare loss along with constraints expressed as the wedge from the FB (Section C.3); and 4) deriving the planner's optimal monetary policy with commitment (Section C.5).

C.1 Social Planner's First Best

Without any frictions, the social planner chooses the terms of trade and allocations to maximize utility subject to the risk sharing condition and the country's production frontier.

$$\begin{aligned}
&\max_{\tilde{C}_t,\tilde{N}_t,\tilde{X}_t,\tilde{S}_t} \log(\tilde{C}_t) - \tilde{N}_t \\
&\text{s.t.} \tilde{C}_t = C^* \tilde{S}_t^{-(1-\nu)}(1+\tau_t)^{-\nu} \\
&\quad \tilde{N}_t^{1-\alpha}\tilde{X}_t^{\alpha} = (1-\nu)\frac{(1+\tau_t)^{\nu}}{\tilde{S}_t^{\nu}}(\tilde{C}_t + \tilde{X}_t) + \nu\frac{Y^*}{\tilde{S}_t}
\end{aligned}$$

The first-order condition for inputs is

$$\tilde{X}_t = \alpha^{\frac{1}{1-\alpha}}(1-\nu)^{-\frac{1}{1-\alpha}}\tilde{S}_t^{\frac{\nu}{1-\alpha}}(1+\tau_t)^{\frac{-\nu}{1-\alpha}}\tilde{N}_t \tag{C.1}$$

Putting equation (C.1) into the market clearing condition to solve for $\tilde{N}_t$ and replacing consumption with $\tilde{S}_t$ yield the social planner's problem in equation (31). The derivative with respect to tariff shocks is

$$-\frac{1}{1+\tau_t} - N\frac{\nu\alpha}{1-\alpha}(1+\tau_t)^{\frac{\nu\alpha}{1-\alpha}-1} < 0$$

This confirms that tariff shocks are welfare decreasing. The optimal response of the terms of trade is

$$\tilde{S}_t = (1+\tau_t)^{\frac{\nu\alpha}{1-\alpha(1-\nu)}}((1-\nu)C^* + \nu Y^*)^{\frac{1-\alpha}{1-\alpha(1-\nu)}}\left((\frac{1-\alpha(1-\nu)}{1-\alpha})^{1-\alpha}\bar{\omega}^{-1}(1-\nu)^{-(1-2\alpha)}\right)^{\frac{1}{1-\alpha(1-\nu)}} \tag{C.2}$$

I characterize the non-stochastic steady state where countries are symmetric without any tariffs. This is consistent with the fact that the social planner would impose zero tariffs as they are welfare decreasing. This symmetric condition is consistent with a unitary terms of trade $S = 1$. Equation (C.2) implies that

$$(1-\nu)C^* + \nu Y^* = \left((\frac{1-\alpha(1-\nu)}{1-\alpha})^{1-\alpha}(1-\nu)^{-(1-2\alpha)}\right)^{-\frac{1}{1-\alpha}} \tag{C.3}$$

Equation (31) implies that the steady state labor supply

$$N = \bar{\omega}^{-\frac{1}{1-\alpha}}(1-\nu)^{\frac{\alpha}{1-\alpha}}((1-\nu)C^* + \nu Y^*) = \frac{(1-\nu)(1-\alpha)}{1-\alpha(1-\nu)} \tag{C.4}$$

From equations (C.2) and (C.3), the simplified terms of trade is

$$\tilde{S}_t = (1+\tau_t)^{\frac{\nu\alpha}{1-\alpha(1-\nu)}} \tag{C.5}$$

Therefore the optimal labor supply is

$$\tilde{N}_t = \frac{(1-\nu)(1-\alpha)}{1-\alpha(1-\nu)} \tag{C.6}$$

The optimal choice of inputs (equation (C.1)) can be simplified using equations (C.5) and (C.6).

$$\tilde{X}_t = (\frac{\alpha}{1-\nu})^{\frac{1}{1-\alpha}} N (1+\tau_t)^{-\frac{\nu}{1-\alpha(1-\nu)}} \tag{C.7}$$

The relationship between inputs and labor supply in the steady-state is

$$X = (\frac{\alpha}{1-\nu})^{\frac{1}{1-\alpha}} N = \alpha^{\frac{1}{1-\alpha}}(1-\nu)^{\frac{-\alpha}{1-\alpha}} \frac{1-\alpha}{1-\alpha(1-\nu)} \tag{C.8}$$

In summary, equations (C.5)-(C.7) characterize $\tilde{S}_t$, $\tilde{N}_t$ and $\tilde{X}_t$ in the first best, and the associated steady state values are $S = 1$ and those in equations (C.4) and (C.8). The symmetric steady state consists of $Y = Y^* = (1-\nu)(C^* + X) + \nu Y^*$, equation (C.3), and equation(C.8). The solution is

$$C = C^* = \frac{(1-\alpha)(\frac{\alpha}{1-\nu})^{\frac{\alpha}{1-\nu}}}{1-\alpha(1-\nu)}(1-\alpha-\nu) \tag{C.9}$$

where the parametric restriction is $1-\alpha-\nu > 0$. Moreover, $C^* = \frac{1-\alpha-\nu}{1-\nu} Y^*$ and $X = \frac{\alpha}{1-\nu} Y^*$.

C.2 Competitive equilibrium

The flexible price competitive equilibrium is identical to the one in Section A.1 except for additional subsidies $1+\psi_p$ to domestic products and $1+\psi_x$ applied to firms purchasing inputs. The optimal pricing is $(1+\psi_p)\frac{P_{H,t}}{P_t} = \frac{MC_t}{P_t}$, and the cost minimization problem for firm i has the objective function $W_t N(i)_t + (1+\psi_x)P_t X(i)_t$. The solution gives the real marginal cost $\frac{MC_t}{P_t} = \frac{1}{\bar{\omega}}(\frac{W_t}{P_t})^{1-\alpha}(1+\psi_x)^{\alpha}$. Aggregating the choice of labor and input yields equations (CE-1) and (CE-2). Since $C_t^{\sigma} = \frac{W_t}{P_t} = \frac{MC_t}{P_t}$, writing the real marginal cost using consumption yields the firms' optimal pricing in equation (CE-0). The proposition below derives the subsidies. I use the subscripts ce and fb to distinguish steady-state values in the competitive equilibrium and the first best in the derivation.

Proposition 4 *With subsidies $1+\psi_p$ and $1+\psi_x$, $S_t = \tilde{S}_t$, and $C_t = \tilde{C}_t$. Moreover, the competitive equilibrium has the same allocation as in the first best in a symmetric steady state, such that allocations $C_{ce} = C_{fb}$, $X_{ce} = X_{fb}$, $Y_{ce} = Y_{fb}$, and $N_{ce} = N_{fb}$ and the price $S_{ce} = S_{fb} = 1$.*

Proof of Proposition 4.

From equation (CE-0), $S_{ce} = 1$ and $S_t = \tilde{S}_t$ require

$$\frac{1+\psi_p}{(1+\psi_x)^{\alpha}} = \left(\frac{C_{ce}^*}{\nu Y_{fb}^* + (1-\nu)C_{fb}^*}\frac{1-\alpha}{1-\alpha(1-\nu)}\right)^{1-\alpha}(1-\nu)^{1-2\alpha} = \left(\frac{1-\alpha-\nu}{1-\alpha(1-\nu)}\right)^{1-\alpha}(1-\nu)^{-\alpha} \tag{C.10}$$

where the second equality uses $C_{ce}^* = C_{fb}^*$. The two subsidies enable $S_t = \tilde{S}_t$, and hence $C_t = \tilde{C}_t$ and $C_{ce}^* = C_{fb}^*$.

Ratios of equations (CE-1) and (CE-2) from the competitive equilibrium imply

$$X_{ce} = \frac{\alpha}{1-\alpha}\frac{1}{1+\psi_x}N_{ce}C_{ce} = \frac{\alpha}{1-\alpha}\frac{1}{1+\psi_x}N_{ce}C_{fb} \tag{C.11}$$

where the second equality uses the fact that $C_{ce} = C_{fb}$ with two subsidies. Notice that $X_{fb} = (\frac{\alpha}{1-\nu})^{\frac{1}{1-\alpha}}N_{fb}$. Suppose $1+\psi_x = C_{fb}(1-\nu)^{\frac{1}{1-\alpha}}\alpha^{-\frac{\alpha}{1-\alpha}}N_{ce}$, then showing $N_{ce} = N_{fb}$ (and hence $Y_{ce}^* = Y_{fb}^*$ directly from the market clearing condition) would conclude the proof.

Using X_{ce} from equation (C.11) and combining it with equations (CE-1), the market clearing condition returns

$$N_{ce}(1-\nu)^{-\frac{\alpha}{1-\alpha}}\alpha^{\frac{1}{1-\alpha}}\frac{1-\alpha}{\alpha} = (1-\nu)C^*_{fb} + \nu Y^*_{ce} \tag{C.12}$$

Applying the symmetric condition to the market clearing condition, using the known relationship that $C_{ce} = C_{fb}$, and expressing X_{ce} using equation (C.11) yield

$$Y^*_{ce} = (1-\nu)C^*_{fb} + (1-\nu)(\frac{\alpha}{1-\nu})^{\frac{1}{1-\alpha}}N_{ce} + \nu Y^*_{ce} \tag{C.13}$$

Using the expression of C_{fb} in equation (C.9) and combining equations (C.12) and (C.13) solves for N_{ce}, which is identical to N_{fb} in equation (C.6).

QED.

These two subsidies alter the steady-state values compared to the baseline model, but the subsidies do not change the log-linearized equilibrium other than in the first order approximation of the market clearing condition. The following equations characterize the linearized competitive equilibrium in the presence of nominal frictions.

$$\pi_{H,t} = \beta\pi_{H,t+1} - \lambda((1-\alpha(1-\nu))s_t - \alpha\nu\tau_t) \tag{C.14}$$

$$y_t = (1-\nu)(-\nu s_t + \nu\tau_t) + (1-\alpha-\nu)c_t + \alpha x_t - \nu s_t \tag{C.15}$$

$$c_t = -(1-\nu)s_t - \nu\tau_t \tag{C.16}$$

$$n_t = y_t - \alpha c_t \tag{C.17}$$

$$x_t = y_t - (1-\alpha)c_t \tag{C.18}$$

C.3 Welfare loss function

This section derives the quadratic welfare loss function using the Lagrangian method in Itskhoki and Mukhin (2023) in two steps: 1) deriving the welfare loss from price dispersions; 2) deriving the welfare loss due to the deviation from the optimal choice of terms of trade and allocations from the first best. The key requirement for this approach is that the terms of trade and the allocations in the competitive equilibrium is feasible in the social planner's first best. (CE) and (FB) share the same the risk sharing condition, the production frontier in (CE) implies the production frontier in (FB), though no identical.

Welfare loss from price dispersion The price dispersion term d_t due to nominal frictions alters factor choice as $\bar{\omega}N_tC_t^{\alpha}(1+\psi_x)^{-\alpha} = (1-\alpha)Y_td_t$ and $\bar{\omega}X_tC_t^{-(1-\alpha)}(1+\psi_x)^{1-\alpha} = \alpha Y_td_t$. Since the price dispersion is already a "second-order" term, given consumption and the terms of trade, it does not affect factor choices. Using this fact, I derive the production frontier with price dispersion: $Y_t = ((1-\nu)\frac{(1+\tau_t)^{\nu}}{S_t^{\nu}}(C_t+X_t)+\nu\frac{Y^*}{S_t})d_t^{-1}$. If the social planner faces this production frontier instead, using the same method as for deriving equation (31), the objective function is

$$\mathcal{L} = -(1-\nu)log(\tilde{S}_t) - \nu log(1+\tau_t) - N\tilde{S}_t^{-1-\frac{\nu\alpha}{1-\alpha}}(1+\tau_t)^{\frac{\nu\alpha}{1-\alpha}}d_t^{-\frac{1}{1-\alpha}} \tag{C.19}$$

The first order approximation around $\tilde{S}_t, \tau_t, \tilde{N}t, \tilde{X}_t$ and $d_t = 1$ is

$$\mathcal{L} = \underbrace{\mathcal{L}(\tilde{S}_t, \tilde{N}t, \tilde{X}_t, d_t = 1)}_{\text{Identical to } (FB)} + \underbrace{\frac{\partial\mathcal{L}}{\partial d_t}|_{d=1}}_{-N}\underbrace{(d_t - 1)}_{\frac{\epsilon}{2\lambda}\pi^2_{H,t}} \tag{C.20}$$

where I use the fact that $d_t - 1 = log(d_t)$ and results at p.86 and p.119 in Galí (2015). Denote $\gamma_\pi = \frac{\epsilon}{2\lambda}$.

The Lagrangian of the social planner's problem for each period in the first best with the multiplier μ_t for the producer frontier is

$$\mathcal{L} = -(1-\nu)log(\tilde{S}_t) - \tilde{N}_t + \mu_t(\tilde{N}_t^{1-\alpha}\tilde{X}_t^{\alpha} - (1-\nu)\tilde{S}_t^{-1}C^* - (1-\nu)\tilde{S}_t^{-(1-\nu)}(1+\tau_t)^{\nu}\tilde{X}_t - \nu\tilde{S}_t^{-1}Y^*)$$

The value of the Lagrangian multiplier in the efficient steady state is $\mu = (1-\alpha)^{-1}(\frac{1-\nu}{\alpha})^{\frac{\alpha}{1-\alpha}}$. The

Hessian of the Lagrangian evaluated at the steady state is

$$\mathbf{H} = \begin{bmatrix} \underbrace{-\frac{1+\alpha-4\nu\alpha+\nu^2\alpha}{1-\alpha}}_{\gamma_s} & 0 & (1-\nu)^2\frac{\alpha}{(1-\alpha)(1-\nu)}NX^{-1} \\ 0 & -\alpha N^{-1} & \alpha X^{-1} \\ (1-\nu)^2\frac{\alpha}{(1-\alpha)(1-\nu)}NX^{-1} & \alpha X^{-1} & -NX^{-2} \end{bmatrix}$$

For terms of trade and factors deviating from the first best, the welfare loss is

$$N\frac{\epsilon}{2\lambda}\pi_{H,t}^2 - \begin{bmatrix} S_t - \tilde{S}_t \\ N_t - \tilde{N}_t \\ X_t - \tilde{X}_t \end{bmatrix}' \mathbf{H} \begin{bmatrix} S_t - \tilde{S}_t \\ N_t - \tilde{N}_t \\ X_t - \tilde{X}_t \end{bmatrix} = N\frac{\epsilon}{2\lambda}\pi_{H,t}^2 - \begin{bmatrix} \hat{s}_t \\ \hat{n}_t N \\ \hat{x}_t X \end{bmatrix}' \mathbf{H} \begin{bmatrix} \hat{s}_t \\ \hat{n}_t N \\ \hat{x}_t X \end{bmatrix}$$

$$= N\left(\frac{\epsilon}{2\lambda}\pi_{H,t}^2 + \begin{bmatrix} \hat{s}_t \\ \hat{n}_t \\ \hat{x}_t \end{bmatrix}' \begin{bmatrix} \gamma_s & 0 & -\frac{\alpha(1-\nu)}{1-\alpha} \\ 0 & \alpha & -\alpha \\ -\frac{\alpha(1-\nu)}{1-\alpha} & -\alpha & 1 \end{bmatrix} \begin{bmatrix} \hat{s}_t \\ \hat{n}_t \\ \hat{x}_t \end{bmatrix}\right)$$

Omitting N and arranging terms yields the objective function in Proposition 3.

C.4 Deriving the Ramsey problem

The competitive equilibrium (equations (C.13)-(C.18)) can be expressed in wedges using the equilibrium in the first best (equations (C.5)-(C.7)) as below.

$$\pi_{H,t} = \beta\mathbb{E}_t(\pi_{H,t+1}) - \lambda(1-\alpha(1-\nu))\hat{s}_t$$

$$\hat{x}_t = -\frac{\nu}{1-\alpha}\hat{s}_t + \frac{2\nu}{1-\alpha(1-\nu)}\tau_t$$

$$\hat{n}_t = -(\frac{\nu}{1-\alpha} + (1-\nu)(1-2\alpha)\hat{s}_t + \frac{2\nu\alpha}{1-\alpha(1-\nu)}\tau_t$$

The social planner's problem is choosing $\{\pi_{H,t}, \hat{s}_t, \hat{n}_t, \hat{x}_t\}_t$ to minimize the expected present value of the above welfare loss subject to the above constraints.

C.5 Deriving results for Section 4.2

The social planner's Lagrangian is

$$\begin{aligned}\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \Big(&(\gamma_s \hat{s}_t^2 + +\gamma_\pi \pi_{H,t}^2 + 2\hat{s}_t \hat{\mathbf{q}}_t' \mathbf{k_x} + \hat{\mathbf{q}}_t' \Sigma \hat{\mathbf{q}}_t) \\ &+ \xi_{1,t}(\pi_{H,t} - \beta \mathbb{E}_t(\pi_{H,t+1}) + \lambda(1-\alpha(1-\nu))\hat{s}_t) \\ &+ \boldsymbol{\xi}_{2,t}'(-\hat{\mathbf{q}}_t + \mathbf{k}_\tau \tau_t - \mathbf{k}_s \hat{s}_t)\Big)\end{aligned}$$

The first-order conditions are

$$\gamma_s \hat{s}_t + \mathbf{q}' \mathbf{k}_x + \lambda(1-\alpha(1-\nu))\xi_{1,t} - \boldsymbol{\xi}_{2,t}' \mathbf{k}_s = 0$$

$$\gamma_\pi \pi_{H,t} + \xi_{1,t} - \xi_{1,t-1} = 0$$

$$\hat{s}_t \mathbf{k}_x + \Sigma \mathbf{q}_t - \boldsymbol{\xi}_{2,t} = 0$$

Arranging terms yields

$$\lambda \xi_{1,t} = -\hat{s}_t \underbrace{(1-\alpha(1-\nu))(\gamma_s - 2\mathbf{k}_s' \mathbf{k}_x + \mathbf{k}_s' \Sigma \mathbf{k}_s)}_{M_s} + \underbrace{(1-\alpha(1-\nu))(\mathbf{k}_\tau' \Sigma \mathbf{k}_s - \mathbf{k}_\tau' \mathbf{k}_x)}_{M_\tau} \tau_t$$

Using the Phillips curve and the optimal producer price inflation yields the optimal path of the terms of trade wedge.

$$\hat{s}_{t+1} = (\frac{\gamma_\pi \lambda^2 (1-\alpha(1-\nu))}{\beta M_s} + 1 + \frac{1}{\beta})\hat{s}_t - \frac{1}{\beta}\hat{s}_{t-1} - \frac{M_\tau}{M_s}(\frac{1}{\beta} - 1 + \rho)\tau_t + \frac{M_\tau}{\beta M_s}\tau_{t-1}$$

The solution in the initial period is equation (32). The solution to the producer price inflation in the initial period is equation (33). All other results follow.

Appendix References

Galí, Jordi, *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, Princeton University Press, June 2015.

Itskhoki, Oleg and Dmitry Mukhin, "Optimal Exchange Rate Policy," Technical Report, National Bureau of Economic Research December 2023.

Witheridge, William, "Monetary Policy and Fiscal-led Inflation in Emerging Markets," 2024.