Could Tariffs Provide a Stimulus? In Search of Elusive Benefits of Protectionism

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Abstract

Motivated by the classical argument for protectionism as demand management, this paper shows two mechanisms under which temporary tariffs stimulate consumption. First, I show that in complete-market, small open-economy New Keynesian models with roundabout production, tariffs do not raise consumption under flexible prices or when active monetary policy follows targeting rules. The first mechanism requires an accommodative monetary policy toward producer price inflation under a fiscal-led price determination regime, or at the zero lower bound. It predicts that U.S. tariffs *depreciate* the dollar, as observed around the "Liberation Day" tariffs. Incomplete-market models using trade elasticities well below one can predict rising consumption, but achieving this with realistic values of trade elasticities is possible due to the second mechanism. It requires that input-output linkages amplify the impact of an appreciation of the terms of trade on improving consumption enough to offset countervailing forces from lower wages and employment. Tariffs misallocate inputs used in production, and the optimal monetary policy can be either expansionary or contractionary.

Keywords: tariffs, production network, monetary policy

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1 Introduction

Protectionism has re-emerged repeatedly since the very beginning of global trade. One objective is to use tariffs as a macroeconomic policy to manage aggregate demand, as Keynes (Eichengreen, 2019) advocated in the 1930s. Tariffs reallocate spending that would otherwise be on foreign goods to domestic products, the so-called expenditure switching channel. Trade policy as a macro stabilization policy is therefore theoretically feasible if this expenditure channel offsets other negative forces. To date, theoretical foundations and empirical evidence[1] on tariffs boosting consumption, the largest component in aggregate demand, remain absent. Keynes' original narrative rested on extreme macroeconomic conditions, such as deep recessions and inactive monetary stabilization under the gold standard or at the zero interest lower bound. A few theoretical studies (Jeanne, 2021; Barattieri et al., 2021; Auray et al., 2024) focusing on these extremities still show opposing results on stimulus effects of trade policy on consumption. Without any stimulus in consumption, the seeming improvement of aggregate demand from merely reallocating expenditure otherwise spent on foreign goods remains counterproductive to macroeconomic objectives.

Could temporary trade barriers ever stimulate consumption? This paper offers two theoretical mechanisms and provides evidence of the empirical relevance of these two mechanisms. Inputs in production play an important role in both mechanisms. This paper also offers a new perspective on conducting monetary policy under complete markets once planners consider the misallocation between inputs and labor due to trade policy.

The paper first proves a very general result about the relationship between consumption and trade barriers within the class of complete-market, small open-economy models with roundabout production. Tariffs reduce consumption under flexible prices and under a monetary policy targeting domestic producer price inflation. This targeting rule has been found to achieve allocations close to the optimal monetary policy Egorov and Mukhin (2023). The result that tariffs depress consumption holds regardless of parameter values in the commonly used one-sector roundabout economy and also holds in an economy with arbitrary production networks under a perfectly elastic labor

[1] Table 1 has a comprehensive list of these studies.

supply.[2]

The first theoretical result is that, as monetary policy becomes more accommodating to producer price inflation, consumption can 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—is necessary for temporary tariffs to increase 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 [3]. Monetary policy is crucial for the net effects from the supply and the demand sides. As monetary policy allows domestic inflation, the supply-side force of lowering the real interest rate is dominant.

When trade policy does stimulate consumption under this mechanism related to inflation expectations, nominal exchange rates depreciate, the opposite of the prediction of nominal appreciation in standard theories. Trump's global tariffs in April 2025 provided a rare case study to test this mechanism in high-frequency event studies of the dollar exchange rate because his tariffs were unexpected and applicable to all U.S. trade partners. The observation that the dollar depreciated following Trump's global tariffs is consistent with the model's prediction: temporary tariffs depreciate the dollar if the market views the U.S. as experiencing a fiscal-led regime with passive monetary policy at that moment determining the price level.

The second theoretical mechanism requires that the input-output linkages amplify the propagation of the terms of trade. I show that in flexible-price small open-economy models with imperfect risk sharing, tariffs can stimulate consumption when the model is calibrated to a trade

[2] Although analytical results are possible only under a perfectly elastic labor supply, the result of falling consumption on impact can be quantitatively verified in a two-sector model with an arbitrary production structure by searching over a realistic parameter space.

[3] 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. As Appendix Section D shows, without inputs in production, even if the world economy faces the zero lower interest rate bound, making monetary policy ineffective, tariffs still *depress* global demand, even though tariffs generate expected inflation.

elasticity well below one. The exact role of the production network is to achieve the same outcome without relying on unrealistic trade elasticities. I analyze an incomplete-market model with arbitrary production networks approximated to second order. This second-order approximation allows propagation through firms' expenditure switching between labor and inputs. To illustrate the importance of this firm-side expenditure switching between factors in production, I analyze a simplified two-sector model with input-output linkages. Under a certain production structure, this model generates a positive response of consumption to tariff shocks. Comparing outcomes from using a Cobb-Douglas production function and a production function with an elasticity substitution between labor and inputs above one, the model shows that firms' substitution between factors further boosts the positive effects on consumption.

Production networks also reduce the degree of risk sharing. In this model of segmented financial markets with a risk-averse arbitrageur, the premium he charges is a weighted sum of sectoral terms of trade. This weighted sum follows a stationary process, but the individual sectoral terms of trade follow an integrated process with martingale terms. In a few numerical examples, this non-stationary sectoral terms of trade can contribute to a one-third response of consumption to tariffs.

A counterintuitive result is that tariffs boost consumption while tariffs reduce employment and real wages. In the second mechanism, the positive effect from the terms of trade appreciation on consumption completely offsets negative effects from lower real wages. I calibrate the input-output matrix to the U.S. economy and find that tariffs, in principle, stimulate consumption when the trade elasticity is above but close to 1 and the trade policy is very persistent.

Inputs also have direct implications 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 as 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 that strictly targets producer price inflation completely eliminates the wedges in consumption and the 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.

Contributions This paper makes four theoretical contributions. The paper is the first paper focusing on the consumption response to trade policy and showing a negative consumption response to trade barriers in complete-market small open-economy models. Recent works, such as Kalemli-Ozcan et al. (2025), Bianchi and Coulibaly (2025), Monacelli (2025), Bergin and Corsetti (2023), and Auclert et al. (2025), show that tariffs are recessionary and inflationary. This recent literature recognizes the ambiguous responses of output and nominal exchange rates, which depend on structural parameters such as trade elasticities and the intertemporal elasticity of substitution. My contribution is to show the prediction that tariffs depress consumption under flexible PPI targeting and that it holds for any values of the structural parameters in a one-sector roundabout economy commonly used the literature. This result also holds in a multi-sector setting with an arbitrary production network, Cobb-Douglas production functions and a perfectly elastic labor supply. To put this result into perspective, this paper shows that complete-market models exhibit a positive correlation between consumption and real exchange rates—the Backus-Smith puzzle—even though the fundamental risk only comes from trade policy.

The second and third theoretical contributions provide two completely different explanations for using trade policy to stimulate consumption. The explanation based on accommodative monetary policy toward PPI inflation is the first in this recent literature at the intersection of trade policy and the macroeconomy. A few studies analyzing trade policy under different monetary policy regimes have not found support for rising consumption. Beyond PPI targeting, Kalemli-Ozcan et al. (2025) considers real interest rate targeting, under which consumption is constant. Monacelli (2025) and Bianchi and Coulibaly (2025) show the possibility of a one-time rise in consumption under CPI targeting followed by a large decline to negative values. This one-time rise in consumption is completely different from the persistent stimulative effects under my mechanism.[4]

The third contribution is developing an analytically tractable small open-economy model with arbitrary constant returns-to-scale (CRS) production functions and providing analytical solutions under both complete and incomplete markets. Tariffs can stimulate consumption in this model. Relative to Qiu et al. (2025) on production networks in a small open economy with balanced trade, my model allows trade imbalances, and I show a novel implication that production networks can reduce risk sharing. Independent contemporary work from Kalemli-Ozcan et al. (2025) develops a production network model of the global economy which nests the model in this paper. Their analytical derivation assumes perfectly elastic labor supply and a CES production function with homogeneous sectoral elasticity of substitution among inputs and labor, but my derivations consider general CRS production functions and a general labor supply elasticity. Although Kalemli-Ozcan et al. (2025) considers a general labor supply elasticity in their qualitative section, they conclude that "[e]lasticity of substitution contributes positively to production and net exports; however, it does not directly contribute to other variables meaningfully". This argument is the opposite of this paper's findings: firms' expenditure switching between labor and inputs amplifies the consumption response to tariffs, making consumption rise even more.

The fourth contribution is deriving a quadratic welfare loss function and the optimal monetary policy when the flexible price competitive equilibrium is suboptimal due to misallocation between labor and inputs used in production. Existing works, such as Bianchi and Coulibaly (2025) in the context of tariffs, have analyzed optimal monetary policy when the social planner lacks fiscal

[4] The paper focuses on small open economies, but in the Appendix Section D, I place this mechanism based on accommodative monetary policy into the context of large open economies at the zero lower bound. My mechanism, along with the amplification of expected inflation from inputs in production, contributes to resolving the debate of trade policy at the worldwide ZLB: it shows the positive effects of tariffs on global demand in a global liquidity trap, in contrast to the predominantly negative effects found in existing studies (Jeanne, 2021; Barattieri et al., 2021; Auray et al., 2024).

instruments to restore efficient allocation, leading to a distorted steady state. The terms of trade externality creates misallocation even in the absence of nominal frictions. Bianchi and Coulibaly (2025)'s analysis of the optimal monetary policy considers the production function with inputs but without the terms of trade externality and without inputs but with the terms of trade externality. Monacelli (2025)[5] argues that having inputs or not does not alter results, including the optimal monetary policy, quantitatively, and he advocates expansionary monetary policy in response to tariff shocks under complete markets. My formula for the optimal monetary policy considers both inputs and the terms of trade externality. Although the setting of complete market is different from Bianchi and Coulibaly (2025), my key result that the optimal monetary policy can be either expansionary or contractionary relative to strict PPI targeting speaks to Monacelli (2025). More broadly, my welfare analysis highlights the non-trivial role of inputs. This paper further develops a Lagrangian approach to deriving a quadratic welfare loss function based on Itskhoki and Mukhin (2023).

This paper starts with a baseline model and discusses the propagation of trade policy to consumption in Section 2. Section 3.1 proposes two theoretical mechanisms through which temporary tariffs can stimulate consumption. Section 4 shows the role of monetary policy in stabilizing allocation inefficiency using a simplified production structure under roundabout production. Section 5 concludes.

2 The propagation of trade policy to consumption in a networked economy

2.1 Real-world trade policy v.s. temporary tariff shocks following AR(1)

This section motivates modeling real-world trade policy as an AR(1) process. Throughout the paper, unexpected tariff shocks occur at the initial period and dissipate according to an auto-regressive

[5] See page 12 of Monacelli (2025).

process, in which the coefficient ρ satisfies $0 \leq \rho < 1$. The only exception is when analyzing the response to trade policy when the economy is at the zero lower bound on interest rates. At the ZLB, trade policy, in a discrete fashion, implements tariffs at the zero lower bound, and ρ, the probability of the economy remaining at the zero lower bound in the next period, is interpreted as the expectation of tariffs being put in place in the next period. Trade policy modeled in both ways can be thought of as a deviation from long-run free trade and such deviations are expected to vanish in the long run.

In reality, a common view is that tariffs are in place for a very long time without any changes, the opposite of what an AR(1) process describes. The nuanced real-world interpretation consistent with AR(1) in the model is that tariffs on disaggregated goods are gradually removed so that the average tariff for a category of goods or a sector is gradually lowered just as in an AR(1) process. In trade data, this average tariff, also called the effective tariff rate, is the total duties divided by the total import value. Therefore, the real-world interpretation of "temporary" or "short-run" trade policy is the gradual reduction in effective average tariffs for broad categories of goods or across sectors.

Real-world trade policy is in fact frequently revised with the exclusions of goods. Trump's tariffs on Chinese goods were implemented in this way in 2018. After the initial tariffs, goods were added to a list of products excluded from tariffs. After the implementation of his 15% tariffs on European goods in August 2025, he then excluded tariffs on some chemical goods in September 2025 (Federal Register 90 FR 46136).

2.2 Baseline model

This section lays out a small open economy model with complete asset markets, M sectors linked in an arbitrary production network structure, and tariff shocks. Relative to the textbook treatment in Galí (2015), the latter two elements are additional ingredients in this paper. Sector-level tariff shocks are uniform for goods within a sector. Shocks across different sectors follow an identical AR(1) process with the same persistence. The introduction of international trade in models with production networks directly extends work in closed economies by Afrouzi and Bhattarai (2023) and Rubbo (2023). A simplifying assumption is the identical trade openness and trade elasticity for sectors producing consumption goods and inputs. This assumption allows the model to explicitly pinpoint the role of the production structure. Given a production structure, introducing heterogeneous trade openness and trade elasticity across sectors does affect the outcomes quantitatively.

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

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

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 $U(C_t, N_t) = \frac{C_t^{1-\sigma}-1}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi}$ for $\sigma \neq 1$. When the inverse of the Frisch elasticity, φ, is zero, the model features a perfectly elastic labor supply. P_t is the price of the final consumption bundle C_t. The consumption aggregator of sectoral consumption $\{C_{m,t}\}_{m=1}^{M}$ is $C_t = \mathcal{C}(C_{1,t}, ..., C_{M,t})$. I assume the functional form of the aggregator is a Cobb-Douglas with sectoral consumption shares β_m^c. Since empirical studies show that the elasticity of substitution for sectoral consumption is slightly less than 1 (Atalay, 2017), this functional form is consistent with empirical evidence. Home-biased sectoral consumption, $C_{m,t}$, consists of home goods $C_{mH,t}$ and foreign consumption goods $C_{mF,t}$ bundled using a CES aggregator $C_{m,t} = \left((1-\nu)^{\frac{1}{\eta}} C_{mH,t}^{\frac{1-\eta}{\eta}} + \nu^{\frac{1}{\eta}} C_{mF,t}^{\frac{1-\eta}{\eta}}\right)^{\frac{\eta}{\eta-1}}$, with the degree of home bias $1-\nu \in (0.5, 1)$ and trade elasticity[6] $\eta > 0$. Home consumption goods come from bundling differentiated varieties, $Y(i)_{m,t}$, produced at home, where the elasticity of substitution among varieties is ϵ. The consumption of home goods is $C_{mH,t} = (\int Y(i)_{m,t}^{\frac{\epsilon-1}{\epsilon}} di)^{\frac{\epsilon}{\epsilon-1}}$. Home importers in sector m pay a uniform sectoral tariff $\tau_{m,t}$ on foreign-produced consumption goods $C_{mF,t}$ and inputs $X_{mF,t}$, as discussed below. Tariff revenues T_t are transferred to households in lump-sum payments.

Households save in state-contingent bonds D_{t+1}. $Q_{t,t+1}$ is the stochastic discount factor for

[6] When $\eta = 1$, $C_{m,t} = \frac{1}{(1-\nu)^{1-\nu}\nu^{\nu}} C_{mH,t}^{1-\nu} C_{mF,t}^{\nu}$. This corresponds to a price index given by $P_{m,t} = P_{mH,t}^{1-\nu} P_{mF,t}^{\nu}$.

nominal payoffs. From the households' optimal labor supply choice, it follows that $C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t}$, where W_t/P_t is the real wage. Given the consumption level in the rest of the world, C_t^*, and the foreign price $\frac{P_{m,t}^*}{P_t^*}$ in sector m normalized by the foreign CPI, P_t^*, the risk-sharing condition under complete markets is

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

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, $\mathcal{E}_t P_{m,t}^* = P_{mF,t}$, to express the "sectoral real exchange rate", $\frac{\mathcal{E}_t P_{m,t}^*}{P_t}$, as the (tariff-exclusive) import prices relative to domestic consumer prices, $\frac{P_{mF,t}}{P_t}$.

Production Monopolistically competitive firms indexed by $i \in [0, 1]$ within each sector m produce differentiated variety i used for inputs and consumption. Firm employs labor and uses inputs $X(i)_{mj,t}$ from sector j according to $Y(i)_{m,t} = \mathcal{F}_m(N(i)_{m,t}, \{X(i)_{mj,t}\}_{j=1}^M)$. Production is constant returns to scale. These inputs are produced by combining home and foreign varieties using the same aggregation function as the consumption bundles. Therefore, the price of inputs is the same as that of the final consumption goods in sector m. Firms receive production subsidies that exactly offset markups in the non-stochastic steady state. 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 $W_t N(i)_{m,t} = \alpha_{m,t} MC_{m,t} Y(i)_{m,t}$, and the optimal demand for the final input produced by sector j is $P_{j,t} X(i)_{mj,t} = \alpha_{0m,t} MC_{m,t} Y(i)_{mj,t}$. Due to the property of a homogeneous of degree one production function, the marginal cost $MC_{m,t}$ and the expenditure shares of labor $\alpha_{0m,t}$ and inputs $\alpha_{mj,t}$ only depend on the wage rate W_t and the prices of inputs $\{P_{m,t}\}_{m=1}^M$. After aggregating across factor demands and using the definition of the aggregate factor demand ($N_{m,t} = \int N(i)_{m,t} di$ and $X_{mj,t} = \int X(i)_{mj,t} di$) and the demand for the differentiated good $Y(i)_{m,t} = (\frac{P_{mH,t}(i)}{P_{mH,t}})^{-\epsilon} Y_{m,t}$, factor demands become $W_t N_{m,t} = \alpha_{m,t} MC_{m,t}^d Y_{m,t}$ and $P_{j,t} X_{mj,t} = \alpha_{0m,t} MC_{m,t}^d Y_{mj,t}$, where $MC_{m,t}^d = MC_{m,t} d_{m,t}$ is the marginal cost adjusted for sectoral price dispersion $d_{m,t} = \int (\frac{P_{mH,t}(i)}{P_{mH,t}})^{-\epsilon} di$.

Market clearing, aggregation, and the steady state The goods market clearing condition is $Y_{m,t} = C_{mH,t} + \sum_j X_{jmH,t} + \nu(\frac{P_{mH,t}}{P_{mF,t}})^{-\eta} Y^*_{m,t}$, where $Y^*_{m,t}$ is the exogenous foreign demand. Moreover, foreign demand depends on $\frac{P^*_{mH,t}}{P^*_{m,t}}$, and applying the Law of One Price and the "small" open economy assumption $P_{mF,t} = \mathcal{E}_t P^*_{m,t}$ gives $\frac{P^*_{mH,t}}{P^*_{m,t}} = \frac{\mathcal{E}_t P^*_{mH,t}}{\mathcal{E}_t P^*_{m,t}} = \frac{P_{mH,t}}{P_{mF,t}}$. The labor market clearing condition is $N_t = \sum_m N_{m,t}$. Let the tariff-exclusive terms of trade be the relative prices of home- and foreign-produced sectoral goods, $S_{m,t} = P_{mH,t}/P_{mF,t}$.

Throughout the paper, I make a few assumptions for the steady state. First, inflation and tariffs are zero. Second, the home country and the rest of the world have identical holdings of assets and the real exchange rate is unitary in the steady state, implying the level of consumption in the home country and the rest of the world is identical according to the risk-sharing condition. I normalize sectoral prices and wages by the CPI and then define the equilibrium. Appendix A.1 defines the competitive equilibrium along with the conditions in the steady state.

Log-linearized equilibrium Let variables in lowercase denote deviations from the non-stochastic steady state. Table 2 summarizes model variables and parameters for the baseline model. Given the nominal interest rate i_t and the system of equations below, the equilibrium consists of quantities $\{c_t, n_t\}$, prices $\{\pi_t, \boldsymbol{s_t}, \boldsymbol{p_t}, \boldsymbol{\pi_{H,t}}\}$. In particular, the risk-sharing condition (eq 4) uses the identity of the sectoral price index $p_{m,t} = (1-\nu)p_{mH,t} + \nu(\tau_{m,t} + p_{mF,t})$. Moreover, the Phillips curve (eq 5) expresses the markup $\mu_{m,t} \equiv p_{mH,t} - mc_{m,t}$ in prices using the identity $mc_{m,t} = w_t \alpha_{0m} + \sum_k \alpha_{mk} p_{k,t}$ for the homogeneous of degree one production function. The aggregate labor demand in eq 9 is written in a general form using a function $\mathcal{K}(.)$. This function comes from log linearizing aggregate labor supply, normalized by domestic expenditure:

$$\frac{W_t}{P_t}\frac{N_t}{C_t} = \mathbf{1}^\top (\boldsymbol{B_{H,t}} + (\boldsymbol{\mu_t} - \boldsymbol{B_{H,t}})\boldsymbol{\Psi_t}^\top)^{-1}(\boldsymbol{B_{H,t}}\boldsymbol{\beta^c} + \boldsymbol{\beta^{c*}_{H,t}}) \tag{2}$$

$\boldsymbol{B_{H,t}} = diag(\{\frac{P_{mH,t}C_{mH,t}}{P_{m,t}C_{m,t}}\})$. Each diagonal element is the consumption share of home goods within each sector, and each off-diagonal element is zero. $\boldsymbol{\beta^{c*}_{H,t}} = diag(\{\frac{P_{mH,t}X^{*}_{m,t}}{P_t C_t}\})$. Each diagonal element is the share of foreign sectoral output at domestic prices relative to domestic consumption expenditure. $\mathcal{K}(.)$ involves the second-order approximation of sectoral production, which requires the first-order approximation of the input-output matrix $\boldsymbol{\Psi_t}$. Knowing the Allen elasticities of substitutions is sufficient to define the second-order approximation. This feature is unique to production networks in the open economy. Using Allen elasticities contrasts with models in the closed economy. There, $\boldsymbol{B_{H,t}}$ is the identity matrix and $\boldsymbol{\beta^{c*}_{H,t}}$ is absent.

$$\text{Consumption share: } \boldsymbol{\beta^{c}}^{\top}\boldsymbol{p_t} = 0 \tag{3}$$

$$\text{Risk sharing: } -\sigma c_t \mathbf{1} + \boldsymbol{p_t} - (1-\nu)\boldsymbol{s_t} - \nu\boldsymbol{\tau_t} = \mathbf{0} \tag{4}$$

$$\text{Phillips curve: } \boldsymbol{\pi_{H,t}} = \beta\mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) + \lambda(w_t\boldsymbol{\alpha_0} + (\boldsymbol{A}-\boldsymbol{I})\boldsymbol{p_t} - \nu\boldsymbol{s_t} + \nu\boldsymbol{\tau_t}) \tag{5}$$

$$\text{Definition of CPI inflation: } \boldsymbol{\pi_{H,t}} - \pi_t\mathbf{1} = \Delta\boldsymbol{p_t} + \nu\boldsymbol{s_t} - \nu\Delta\boldsymbol{\tau_t} \tag{6}$$

$$\text{Labor supply: } \sigma c_t + \varphi n_t = w_t \tag{7}$$

$$\text{IS curve: } c_t = \mathbb{E}_t(c_{t+1}) - \frac{1}{\sigma}(i_t - \mathbb{E}_t(\pi_{t+1})) \tag{8}$$

$$\text{Aggregate production: } w_t + n_t - c_t = \mathcal{K}(c_t, \boldsymbol{s_t}, w_t, \boldsymbol{\tau_t}) \tag{9}$$

2.3 The mechanism of trade policy propagation in a simplified model with roundabout production

I use a one-sector roundabout production with the production function $Y(i)_t = N(i)_t^{1-\alpha}X(i)_t^{\alpha}$ to illustrate the mechanism of depressed consumption under PPI targeting. The log-linearized labor supply condition is

$$\sigma c_t + \varphi n_t = w_t = \frac{mc_t}{1-\alpha} \tag{10}$$

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 (10).

$$(1 + \varphi\alpha)n_t = y_t - \alpha\sigma c_t \tag{11}$$

The CES aggregator implies that 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 the consumer price, $\frac{P_{F,t}}{P_t}$. Domestic producer prices can be expressed in relation to the terms of trade and tariffs.

$$p_{H,t} = \nu s_t - \nu\tau_t \tag{12}$$

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

$$\sigma c_t = -(1 - \nu)s_t - \nu\tau_t \tag{13}$$

The two expressions above provide insight into the differences 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 (13) 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.

$$\pi_{H,t} = \pi_t - \Delta p_{H,t} = \pi_t - (\nu\Delta s_t - \nu\Delta\tau_t) \tag{14}$$

The log-linearized households' Euler equation is

$$c_t = \mathbb{E}_t(c_{t+1}) - \frac{1}{\sigma}(i_t - \mathbb{E}_t(\pi_{t+1})) \tag{15}$$

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

$$\kappa_y y_t = -\kappa_s s_t + \kappa_c c_t + \kappa_\tau \tau_t \tag{16}$$

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

$$\pi_{H,t} = \beta\mathbb{E}_t(\pi_{H,t+1}) + \lambda(mc_t - p_{H,t}) \tag{17}$$

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 (10)-(17) characterize the equilibrium.

I first show that tariffs in the baseline complete-market Neoclassical model reduce consumption. 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 (10), (11), (16), (13), (12), and firms' optimal pricing $p_{H,t} = mc_t$ jointly characterize the equilibrium. Substituting equations (10), (11), and (12) into firms' optimal pricing yields a relationship between consumption, output, terms of trade and the 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 (13)) and the market clearing (equation (16)) yields the equilibrium effects of tariffs on consumption: $\frac{dc_t}{d\tau_t} < 0$. Tariffs depress consumption. The reason 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.

Tariffs under a PPI-targeting monetary policy rule In the presence of nominal frictions and an interest rate rule targeting PPI, depressed consumption in the Neoclassical model carries over. 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.

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, the equations 18-20 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 (16) determines the response of output.

$$\pi_{H,t} = \beta \mathbb{E}_t(\pi_{H,t+1}) + \lambda\left(\sigma(\frac{1}{1-\nu} - \alpha)c_t + \frac{\nu}{1-\nu}\tau_t\right) \tag{18}$$

$$c_t = \mathbb{E}_t(c_{t+1}) - \frac{1-\nu}{\sigma}\big(i_t - \mathbb{E}_t(\pi_{H,t+1}) - \frac{\nu}{1-\nu}\mathbb{E}_t(\Delta\tau_{t+1})\big) \tag{19}$$

$$i_t = \max\{-r^n, \phi_\pi \pi_{H,t}\} \tag{20}$$

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 (18)), whereas expected tariffs enter the IS curve (equation (19)).

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 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 flatter as the share of inputs in production increases.

The response of consumption to tariffs in general equilibrium is

$$\frac{dc_t}{d\tau_t} = -\frac{\nu\sigma^{-1}}{\mathcal{M}}\left\{\lambda(\phi_\pi - \rho) + (1-\rho)(1-\beta\rho)\right\} < 0 \tag{21}$$

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 intertemporal 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 21.

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 the 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. Contemporary works by Kalemli-Ozcan et al. (2025) and Monacelli (2025) also show that the response of output is ambiguous.

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

$$\pi_{H,t} = \beta \mathbb{E}_t(\pi_{H,t+1}) + \lambda_c c_t + \lambda_\tau \tau_t \tag{22}$$

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

$$\frac{dc_t}{d\tau_t} = -\frac{(1-\beta\rho)(1-\rho)\frac{\nu}{\sigma} + \frac{1-\nu}{\sigma}(\phi_\pi - \rho)\lambda_\tau}{(1-\beta\rho)(1-\rho) + \frac{1-\nu}{\sigma}(\phi_\pi - \rho)\lambda_c} < 0 \tag{23}$$

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

Proposition 1 *Tariffs depress consumption under roundabout production 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.2.2 for the proof).*

In sum, whenever monetary policy targets PPI[7], the inflationary effects arising from tariffs and the rising nominal interest rate dominate any countervailing channels, increasing the real interest rate, and further reducing consumption.

From the risk-sharing condition, falling consumption also implies that the real exchange rate appreciates. Under the assumption that the prices of imports equal the foreign CPI in the home country's currency, $P_{F,t} = \mathcal{E}_t P_t^*$, the initial change in the exchange rate can be expressed using the terms of trade and domestic producer price inflation $e_0 = -s_0 + \pi_{H,0}$. Using the equilibrium response of consumption, terms of trade, and inflation from Proposition 1, and applying a monetary policy that only targets producer price inflation ($\phi_y = 0$) and assuming the restrictions on

[7] Under strict PPI targeting, consumption falls. Setting $\pi_{H,t} = \mathbb{E}_t(\pi_{H,t}) = 0$ in equation (22) implies $c_t = -\frac{\lambda_\tau}{\lambda_c}\tau_t < 0$.

parameters of tariff shock persistence, input share, and the labor supply elasticity ($\rho = \alpha = 0$, and $\varphi = 1$), the impact response of the nominal exchange rate is

$$\frac{de_0}{d\tau_0} = (1 - \sigma\eta)(\phi_\pi - 1)\mathcal{M}^{fx} \tag{24}$$

where $\mathcal{M}^{fx} = \frac{\lambda\nu}{\sigma+\lambda\phi_\pi(1-\nu)(\sigma+1-\nu+\frac{\sigma\nu}{1-\nu}(1+\eta(2-\nu))} > 0$.

Generally, a simple model can in principle generate nominal exchange rate depreciation but at the cost of unrealistic parameter restrictions. The reason is that tariffs are highly recessionary in this case by depressing consumption and output. As a result, terms of trade is lowered and domestic producer price inflation is subsequently lowered. This means that the relative price of foreign goods is higher, which is isomorphic to nominal exchange rate depreciation, as the foreign price level is held constant.

Although the focus is PPI targeting, I show in Appendix A.3.2 that tariffs also depress consumption under strict CPI targeting. When monetary policy follows a general rule targeting CPI, consumption may rise on impact followed by a decline. However, this occurs only under certain parameter values. Contemporary work by Monacelli (2025) also points this out. What is also left for consideration is real interest rate targeting, for example in Kalemli-Ozcan et al. (2025). Again, consumption stays constant instead of rising.

Overall, when monetary policy actively manages inflation, regardless of PPI or CPI, no matter how strict they are, short-run trade policy unambiguously depresses demand. In the next section, I show that this simple conclusion carries over to a realistic economy with input and output linkages.

2.4 PPI targeting and the propagation of tariff shocks in production networks

In light of the previous results in the simplified production structure, this section shows that consumption falls under a generalized PPI targeting rule and a general production structure. I focus on the case in which tariffs are uniform across sectors so that the vector of tariff shocks is $\boldsymbol{\tau_t} = \tau_t\mathbf{1}$.

I start with the special case of perfectly elastic labor supply $\varphi = 0$. The IS curve, Phillips curve and the risk-sharing condition in vector form below pin down the equilibrium. Here, the aggregate production does not affect outcomes, and the input-output linkages merely amplify/dampen the response of prices and do not provide additional transmission mechanisms.

$$\sigma c_t + (1-\nu)\boldsymbol{\beta^{c}}^{\top}\boldsymbol{s_t} + \nu\tau_t = 0$$

$$\boldsymbol{\pi_{H,t}} = \beta\mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) + \lambda(-(\boldsymbol{I} - (1-\nu)\boldsymbol{A})\boldsymbol{s_t} + \nu\tau_t\boldsymbol{\alpha_0})$$

$$\mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) - \boldsymbol{\phi}^{\top}\boldsymbol{\pi_{H,t}}\mathbf{1} = \mathbb{E}_t(\Delta\boldsymbol{s_{t+1}})$$

Combining them yields the equilibrium response of consumption to uniform tariffs. The following proposition summarizes the result.

Proposition 2 *Under a perfectly elastic labor supply and monetary policy,* $i_t = \max(-r^n, \boldsymbol{\phi}^{\top}\boldsymbol{\pi_{H,t}})$*, targeting sectoral PPI inflation with weights* $\phi_m > 1$*, uniform tariffs across sectors depress consumption for any production network structure (see Appendix A.2.3 for the proof).*

Aggregate production determines the equilibrium when the labor supply curve is not perfectly elastic ($\varphi > 0$). Proving that consumption falls in this complete-market model for an arbitrary production network and any labor supply elasticity is challenging. I focus on a version of the model under PPI targeting when the production function is approximated to first order. Using a numerical search procedure, I cannot find a positive response of consumption for any production network structure or within a reasonable range of labor supply elasticities.

This first-order approximation of the production function is equivalent to assuming a Cobb-Douglas production function. The substitution between labor and inputs vanishes. In the next section, firms' expenditure switching between labor and inputs requires a *second-order* approximation of the production function.

It is still useful to characterize the equilibrium for $\varphi > 0$. The risk-sharing condition and the labor supply remain the same. Using the definition of the labor shares $\boldsymbol{\alpha_0} = (\boldsymbol{I} - \boldsymbol{A})\mathbf{1}$, the Phillips curve in equation 5 can be written in terms of labor, $\boldsymbol{\pi_{H,t}} = \beta\mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) + \lambda(\varphi n_t \boldsymbol{\alpha_0} - (\boldsymbol{I} - (1 - \nu)\boldsymbol{A})\boldsymbol{s_t} + \nu \boldsymbol{A}\mathbf{1}\tau_t)$.

Since the aggregate production function is defined in conjunction with the aggregate labor market clearing condition, the first-order approximation of the production function can be interpreted as showing how labor demand is affected by domestic demand, sectoral terms of trade, and tariffs in equilibrium.

$$
\begin{aligned}
&(1 + \varphi(1 - \mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{\alpha_0})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c}))n_t \\
&= -(\sigma - 1)(1 - \nu)\mathbf{1}^\top \boldsymbol{\Omega}^{-1}\boldsymbol{\beta^c} c_t \\
&\quad + \nu(1 - \nu)(\eta - 1)\mathbf{1}^\top(\boldsymbol{I} - (1 - \nu)\boldsymbol{A}^\top)^{-1}\boldsymbol{\beta^c}\tau_t - (1 + \nu(2 - \nu)(\eta - 1))\mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{s_t})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c} \\
&\quad + (1 - \nu)\mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{A}\boldsymbol{s_t})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c} + \nu \mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{A}\mathbf{1})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c}\tau_t
\end{aligned}
$$

The first line is the effect of changes in real wages on firms' labor demand, while the second line shows how the expenditure switching from the real exchange rate affects demand and hence the use of labor in production. In the second line, the demand for domestic goods rises as the direct effect of rising import prices. Falling terms of trade also achieve the same effect of promoting domestic demand. The third line describes how rising output prices directly increase production and the demand for labor.

3 Trade policy and stimulus in consumption: two mechanisms

3.1 Accommodative monetary policy to producer price inflation

This section shows that tariffs may stimulate demand under alternative monetary policy regimes: 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 and the production structure do not influence the qualitative argument for demand-stimulating tariffs. Therefore, to simplify the exposition while focusing on the key mechanism, I assume the economy follows a simple roundabout production structure and the labor supply is perfectly elastic, $\varphi = 0$, as in Section 2.3. Although this is a special case of the production network, previous results already show that consumption falls under perfectly elastic labor supply regardless of the structure of the production network. Showing the opposite result under alternative monetary policy in a simplified model is therefore sufficient to highlight the importance of this mechanism.

3.1.1 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.

$$d_t^G = \frac{1-(1-\beta)\gamma_d}{\beta} d_{t-1}^G + (\phi_\pi - \frac{1}{\beta})\pi_{H,t} \tag{25}$$

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 the discount factor such that $\lambda + \beta >$

1. Standard calibrations generally satisfy this assumption.

Proposition 3 *When $\lambda+\beta>1$, consumption rises in the initial response to tariff shocks, $\frac{dc_0}{d\tau_0}>0$. Moreover, tariffs are inflationary, $\frac{d\pi_{H0}}{d\tau_0}>0$ (see Appendix A.4 for the proof).*

The real fiscal balance is a state variable implied by the fiscal policy rule, and the stability of forward looking producer price inflation and consumption requires either fiscal policy or monetary policy has a large reaction to tariff shocks. In a passive monetary policy regime, equation (25) shows that the real value of debt has an auto-regressive coefficient greater than 1, ensuring stability.

While the anticipation of future lower tariffs does increase the real interest rate due to the intertemporal consumption trade-off, the intuition behind rising consumption is that monetary policy can afford a rise in inflation and that the expected inflation created is large enough to offset the rise in the real interest rate directly from anticipated lower tariffs. While higher inflation does help the government inflate away the debt and government can afford a larger real balance, the fiscal rule with the parameter $\gamma_d<1$ states that tax revenues grow at a slower pace than debt, preventing the debt from blowing up.

3.1.2 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 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 $\zeta_L = log(Z_L)$. After setting $i = -r^n$ and applying the method of undetermined coefficients to equations (19) and (18), adjusted for preference shocks, the equilibrium response of consumption is

$$c_L = -\frac{\nu}{\sigma}\frac{(1-\beta\rho)(1-\rho)-\lambda\rho}{\mathcal{N}}\tau_L - \frac{(1-\nu)(1-\beta\rho)}{\mathcal{N}}(-r^n - (1-\rho)(1+\nu)\zeta_L) \tag{26}$$

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).

Empirical relevance of passive monetary policy through "Liberation Day" tariffs The announcement of the U.S. "Liberation Day" tariffs in April 2025 offers an opportunity to validate the mechanism for demand-stimulating tariffs under passive monetary policy. Given that tariffs imposed by the small open economy model are for imports from the rest of the world, the global tariffs exactly match this criterion. Moreover, the announcement is unexpected and the majority of U.S. trading partners did not either announce or implement the retaliation[8]. Therefore, the high-frequency event study approach offers a plausible identification of the tariff shock on the exchange rate, as Benguria and Saffie (2025) and Ostry et al. (2025) did.

In the model, under the complete market setup, applying the risk sharing condition, the nominal exchange rate on impact from tariffs is $e_0 = -s_0 + \pi_{H,0} = \frac{\sigma c_0 + \nu\tau_0}{1-\nu} + \pi_{H,0}$. In a regime dominated by passive monetary policy, trade policy is inflationary and stimulative from the Propo-

[8]See Foreign Retaliations Timeline maintained by USITC at https://www.trade.gov/feature-article/foreign-retaliations-timeline.

sition 3. Therefore, the nominal exchange rate depreciates. Moreover, the impact of trade policy also implies that the terms of trade depreciate.

Figure 1 plots the dollar index around the announcement of tariffs. The sudden but small fall in the index (representing that the dollar depreciated on the next day of the announcement) confirms the model prediction, often deemed puzzling. Moreover, the American global tariffs also depreciated the terms of trade by lowering the export prices in April and May 2025 in Figure 2.

These two graphs together with observations from other works[9] show that the response of the exchange rates were unusual. As shown above, existing models explain this behavior but require unrealistically low trade elasticity parameters. The large-scale tariffs did not provoke any retaliations in practice other than by China. The explanation based on retaliation is not satisfactory in explaining the bilateral dollar depreciation with respect to nations that neither announced nor implemented retaliations.

3.2 Incomplete market and the amplification of the terms of trade appreciation within the production network

This section shows that the production network amplifies the propagation of the terms of trade to consumption in incomplete markets and that persistent trade policy can realistically stimulate consumption. The previous mechanism focuses on the role of monetary policy in a sticky-price environment, but the mechanism here does not rely on inflation expectations. To sharply isolate the channel, this section sticks to an environment without nominal frictions.

To get the intuition for why trade policy stimulates consumption in incomplete markets, I turn to the model of roundabout production in Section 2.3 of the simplest form by assuming perfectly elastic labor supply and no inputs in production. I follow Itskhoki and Mukhin (2023)'s approach

[9] Barattieri et al. (2021) in Figure 7 shows that the nominal exchange rate in Turkey appreciates on impact from antidumping investigations. There are no significant changes for Canada in Figure 6. In the online Appendix Figure 18.A, SVAR results indicate that Indian exchange rates depreciated. Benguria and Saffie (2025) and Ostry et al. (2025) shows that the announcement of "Liberation Day" tariffs depreciated the dollar. As they mention, this contrasts early evidence that U.S. tariffs on individual countries, such as China, Mexico, and Canada instead of tariffs at the global scale, appreciate the dollar. Ostry et al. (2025) argue that retaliations by trading partners would explain the depreciation of the dollar in April 2025.

of segmented financial markets with a risk-averse arbitrageur in defining the flexible price equilibrium. In this approach, the deviation from the uncovered interest parity depends on a parameter ω, which summarizes the risk aversion of the arbitrageur and the volatility of expected nominal exchange rate appreciation. I assume that the carry trade profits from the arbitrageur are not transferred to the home country.[10] The labor market clearing condition returns a simple relationship between consumption and the terms of trade: $\sigma c_t = \nu s_t - \nu \tau_t$. Rising consumption only happens when the terms of trade appreciate. The international risk sharing condition and the balance of payments will pin down these two variables.

$$
\begin{aligned}
&\text{Risk sharing: } \mathbb{E}_t(\Delta s_{t+1}) = -\omega b_t^*,\ \omega > 0 \\
&\text{Balance of payments: } b_t^* - \beta b_{t-1}^* = \nu(1 - 2\eta + \nu\eta)s_t - \nu c_t - \Lambda_\tau \tau_t \\
&\qquad\qquad\qquad\qquad\qquad\qquad = \Lambda_s s_t + \underbrace{\Lambda_\tau \tau_t}_{>0},\ \Lambda_s = \nu(1 - 2\eta + \nu\eta) - \frac{\nu^2}{\sigma}
\end{aligned}
$$

From the risk sharing condition, an initial appreciation of the terms of trade means that it is expected to depreciate. This is consistent with a positive value of b_t^*, which represents the home country's net foreign asset position. In this segmented market, as the arbitrageur is long foreign bonds and short home bonds, he requires a premium in the form of expected real appreciation of the foreign currency. The home country's real appreciation corresponds to the appreciation of the terms of trade. The foreign country's real appreciation is consistent with expected terms of trade depreciation. A large rise in s_t on impact needs to offset the direct negative effect of tariffs. This large response of s_t only occurs when $\Lambda_s < 0$. A necessary condition, regardless of the value of the IES, is $\eta < 1$.[11]

Λ_s is interpreted as the equilibrium effect of terms of trade appreciation on trade balances. It consists of three forces: 1) a negative force from falling import demand due to falling consumption; a negative force on trade balances through reduced export demand as the home country's products become more expensive; and 3) holding the quantity of exports and imports constant, a positive

[10] It remains an interesting exercise to consider the case with transfers.

[11] The complete derivation is in Appendix A.3.1.

force on trade balances from the net valuation of exports relative to imports.

$\Lambda_s < 0$ means that the two negative forces of worsening trade balances are dominating as s_t rises. This is only possible when η is well below one in this simple model. The exact role of the production network is to amplify the propagation of sectoral terms of trade to consumption through the labor market and to alter the valuation effect of terms of trade on aggregate trade balances. Overall, under certain network structures, tariffs can improve consumption under realistic $\eta \geq 1$ and $\sigma \geq 1$.

Equilibrium and the structure of the network Previous approximation of the production function assumes a constant input-output matrix (i.e. $\boldsymbol{A_t}$ is constant). Under a homogeneous of degree one production function, a well-known result is that the input-output matrix can be written using real factor prices—real wages and sectoral producer prices, normalized by CPI. I linearize this input-output matrix because as I demonstrate below, changing factor prices alters input shares and firms' expenditure switching between inputs and labor which affects the propagation of trade policy. This firm-side expenditure switching is a potent amplification mechanism. The flexible price equilibrium under the incomplete market consists of the four equations. The sectoral price index defined using sectoral consumption shares remains the same as in equation 3, and the additional three equations are below.

$$\text{Risk sharing: } \mathbb{E}_t(\sigma \Delta c_{t+1}\mathbf{1} - \Delta \boldsymbol{p_{t+1}} + \nu \Delta \tau_{t+1}\mathbf{1} + (1-\nu)\Delta \boldsymbol{s_{t+1}}) = -\omega b^* \mathbf{1}$$

$$\text{Balance of payments: } \beta b_t^* - b_{t-1}^* = h_n n_t + h_c c_t + \boldsymbol{H_s}^\top \boldsymbol{s_t} + \boldsymbol{H_p}^\top \boldsymbol{p_t} + h_\tau \tau_t$$

$$\text{Aggregate production: } k_n n_t = \boldsymbol{K_s}^\top \boldsymbol{s_t} + k_\tau \tau_t + \boldsymbol{K_p}^\top \boldsymbol{p_t} + k_d c_t$$

To illustrate the role of the production structure in rationalizing a positive consumption response to trade policy, I choose a two-sector version of the model. I choose the persistence of trade shocks $\rho = 0.9$, trade openness $\nu = 0.3$ and standard values of elasticities (trade elasticity $\eta = 1.5$, risk aversion $\sigma = 2$, the elasticity of substitution between inputs $\theta^Z = 0.1$ (Atalay, 2017), the elasticity of substitution between labor and inputs $\theta^L = 1.8$. I choose the consumption share for one sector to be 0.7, that is, consumption is concentrated in one sector. Moreover, I set the input share from sector 1 used in sector 1 to be 0.6. Figure 3 plots all possible production network structures required for the impact response of consumption to be positive. In particular, the 45-degree line implies that the labor share in sector 2 is zero. The shaded yellow area represents the combinations of input shares in sector 2. As the combination is close to this 45-degree line, the labor share in the second sector is close to zero. In fact, this is the case for these chosen parameter values: considering all possible production structures, the labor share in the second sector needs to be small enough in order to generate enough propagation of the terms of trade to consumption, resulting in a rising consumption.

Figure 4 further chooses one of the input-output matrix $A = \left(\begin{smallmatrix} 0.6 & 0.2 \\ 0.15 & 0.8 \end{smallmatrix}\right)$ and simulates the impulse response to a 1% tariff. It also compares the responses when the production function is Cobb-Douglas and when the model is a one-sector roundabout economy with the input share being 0.6. For this particular set of parameters, the impulse responses between the baseline and the case assuming no input-labor substitution are close and positive. This contrasts with the decrease in consumption under the roundabout economy. Moreover, labor supply and real wages fall much more in the baseline model than in the roundabout economy.

Rising consumption while falling real wages and labor supply may seem surprising in standard intuition. In this economy, consumption and the terms of trade are pinned down through the balance of payments and the risk sharing condition instead of the labor market clearing condition. The input-output linkages make labor demand more sensitive to changes in real wages and input prices due to fluctuations in the terms of trade. However, this elevated sensitivity is exactly what makes rising import demand from consumption more sensitive to the terms of trade, which is necessary to generate a strong force that worsens the trade balances when the terms of trade improves.

By varying σ with and without a perfectly elastic labor supply, Figure 5 decomposes the impact effect of tariffs on consumption into the forces from labor supply and from input-labor substitution. Consumption is much lower in models with a Cobb-Douglas production function even though labor supply is very elastic. To further illustrate the role of firms' substitution between inputs and labor,

Figure 6 varies the elasticity of substitution between inputs and labor, while keeping all other values as the baseline used in Figure 4. As the elasticity rises, the impact effect of tariffs on consumption increases.

Decomposing two roles of the production network Production networks play two roles in the model. First, input-output linkages are potent amplification mechanisms. One interpretation is that the input-output linkages relaxes the range of other parameters required to generate positive consumption responses to tariffs. This operates though the direct amplification in the production networks. This amplification mechanism is similar to choosing a large input share in a one-sector roundabout economy. Moreover, another source of amplification comes from firms' substitution between labor and inputs.

Second, a large improvement in the terms of trade comes from the "wealth effect"—the country is able to save in foreign assets as its trade balances improves due to tariffs. Having production networks reduces the international risk sharing and allows the home countries to have very drastic response of terms of trade to enjoy this "wealth effect". This flexible price model features a negative correlation between the real exchange rate and consumption. The UIP premium that the risk-averse arbitrageur charges is essentially a weighted sum of sectoral terms of trade. This linear combination of terms of trade is stationary, but individual sectoral terms of trade follow an integrated process, that is, $\Delta \boldsymbol{s_t}$ is stationary. Temporary shocks cannot generate a permanent terms of trade deviation from the steady state. Writing $\boldsymbol{s_0} = \bar{\boldsymbol{m}}$ and $\forall t \geq 1$, $\boldsymbol{s_t} = \boldsymbol{s_0} + \sum_{h=0}^{t} \Delta \boldsymbol{s_h}$, and applying $\lim_{t\to\infty} \boldsymbol{s_t} = \boldsymbol{0}$, the constant martingale terms $\bar{\boldsymbol{m}}$ in $\boldsymbol{s_t}$ can be solved via forward iterations. The response of consumption to tariff shocks consists of impacts from stationary and non-stationary terms as follows.

$$c_t = \check{\boldsymbol{\Sigma}}_{\boldsymbol{\tau}} \tau_t + \underbrace{\check{\boldsymbol{\Sigma}}_{\boldsymbol{a}} \boldsymbol{s_t}}_{\text{stationary}} + \overbrace{\check{\boldsymbol{\Sigma}}_{\boldsymbol{b}} \boldsymbol{s_t}}^{\text{not stationary}} \tag{27}$$

If the production structure is completely symmetric across sectors, what is relevant to both consumption and the risk-averse arbitrageur is a single economy-wide terms of trade. Hence, the non-stationary terms from sectoral terms of trade $\check{\boldsymbol{\Sigma}}_{\boldsymbol{b}} \boldsymbol{s_t}$ will disappear.

Figure 7 decomposes the initial response of consumption into three components as in equation 27. The effect from sectoral production heterogeneity (labeled as "Effects from sectoral heterogeneity") is roughly one-third of the direct effect $\check{\boldsymbol{\Sigma}}_{\boldsymbol{a}}\boldsymbol{s_0}$ (labeled as "Effects from terms of trade"). For the impact response, $\check{\boldsymbol{\Sigma}}_{\boldsymbol{b}}\boldsymbol{s_0}$ depends on the constant term $\bar{\boldsymbol{m}}$. This term describes the effect of having sectoral production heterogeneity in lowering risk sharing. Tariffs allow a country to improve trade balance and hence the net foreign asset positions. This has a permanent and yet constant effect on altering the cost of consumption bundles, holding the income constant.

The empirical relevance of the mechanism based on the production network in the U.S. I calibrate the model to the U.S. economy and provide a quantitative assessment of the empirical relevance of the mechanism. I follow Antonova et al. (2025), a contemporary paper on tariffs in a model with production networks but with Cobb-Douglas production functions, in constructing the input-output matrix $\boldsymbol{A}$, consumption shares $\boldsymbol{\beta^c}$, and labor shares $\boldsymbol{\alpha_0}$. I use the newly released Use Matrix in 2024 and remove sectors related to the government and whose production is not used in other sectors, leaving 63 sectors in the end.[12] Labor shares are the "Compensation of employees" divided by the sum of sectoral production and "Compensation of employees". Consumption shares are sectoral shares of "Personal consumption expenditures". I calibrate the trade openness ν using the 2024 Import Matrix, and the sectoral size-weighted trade openness is $\nu = 0.08$. I use the estimates from Miranda-Pinto and Youngs (2022) to calibrate sectoral elasticities of substitution between labor and inputs. The size-weighted average elasticity is $\theta^L = 1.80$. I select the standard value of (inverse) IES $\sigma = 2$, the (inverse) Frisch elasticity of labor supply $\varphi = 1$, and a uniform sectoral elasticity of substitution between inputs being $\theta^Z = 0.1$ (Miranda-Pinto and Youngs, 2022). Free parameters left are trade elasticity and the persistence of the tariff shocks. I vary the trade elasticity within a narrow realistic range between 1 and 2 used in the macro literature.

I first choose $\eta = 1.5$ and a very persistent tariff shock $\rho = 0.99$. Figure 8 shows that for

[12] The following sectors with BEA industry code in parentheses are removed: Motor vehicle and parts dealers (441), Food and beverage stores (445), General merchandise stores (452), Federal general government (defense) (GFGD), Federal general government (nondefense) (GFGN), Federal government enterprises (GFE), State and local general government (GSLG), State and local government enterprises (GSLE), Scrap, used and secondhand goods, and Non-comparable imports and rest-of-the-world adjustment.

a 1% tariff uniform across sectors reduces consumption by 0.015%, even though consumption gradually rises to positive values over time. When trade elasticity is lowered to $\eta = 1$, which is a lower bound used in the macro literature, Figure 9 shows that consumption increases by 0.02% on impact of the tariff shock. Though the response is very small, the model with production networks provides amplification relative to a model of a one-sector roundabout economy with the share of inputs being 0.6. In that model, the impact response of consumption is positive but is essentially zero. To put the quantitative implication into perspective, Trump's 15% global tariffs, uniform across trading partners and uniform across sectors, would imply an annualized increase in the consumption of U.S. households by $24 billion, based on consumption expenditure in the 2024 U.S. GDP.

The impact effect of trade policy depends on the persistence. While the trade elasticity remains at $\eta = 1$, I lower the persistence to $\rho = 0.9$. Figure 10 shows that consumption drops by 0.1% for the calibrated U.S. economy, though consumption is slightly higher in the one-sector roundabout economy. The exercises so far assume the homogeneity of the elasticity of substitution between labor and inputs. Appendix Figure E.2 shows the impulse response to tariff shocks using sectoral elasticity θ_m^L from Miranda-Pinto and Youngs (2022), but the response of consumption does not vary much. At least for the U.S. economy, the size-weighted elasticity provides a good approximation to the propagation of tariff shocks.

4 Optimal monetary policy under tariff-induced misallocation

This section illustrates the implications of inputs in production for 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 2.3. 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 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, 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 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 rewritten as the problem of choosing the optimal terms of trade.

$$\max_{\tilde{S}_t} -(1-\nu)log(\tilde{S}_t) - \nu log(1+\tau_t) - N\tilde{S}_t^{-1-\frac{\nu\alpha}{1-\alpha}}(1+\tau_t)^{\frac{\nu\alpha}{1-\alpha}} \tag{30}$$

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 raises 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 for 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 $1+\psi_x$ such 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, factor allocations—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 the 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 $\nu \to 0$. The non-equivalence of the production frontiers in (FB) and (CE) occurs because firms do not internalize the consequences 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' output from a concave production function cannot be greater than production using factors in aggregate.

Welfare loss and optimal monetary policy I derive the quadratic welfare loss function by extending the Lagrangian method in Itskhoki and Mukhin (2023) to a setting with inputs in production. With nominal frictions and the subsidies mentioned above, Proposition 4 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 4 *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.*

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

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

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

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, on impact from 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 B.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 given by

$$\hat{s}_0 = \mu_{opt,1}\hat{s}_{-1} + \tau_0 \frac{\mu_{opt,1}}{1-\beta\rho\mu_{opt,1}} \frac{M_\tau}{M_s}(1-\beta(1+\mu_{opt,1}-\rho)) \tag{31}$$

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 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 11 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.

The initial producer price inflation is

$$\pi_{H,0} = \frac{M_\tau}{(1-\beta\rho\mu_{opt,1})\lambda\gamma_\pi}(1+\mu_{opt,1}(1-\beta(1+\mu_{opt,1}))) > 0 \tag{32}$$

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 on impact under the optimal monetary policy.

5 Conclusion

Are there aggregate benefits of temporary trade barriers? Keynes (Eichengreen, 2019) viewed trade policy as a substitute for monetary policy to manage aggregate demand in the 1930s. So far, empirical and theoretical studies find pervasive negative effects of temporary trade barriers on output and employment. Tariffs have theoretically ambiguous effects on aggregate demand. Tariffs can stimulate demand when the positive effects from the expenditure switching channel offset negative forces from falling incomes. Beyond this well-known theoretical possibility, this paper offers two theoretical mechanisms through which temporary tariffs can stimulate consumption, which has the largest share in aggregate demand. These two mechanisms are empirically relevant to the U.S. economy. Given the prominent role of inputs in both channels, this paper also discusses how monetary policy should respond to the misallocation between inputs and labor created by tariffs.

While tariffs depress consumption under a Taylor-rule type monetary policy with flexible PPI targeting, consumption may rise when fiscal policy actively determines the price level and when monetary policy remains inactive due to the zero interest rate lower bound. Under a fiscal-led regime of price determination, the mechanism predicts that tariffs depreciate nominal exchange rates, a puzzling prediction in standard models but observed in Trump's "Liberation Day" tariffs in April 2025.

Tariffs can boost consumption when risk sharing is lacking in standard models, but a trade elasticity well below unity is a necessary condition. Production network structures can amplify the propagation of appreciating terms of trade within the labor market. As a result, a small rise in the terms of trade can increase consumption, driving the rise in imports and becoming the dominant force. I calibrate a small open-economy, flexible-price model with production network structures in the U.S. The model predict that very persistent tariffs stimulate consumption when the trade elasticity is above but close to 1.

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. Depending on the input share in production, the optimal monetary policy may either stimulate or depress consumption relative to that under strict PPI targeting.

Table 1: Literature review of the macroeconomic dimensions of trade policy

Year	Paper
Prior to 2000	Rauch (1999); Krugman (1982)
2001–2018	Obstfeld and Rogoff (2001); Anderson and van Wincoop (2004); Broda and Weinstein (2006); Bilbiie et al. (2008); Hall (2009); Coenen et al. (2010); Caliendo et al. (2017); Epifani and Gancia (2017); World Bank (2017)
2018–2024	Erceg et al. (2018); Lindé and Pescatori (2019); Bergin and Corsetti (2020); Caldara et al. (2020); Barattieri et al. (2021); Bergin and Corsetti (2023); Auray et al. (2024); Jeanne and Son (2024); Bianchi and Coulibaly (2024)
2025	Alessandria et al. (2025); Auclert et al. (2025); Auray et al. (2025); Baqaee and Malmberg (2025); Monacelli (2025); Werning and Costinot (2025); Kalemli-Ozcan et al. (2025)

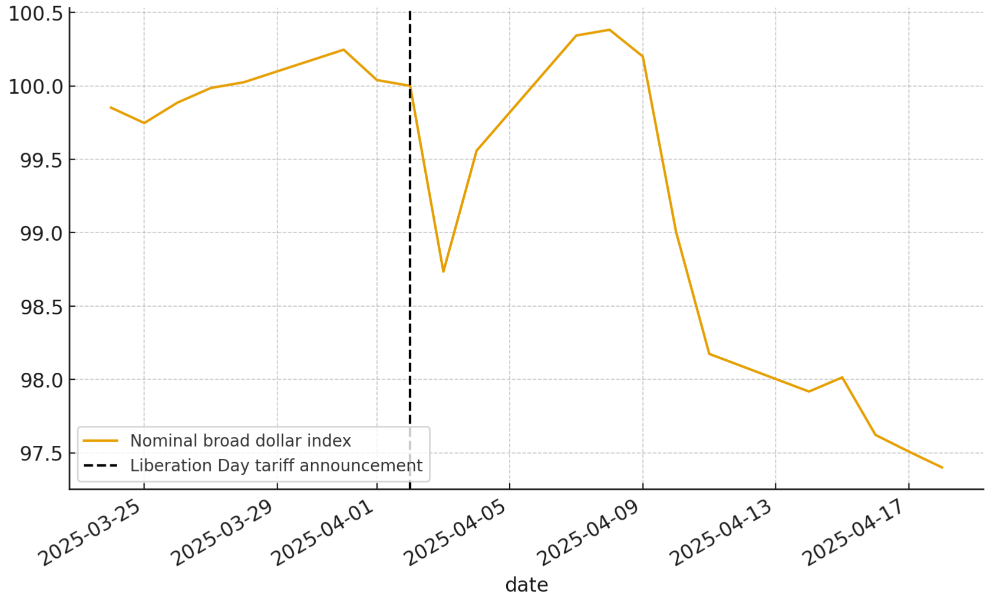
Notes: See Meng et al. (2023) for a discussion of empirical evidence on trade policy and the macroeconomy. There are also recent empirical studies of exchange rates by Benguria and Saffie (2025) and Ostry et al. (2025).

Table 2: Description of variables

Sectoral variables in log deviations	
Price	$\boldsymbol{p_t} = (p_{1,t} \ \ldots \ p_{M,t})^\top$
Producer price inflation	$\boldsymbol{\pi_{H,t}} = (\pi_{1H,t} \ \ldots \ \pi_{MH,t})^\top, \ \pi_{mH,t} \equiv p_{mH,t} - p_{mH,t-1}$
Terms of trade	$\boldsymbol{s_t} = (s_{1,t} \ \ldots \ s_{M,t})^\top, \ s_{m,t} \equiv p_{mH,t} - p_{mF,t}$
Tariff shocks	$\boldsymbol{\tau}_t = (\tau_{1,t} \ \ldots \ \tau_{M,t})^\top$
Input-output definitions	
Consumption shares	$\boldsymbol{\beta^c} \in \mathbb{R}^M, \ \beta^c_m = \frac{P_m C_m}{PC}$
Labor shares	$\boldsymbol{\alpha_0} \in \mathbb{R}^M, \ \alpha_{0m} = \frac{W N_m}{MC_m Y_m}$
Input shares	$\boldsymbol{A} \in \mathbb{R}^M \times \mathbb{R}^M, \ \alpha_{mj} = \frac{P_j X_{mj}}{MC_m Y_m}$
	$\boldsymbol{\Psi} = (\boldsymbol{I} - \boldsymbol{A})^{-1}, \boldsymbol{\Omega} = (1-\nu)\boldsymbol{I} + \nu \boldsymbol{\Psi}^\top$
Substitution elasticities	$\{\theta^k_{mj}, \ \theta^L_{mj}\}$ between inputs in sector m's production

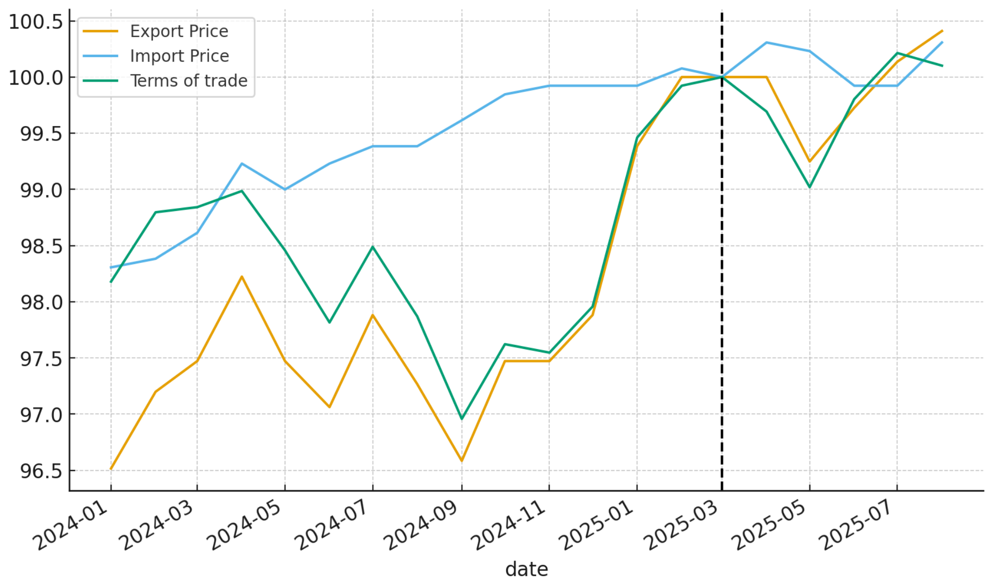
Note: When assuming input-labor substitution is homogeneous across sectors, the elasticity of substitution between inputs is θ^Z, and the elasticity of substitution between labor and inputs is θ^L.

Figure 1: Nominal broad dollar index around the “Liberation Day” tariff announcement



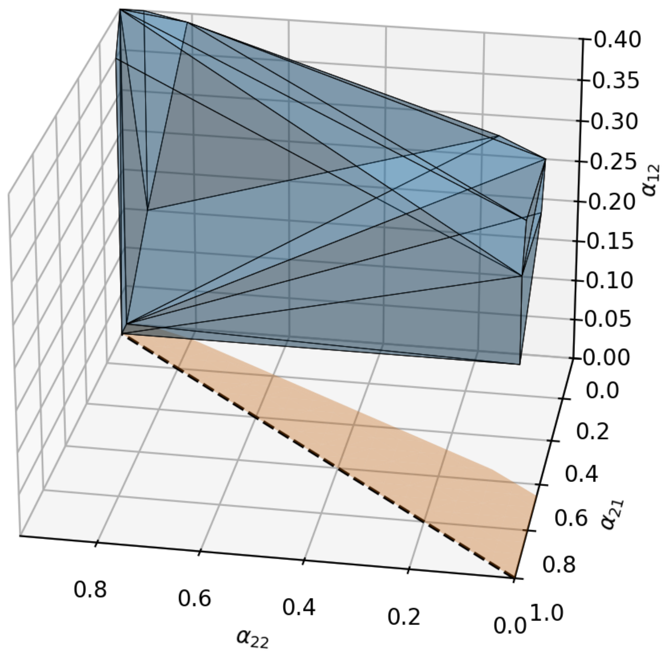
Notes: The index value is normalized to the value on April 2, 2025. Vertical line on April 2, 2025 indicates the day after the announcement of Trump’s global tariffs. A lower index value means the dollar depreciates. Source: FRED Nominal Broad U.S. Dollar Index (DTWEXBGS).

Figure 2: Monthly (tariff-exclusive) terms of trade (export price/import price)



Notes: The export price is measured by the export price index for nonagricultural commodities (EIUIQEXAG). The import price is measured by the import price index excluding fuels (EIUIREXFUELS).

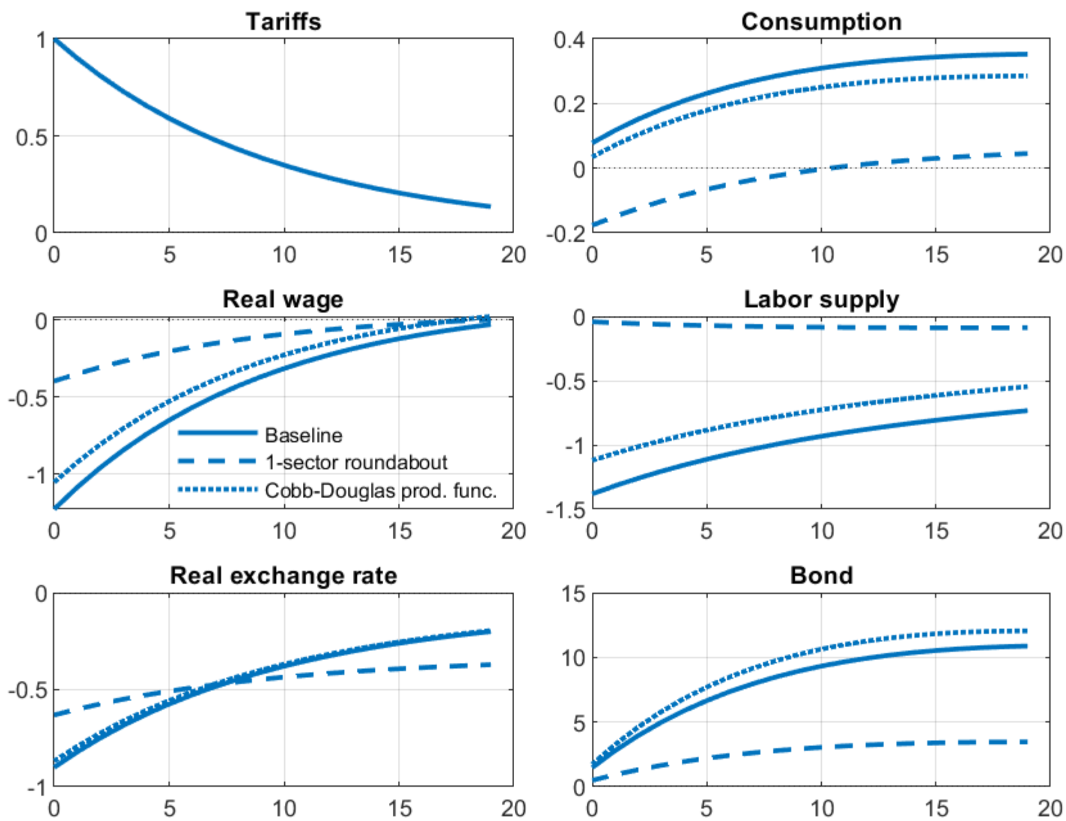
Figure 3: Production network requirements in a two-sector model for a positive response of consumption to tariff shocks



Notes: This figure shows the required production network structure in a two-sector model for a positive impact response of consumption. The input share from sector 1 used in sector 1, α_{11}, is fixed at 0.6. The input share from sector 2 used in sector 1, α_{12}, is on the z-axis. α_{21} is on the y-axis, and α_{22} is on the x-axis. The 45-degree line in the horizontal plane refers to the combinations of α_{22} and α_{21} resulting a zero labor share in sector 2, that is, $\alpha_{22} + \alpha_{21} = 1$. The yellow shaded area in that horizontal plane are combinations of α_{22} and α_{21} permissible in the production network. Other fixed values are in the table below.

trade openness	ν	0.3
consumption share	$\boldsymbol{\beta^c}$	$(0.7, 0.3)'$
input–output matrix	$\boldsymbol{A}$	$\begin{pmatrix} 0.6 & \text{z-axis} \\ \text{x-axis} & \text{y-axis} \end{pmatrix}$
trade elasticity	η	1.5
elasticity of sub. b/w labor & inputs	θ^L	1.8
elasticity of sub. b/w inputs	θ^Z	0.1
persistence of tariff shocks	ρ	0.9
inverse IES	σ	2
inverse Frisch labor supply elasticity	φ	1

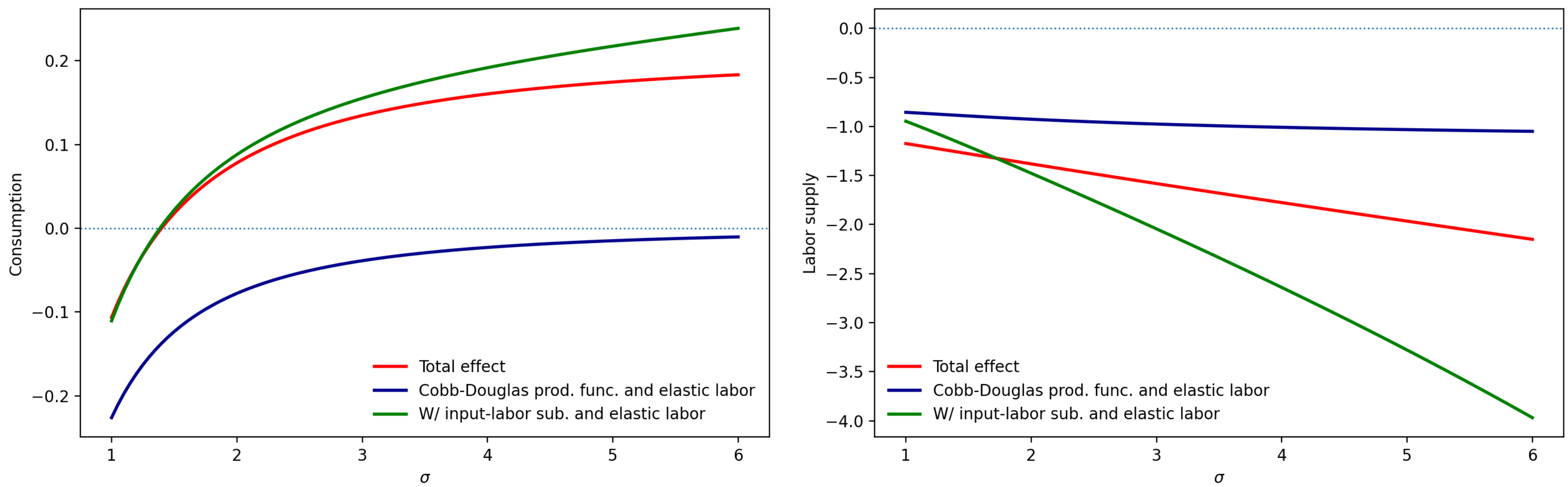
Figure 4: Impulse responses (in percent deviations from the s.s.) to 1% tariff shocks in a two-sector model



Notes: This figure shows the impulse responses to 1% tariff shocks. There are two sectors in the baseline model, and the production structure is one of the structures that meet the requirement of rising consumption in Figure 3. All variables, except for the graph labeled "Bond", are in percent deviations from the free-trade steady state. "Bond" plots b_t^*, the home country's net foreign asset position denominated in foreign currency as a share of steady-state consumption expenditure. There are three models, the baseline model with production networks, a one-sector roundabout economy as in Section 2.3, and the baseline model assuming Cobb-Douglas production functions, $\theta^Z = \theta^L = 1$. The table below summarizes other parameter values.

	Baseline	No input-labor sub. channel	1-sector roundabout
consumption share $\boldsymbol{\beta}^c$		$(0.7, 0.3)'$	n/a
$\boldsymbol{A}$ or input share α in 1-sector roundabout		$\begin{pmatrix} 0.6 & 0.2 \\ 0.15 & 0.8 \end{pmatrix}$	0.6
trade elasticity η		1.5	
elasticity of sub. b/w labor & inputs θ^L	1.8	1	n/a
elasticity of sub. b/w inputs θ^Z	0.1	1	n/a
ρ		0.9	
σ		2	
φ		1	

Figure 5: Transmission channel: the role of σ

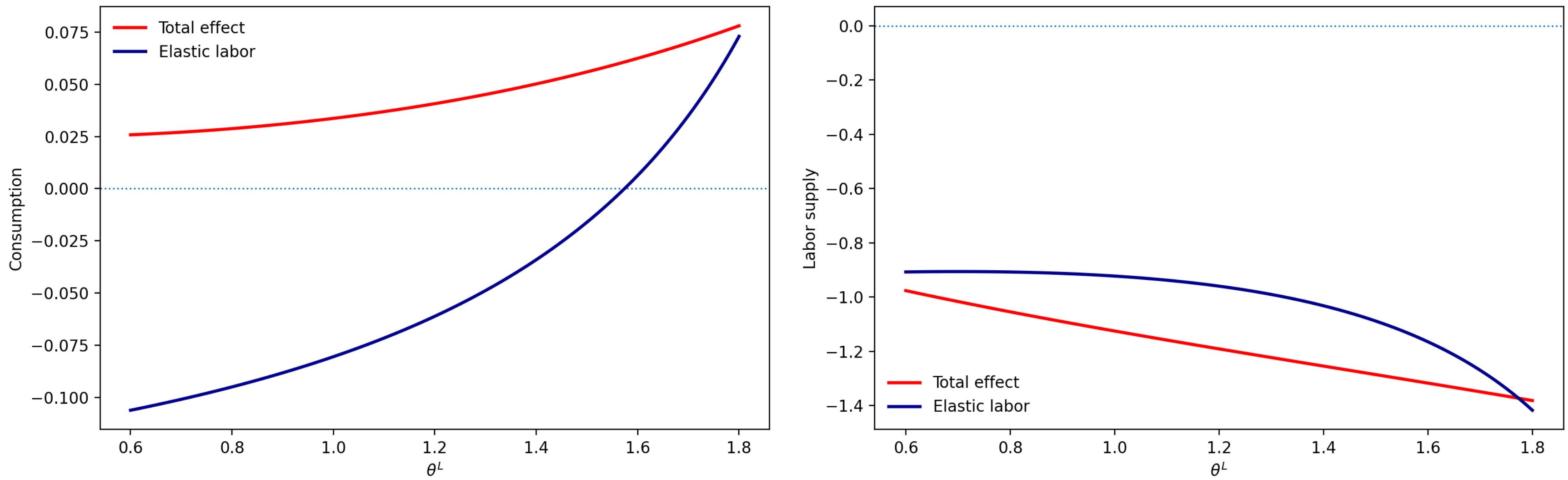


(a) Consumption (b) Labor supply

Notes: The figure shows the role of σ on the impact effects (in percent deviations from the s.s.) of consumption and labor supply in a two-sector model with production networks. The network structure, $\boldsymbol{A} = \left(\begin{smallmatrix} 0.6 & 0.2 \\ 0.15 & 0.8 \end{smallmatrix}\right)$, is identical to that in Figure 4. There are three models. These models share identical parameter values of $\nu = 0.3$, $\boldsymbol{\beta^c} = (0.7, 0.3)'$, $\rho = 0.9$, and $\eta = 1.5$. "Total effect" refers to the baseline model. "Cobb-Douglas prod. func. and elastic labor" refers to modifying φ to 0.01 and setting $\theta^L = \theta^Z$ to 1 in the baseline model. "W/ input-labor sub. and elastic labor" refers to modifying φ to 0.01 in the baseline model. The table below summarizes these models.

	Total effect	Cobb-Douglas prod. func.& elastic labor	W input-labor sub. & elastic labor
elasticity of sub. b/w labor & inputs θ^L	1.8	1	1.8
elasticity of sub. b/w inputs θ^Z	0.1	1	0.1
σ		varying	
φ	1	0.01	0.01

Figure 6: Transmission channel: the role of θ^L



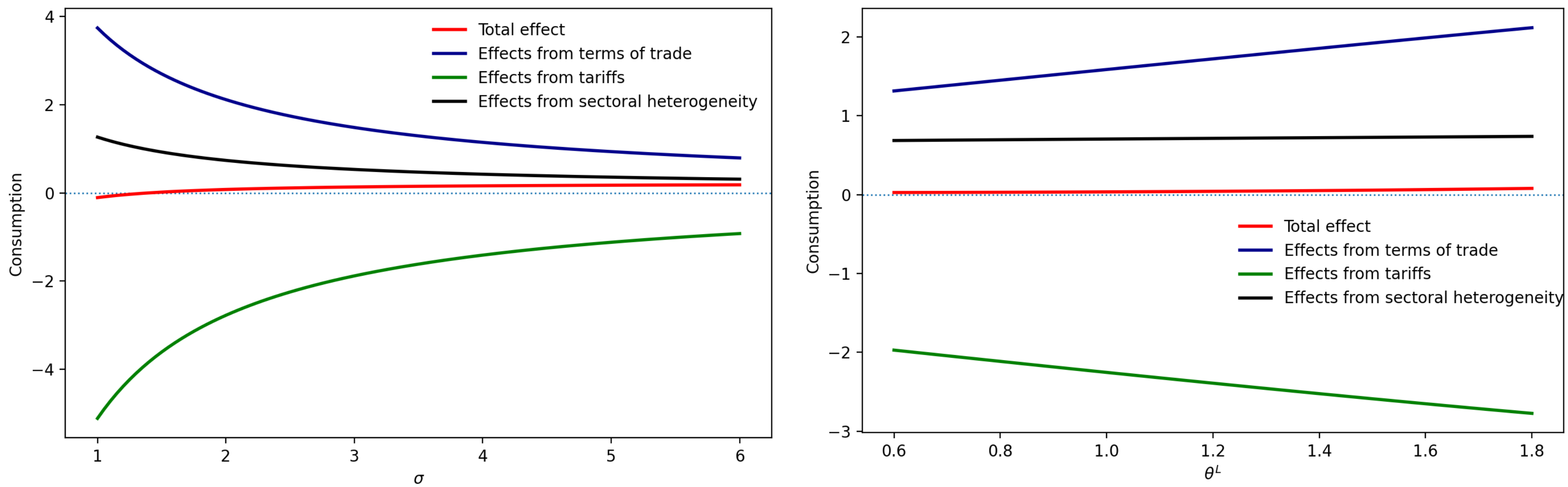
(a) Consumption

(b) Labor supply

Notes: The figure shows the role of θ^L on the impact effects (in percent deviations from the s.s.) of consumption and labor supply in a two-sector model with production networks. The network structure, $\boldsymbol{A} = \begin{pmatrix} 0.6 & 0.2 \\ 0.15 & 0.8 \end{pmatrix}$, is identical to that in Figure 4. There are two models. These models share identical parameter values of $\nu = 0.3$, $\boldsymbol{\beta^c} = (0.7, 0.3)'$, $\rho = 0.9$, and $\eta = 1.5$. "Total effect" refers to the baseline model. "Elastic labor" refers to modifying φ to 0.01 in the baseline model.

	Total effect	Elastic labor
elasticity of sub. b/w labor & inputs θ^L	varying	
elasticity of sub. b/w inputs θ^Z	0.1	
σ	2	
φ	1	0.01

Figure 7: The role of sectoral heterogeneity in production



(a) Varying σ

(b) Varying θ^L

Notes:

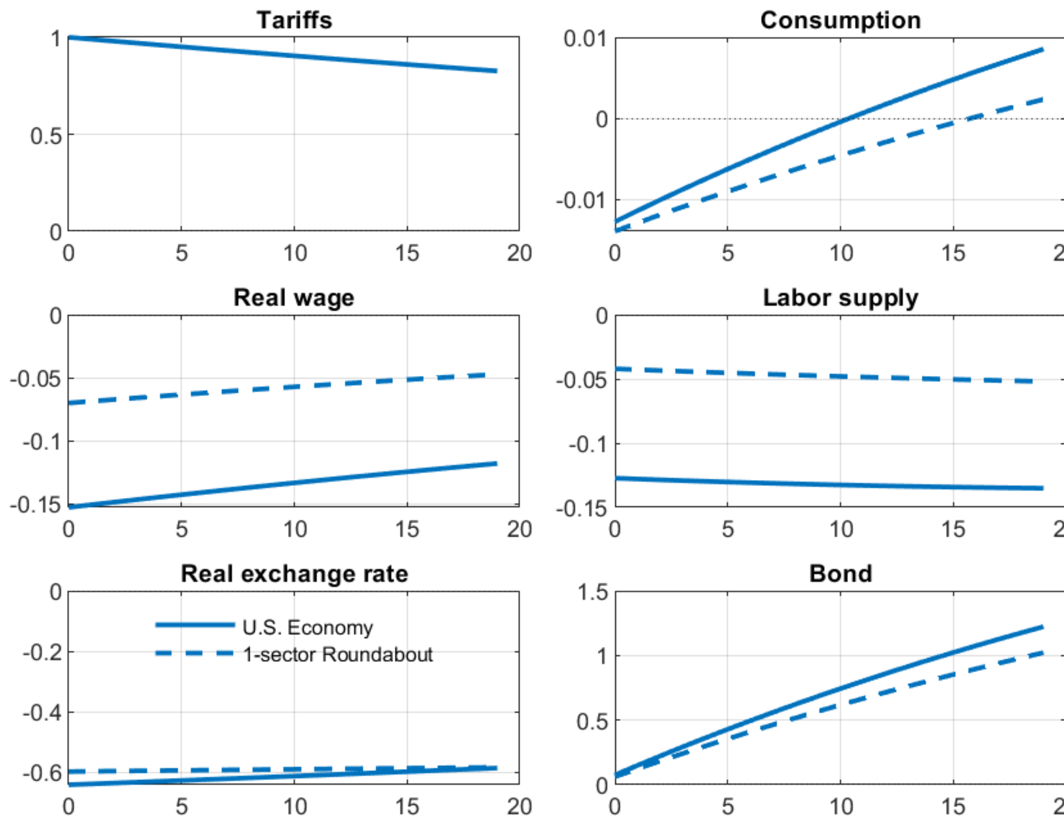
The figure shows the role of sectoral heterogeneity in consumption and production on the impact effects (in percent deviations from the s.s.) of consumption in a two-sector model with production networks. The network structure, $\boldsymbol{A} = \left(\begin{smallmatrix} 0.6 & 0.2 \\ 0.15 & 0.8 \end{smallmatrix}\right)$, is identical to that in Figure 4. Other parameter values are $\nu = 0.3$, $\boldsymbol{\beta^c} = (0.7, 0.3)'$, $\rho = 0.9$, $\theta^Z = 0.1$, $\theta^L = 1.8$, $\varphi = 1$, and $\eta = 1.5$.

Individual sectoral terms of trade follow an integrated process, that is, $\Delta s_{m,t}$ is a stationary variable. However, a linear combination of sectoral terms of trade is also stationary, which is referred to as *stationary transformation of sectoral terms of trade*. This sector-weighted terms of trade influence the UIP deviation.

The effect of tariffs on consumption can be decomposed into the direct effect from tariffs ("Effects from tariffs" in the figure), and the effect from *stationary transformation of sectoral terms of trade* ("Effects from terms of trade" in the figure). This term is proportional to b_0^*. The residual effects ("Effects from sectoral heterogeneity" in the figure).

There would be a single economy-wide terms of trade trade, influencing the real exchange rate, when all sectors are symmetric. Therefore, "Effects from sectoral heterogeneity" would be zero in a completely symmetric production network structure.

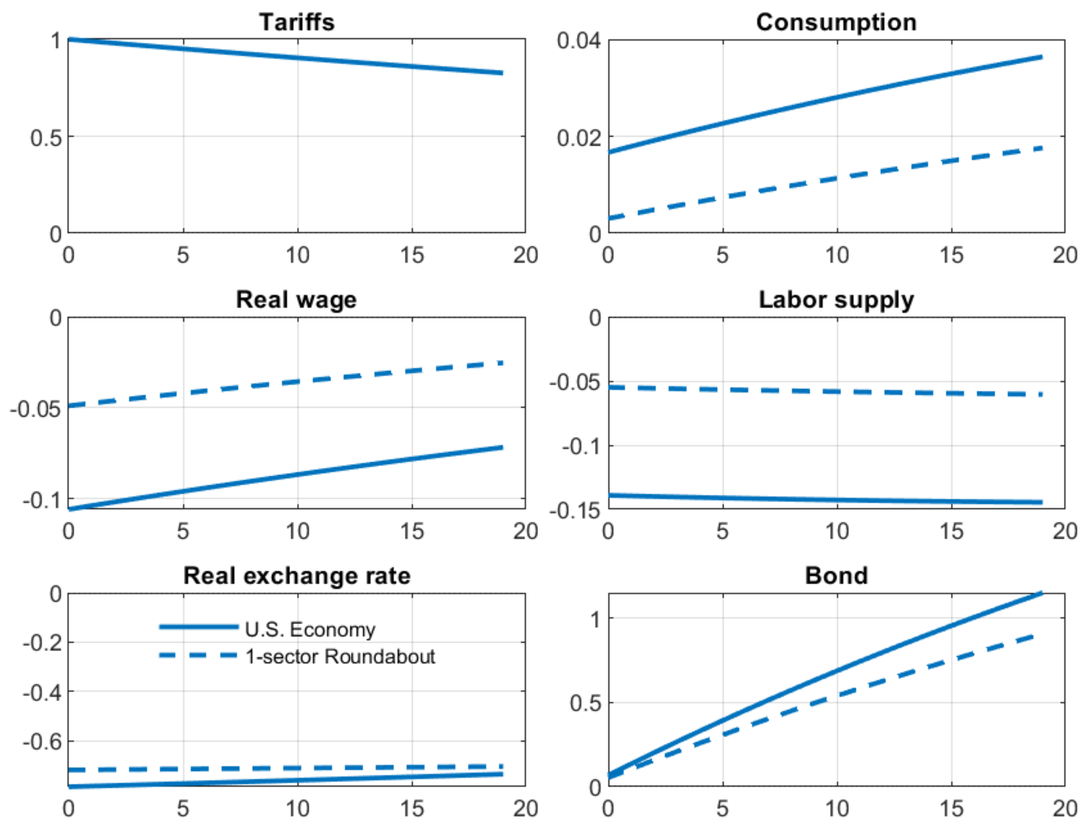
Figure 8: Trade policy in a calibrated model (high shock persistence and high trade elasticity)



Notes: This figure shows the impulse response to 1% tariff shocks. All variables, except for the graph labeled "Bond", are in percent deviations from the free trade steady state. "Bond" plots b_t^*, the home country's net foreign asset position denominated in foreign currency as a share of steady-state consumption expenditure. Section 2.3 describes a one-sector roundabout economy. The table below lists the calibrated and fixed parameters.

	calibrated to the U.S.	1-sector roundabout
trade openness ν	Yes (0.08)	0.08
consumption share $\boldsymbol{\beta}^c$	Yes	n/a
$\boldsymbol{A}$ or input share α in 1-sector roundabout	Yes	0.6
trade elasticity η	1.5	
elasticity of sub. b/w labor & inputs θ^L	1.8	n/a
elasticity of sub. b/w inputs θ^Z	0.1	n/a
ρ	0.99	
σ	2	
φ	1	

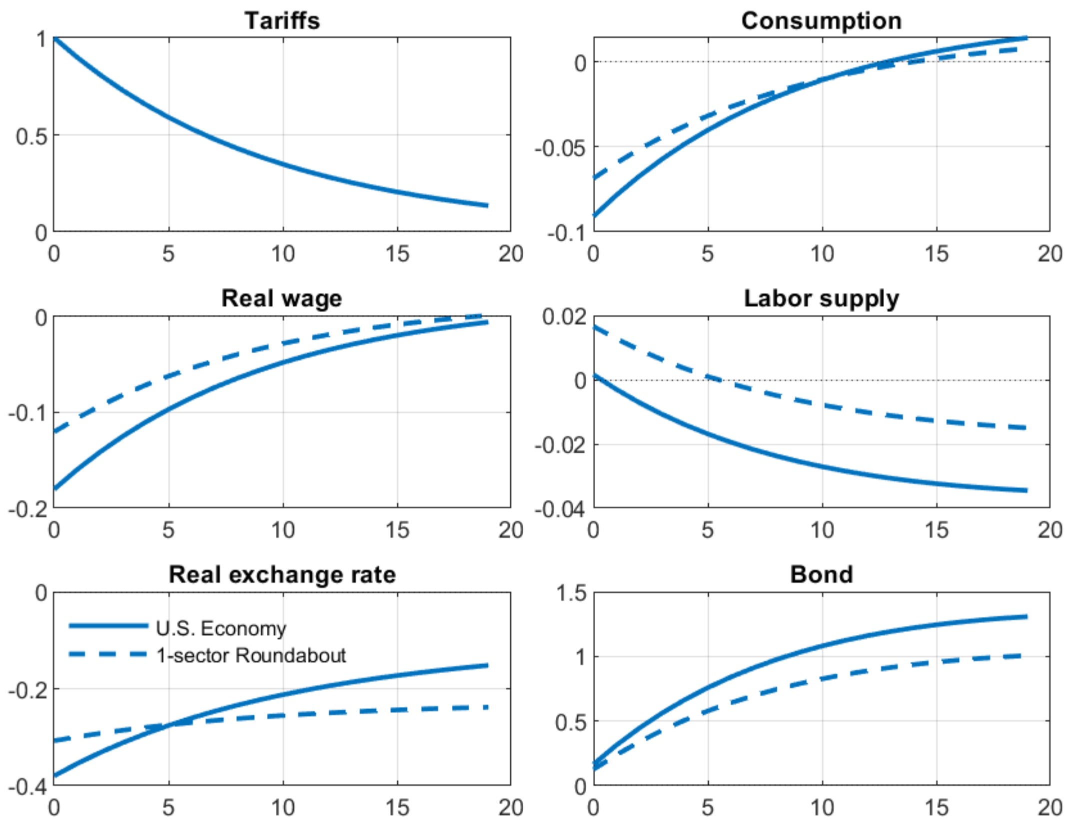
Figure 9: Trade policy in a calibrated model (high shock persistence and low trade elasticity)



Notes: This figure show production structure for a positive response of consumption based on the fixed parameters below.

	calibrated to the U.S.	1-sector roundabout
trade openness ν	Yes (0.08)	0.08
consumption share $\boldsymbol{\beta^c}$	Yes	n/a
$\boldsymbol{A}$ or input share α in 1-sector roundabout	Yes	0.6
trade elasticity η	1	
elasticity of sub. b/w labor & inputs θ^L	1.8	n/a
elasticity of sub. b/w inputs θ^Z	0.1	n/a
ρ	0.99	
σ	2	
φ	1	

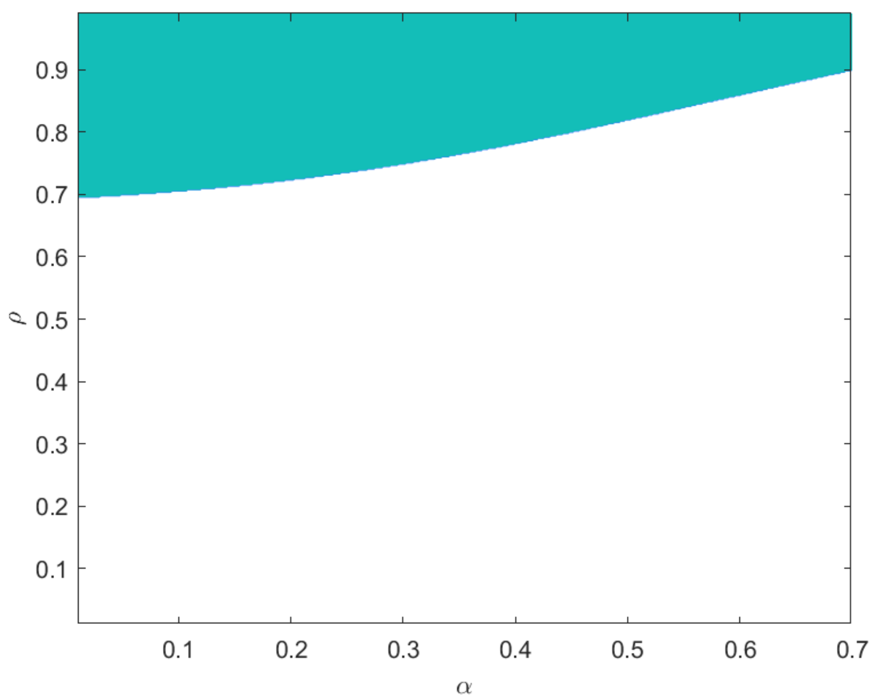
Figure 10: Trade policy in a calibrated model (low shock persistence and high trade elasticity)



Notes: This figure shows the impulse response to 1% tariff shocks. All variables, except for the graph labeled "Bond", are in percent deviations from the free trade steady state. "Bond" plots b_t^*, the home country's net foreign asset position denominated in foreign currency as a share of steady-state consumption expenditure. Section 2.3 describes a one-sector roundabout economy. The table below lists the calibrated and fixed parameters.

	calibrated to the U.S.	1-sector roundabout
trade openness ν	Yes (0.08)	0.08
consumption share $\boldsymbol{\beta^c}$	Yes	n/a
$\boldsymbol{A}$ or input share α in 1-sector roundabout	Yes	0.6
trade elasticity η	1.5	
elasticity of sub. b/w labor & inputs θ^L	1.8	n/a
elasticity of sub. b/w inputs θ^Z	0.1	n/a
ρ	0.9	
σ	2	
φ	1	

Figure 11: 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 $\lambda = 0.0858$.

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Online Appendix
Could Tariffs Provide a Stimulus? In Search of Elusive Benefits of Protectionism

Jeremy Meng

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A A small open-economy model

A.1 Equilibrium conditions in the baseline model

A.1.1 Nonlinear equilibrium

This section describes the nonlinear equilibrium in the most general setup. The log-linearized equilibrium in the text is a special case where sectoral nominal frictions, trade openness, and trade elasticity are identical across sectors. The competitive equilibrium consists of $4 \times M$ auxiliary variables from Calvo nominal frictions $\{\frac{\tilde{P}_{mH,t}}{P_{mH,t}}, \frac{X^1_{m,t}}{P_{mH,t}}, \frac{X^2_{m,t}}{P_t}, d_{m,t}\}$, $M+1$ inflation terms $\{\Pi_{mH,t}, \Pi_t\}$, $2 \times M^2 + 4 \times M + 2$ variables related to quantities $\{Y_{m,t}, N_{m,t}, N_t, C_{m,t}, C_{mH,t}, C_t\}$, $\{X_{jmH,t}, X_{mj,t}\}$, and $5 \times M + 2$ variables related prices $\{\frac{MC_{m,t}}{P_t}, \frac{W_t}{P_t}, \frac{P_{m,t}}{P_t}, \frac{P_{mH,t}}{P_t}, \frac{P_{mF,t}}{P_t}, Q_{t,t+1}, I_t\}$.

The log-linearized equilibrium assumes that sectoral Phillips curves have identical slopes, $\theta_m = \lambda \, \forall m$.

Calvo pricing and price dispersion ($6 \times M$ equations)

$$\Pi^{1-\epsilon}_{mH,t} = \theta_m + (1-\theta_m)\left(\frac{\tilde{P}_{mH,t}}{P_{mH,t}\Pi_{mH,t}}\right)^{1-\epsilon} \tag{A.1}$$

$$\frac{X^1_{m,t}}{P_{mH,t}}\frac{P_{mH,t}}{P_t} = \frac{X^2_{m,t}}{P_t} \tag{A.2}$$

$$\frac{X^1_{m,t}}{P_{mH.t}} = \left(\frac{\tilde{P}_{mH,t}}{P_{mH,t}}\right)^{1-\epsilon} Y_{m,t} + \theta_m \mathbb{E}_t(Q_{t,t+1}\frac{X^1_{mH,t+1}}{P_{mH,t+1}}\Pi_{mH,t+1}(\frac{\tilde{P}_{mH,t}}{P_{mH,t}}\Pi^{-1}_{mH,t+1}(\frac{\tilde{P}_{mH,t+1}}{P_{mH,t+1}})^{-1})^{1-\epsilon}) \tag{A.3}$$

$$\frac{X^2_{m,t}}{P_t} = \frac{MC_{m,t}}{P_t}(\frac{\tilde{P}_{mH,t}}{P_{mH,t}})^{-\epsilon}Y_{m,t} + \theta_m \mathbb{E}_t(Q_{t,t+1}\frac{X^2_{m,t+1}}{P_{t+1}}\Pi_{t+1}(\frac{\tilde{P}_{mH,t}}{P_{mH,t}}\Pi^{-1}_{mH,t+1}(\frac{\tilde{P}_{mH,t+1}}{P_{mH,t+1}})^{-1})^{-\epsilon}) \tag{A.4}$$

$$d_{m,t} = \theta_m d_{m,t-1}\Pi^{\epsilon}_{mH,t} + (1-\theta_m)(\frac{\tilde{P}_{mH,t+1}}{P_{mH,t+1}})^{-\epsilon} \tag{A.5}$$

$$\frac{\Pi_{mH,t}}{\Pi_t} = \frac{P_{mH,t}}{P_t}\frac{P_{t-1}}{P_{mH,t-1}} \tag{A.6}$$

Production $(3 \times M + 2 \times M^2$ equations)

$$\frac{W_t}{P_t} N_{m,t} = \alpha_{m0,t}(\frac{W_t}{P_t}, \{\frac{P_{m,t}}{P_t}\}_m) Y_{m,t} \frac{MC_{m,t}}{P_t}(\frac{W_t}{P_t}, \{\frac{P_{m,t}}{P_t}\}_m) d_{m,t} \tag{A.7}$$

$$\frac{P_{j,t}}{P_t} X_{mj,t} = \alpha_{mj,t}(\frac{W_t}{P_t}, \{\frac{P_{m,t}}{P_t}\}_m) Y_{m,t} \frac{MC_{m,t}}{P_t}(\frac{W_t}{P_t}, \{\frac{P_{m,t}}{P_t}\}_m) d_{m,t} \tag{A.8}$$

$$\frac{MC_{m,t}}{P_t} = \mathcal{G}(\frac{W_t}{P_t}, \{\frac{P_{m,t}}{P_t}\}_m) \tag{A.9}$$

$$X_{mjH,t} = (1-\nu)(\frac{P_{jH,t}}{P_t} \frac{P_t}{P_{j,t}})^{-\eta} X_{mj,t} \tag{A.10}$$

$$\frac{P_{m,t}}{P_t} = ((1-\nu)(\frac{P_{mH,t}}{P_t})^{1-\eta} + \nu(\frac{(1+\tau_{m,t} P_{mF,t}}{P_t})^{1-\eta})^{\frac{1}{1-\eta}} \tag{A.11}$$

Household demand $(5 + 2 \times M$ equations)

$$C_t^\sigma N_t^\varphi = \frac{W_t}{P_t} \tag{A.12}$$

$$C_{m,t} = \beta_m^c (\frac{P_{m,t}}{P_t})^{-1} C_t \tag{A.13}$$

$$C_{mH,t} = (1-\nu)(\frac{P_{mH,t}}{P_t} \frac{P_t}{P_{mH,t}})^{-\eta} C_{m,t} \tag{A.14}$$

$$Q_{t,t+1} = \beta((\frac{C_{t+1}}{C_t})^{-\sigma} \Pi_{t+1}^{-1}) \tag{A.15}$$

$$1 + I_t = \mathbb{E}_t(Q_{t,t+1}) \tag{A.16}$$

$$1 + I_t = \beta^{-1}(\prod_{m=1}^{M} \Pi_{mH,t}^{\phi_m}) \tag{A.17}$$

Market clearing $(1 + M$ equations)

$$N_t = \sum_m N_{m,t} \tag{A.18}$$

$$Y_{m,t} = C_{mH,t} + \nu(\frac{P_{mH,t}}{P_t} \frac{P_t}{P_{mF,t}})^{-\eta} Y_m^* + \sum_j X_{jmH,t} \tag{A.19}$$

Risk sharing (M equations)

$$C_t^{-\sigma}\frac{P_{mF,t}}{P_t} = C^{*-\sigma}\frac{P^*_{m,t}}{P^*_t} \tag{A.20}$$

A.1.2 Deriving aggregate labor supply

First define the sectoral production share as

$$\lambda_{m,t} = \frac{P_{mH,t}Y_{m,t}}{P_tC_t}$$

Define $\boldsymbol{\lambda_t^c} = (\lambda^c_{1,t}, ..., \lambda^c_{M,t})^\top$. Using the definition of the input-output structure in Table 2 and the definition of $\boldsymbol{B_{H,t}}$ and $\boldsymbol{B^*_{H,t}}$ in Section 2.2,

$$\boldsymbol{\lambda_t^c} = \boldsymbol{B_{H,t}\beta^c} + \boldsymbol{B_{H,t}A_t^\top\mu_t^{-1}\lambda_t^c} + \boldsymbol{B^*_{H,t}} \tag{A.21}$$

From firms' labor demand,

$$\begin{aligned}\frac{W_t}{P_t}N_t = \sum_m \alpha_{0m,t}\frac{MC^d_{m,t}}{P_t}Y_{m,t} \rightarrow \frac{W_t}{P_t}\frac{N_t}{C_t} &= \sum_m \alpha_{0m,t}\frac{1}{\mu_{m,t}}\lambda^c_{m,t} \\ \rightarrow \frac{W_t}{P_t}\frac{N_t}{C_t} &= \boldsymbol{\alpha_{0,t}^\top\mu_t^{-1}\lambda_t^c}\end{aligned} \tag{A.22}$$

The aggregate labor supply in eq 2 comes from combining equations A.22 and A.21.

A.1.3 Steady-state

In the steady state, PPI inflation and tariffs are zero. Eq A.21 implies $\boldsymbol{\lambda^c} = (\boldsymbol{I}-\boldsymbol{A}^\top)^{-1}\boldsymbol{\beta^c} = \boldsymbol{\Psi}^\top\boldsymbol{\beta^c}$. Eq A.22 implies $\frac{W}{P}\frac{N}{C} = (\boldsymbol{\alpha_0^\top\lambda^c})(\boldsymbol{1}^\top(\boldsymbol{I}-\boldsymbol{A}^\top)\boldsymbol{\Psi}^\top\boldsymbol{\beta^c}) = 1$.

A.2 A one-sector complete market model with roundabout production

A.2.1 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.2.2

Proof of Proposition 1. Given equation (16) 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 $\kappa_{app,\tau} = \frac{\nu \frac{\kappa_s \phi y}{\kappa_y} + \nu(1-\rho)}{1-\nu} > 0$, $\kappa_{app,c} = \frac{\frac{\kappa_s \phi y}{\kappa_y}\sigma + (1-\nu)\frac{\kappa_c \phi y}{\kappa_y}}{1-\nu} > 0$. Using notations of κ_c, κ_c, κ_τ, and κ_s in the market clearing condition in eq. 16,

$$\lambda_c = \lambda \left(\frac{(1-\alpha)\sigma}{1+\alpha\varphi} + \frac{\kappa_c}{\kappa_y} \frac{(1-\alpha)\varphi}{1+\alpha\varphi} + \frac{\sigma}{1-\nu} \left(\frac{(1-\alpha)\varphi}{1+\alpha\varphi} \frac{\kappa_s}{\kappa_y} + \nu \right) \right)$$

$$\lambda_\tau = \lambda \left(\nu + \frac{(1-\alpha)\kappa_\tau \varphi}{(1+\alpha\varphi)\kappa_y} + \frac{\nu}{1-\nu} \left(\frac{(1-\alpha)\varphi}{1+\alpha\varphi} \frac{\kappa_s}{\kappa_y} + \upsilon \right) \right)$$

QED.

A.2.3

Proof of Proposition 2. The equilibrium consists of

$$\sigma c_t + (1-\nu)\boldsymbol{\beta}^{\boldsymbol{c}\top} \boldsymbol{s_t} + \nu \tau_t = 0 \tag{A.23}$$

$$\boldsymbol{\pi_{H,t}} = \beta \mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) + \lambda(-(\boldsymbol{I} - (1-\nu)\boldsymbol{A})\boldsymbol{s_t} + \nu \tau_t \boldsymbol{\alpha_0}) \tag{A.24}$$

$$\mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) - \boldsymbol{\phi}^\top \boldsymbol{\pi_{H,t}} \mathbf{1} = \mathbb{E}_t(\Delta \boldsymbol{s_{t+1}}) \tag{A.25}$$

Guessing the solutions to take the following forms and plugging them into the equilibrium conditions.

$$c_t = \check{a}\tau_t$$

$$\boldsymbol{\pi_{H,t}} = \check{\boldsymbol{B}}\tau_t$$

$$\boldsymbol{s_t} = \check{\boldsymbol{D}}\tau_t$$

A simple algebraic manipulation yields the following relationship.

$$\check{\boldsymbol{D}} = -\frac{\rho}{1-\rho}\check{\boldsymbol{B}} + \frac{1}{1-\rho}\boldsymbol{\phi}^\top \check{\boldsymbol{B}}\mathbf{1}$$

Replacing $\check{\boldsymbol{D}}$ using the relationship above in the Phillips curve returns the solution for sectoral inflation.

$$
\begin{aligned}
&\left(((1-\beta\rho)(1-\rho)\boldsymbol{I}-\lambda\rho(\boldsymbol{I}-(1-\nu)\boldsymbol{A})+\lambda(\boldsymbol{I}-(1-\nu)\boldsymbol{A})\mathbf{1}\otimes\boldsymbol{\phi}^{\mathsf{T}}\right)\check{\boldsymbol{B}}=(1-\rho)\lambda\nu\boldsymbol{A}\mathbf{1}\\
&\Rightarrow\check{\boldsymbol{B}}=\left[\{(1-\beta\rho)(1-\rho)\boldsymbol{I}+\lambda(\mathbf{1}\otimes\boldsymbol{\phi}^{\mathsf{T}}-\rho\boldsymbol{I})\}-\lambda(\mathbf{1}\otimes\boldsymbol{\phi}^{\mathsf{T}}-\rho\boldsymbol{I})(1-\nu)\boldsymbol{A}\right]^{-1}(1-\rho)\lambda\nu\boldsymbol{A}\mathbf{1}
\end{aligned}
$$

Given that each element in $\boldsymbol{\phi}$ is greater than 1, each element of the matrix $\lambda(\mathbf{1}\otimes\boldsymbol{\phi}^{\mathsf{T}}-\rho\boldsymbol{I})(1-\nu)$ is therefore smaller than the corresponding element in $(1-\beta\rho)(1-\rho)\boldsymbol{I}+\lambda(\mathbf{1}\otimes\boldsymbol{\phi}^{\mathsf{T}}-\rho\boldsymbol{I})$. It follows that each element of $\check{\boldsymbol{B}}$ is positive. This means that tariffs create inflation in all sectors. Hence, it is straightforward to further show that consumption falls since each element in $\check{\boldsymbol{D}}$ is negative.

QED.

A.3 Other modeling features

A.3.1 Derivation for a simple incomplete market model

I 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.

$$\sigma c_t = \nu s_t - \nu \tau_t \tag{A.26}$$

$$b_t^* - \frac{1}{\beta}b_{t-1}^* = \underbrace{\frac{1}{\beta}\left(\nu(1-2\eta+\nu\eta)-\frac{\nu^2}{\sigma}\right)}_{\hat{\kappa}_s} s_t + \underbrace{\frac{1}{\beta}\left(\frac{\nu^2}{\sigma}+\eta\nu(1-\nu)\right)}_{\hat{\kappa}_\tau}\tau_t \tag{A.27}$$

$$\mathbb{E}_t\left(\sigma\Delta c_{t+1}+(1-\nu)\Delta s_{t+1}+\nu\Delta\tau_{t+1}\right) = -\omega b_t^* \tag{A.28}$$

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 (10)) and firms' optimal pricing $p_{H,t} = mc_t$ yields equation (A.26). Equation (A.27) is the first-order approximation of the balance of payments, and equation (A.28) is the risk sharing condition. The equilibrium terms of trade s_t follow an ARMA(2,1) process:

$$s_t = (\rho + \mu_{in,1})s_{t-1} - \rho\mu_{in,1}s_{t-2} + \hat{\chi}_1\epsilon_{\tau,t} - \hat{\chi}_1\mu_{in,1}\rho\epsilon_{\tau,t-1} \tag{A.29}$$

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.

$$\frac{\nu + \sigma\eta(1-\nu)}{\nu + \sigma\eta(1-\nu) - \sigma(1-\eta)}\frac{1-\beta\mu_{in,1}}{1-\beta\mu_{in,1}\rho} - 1 \tag{A.30}$$

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.

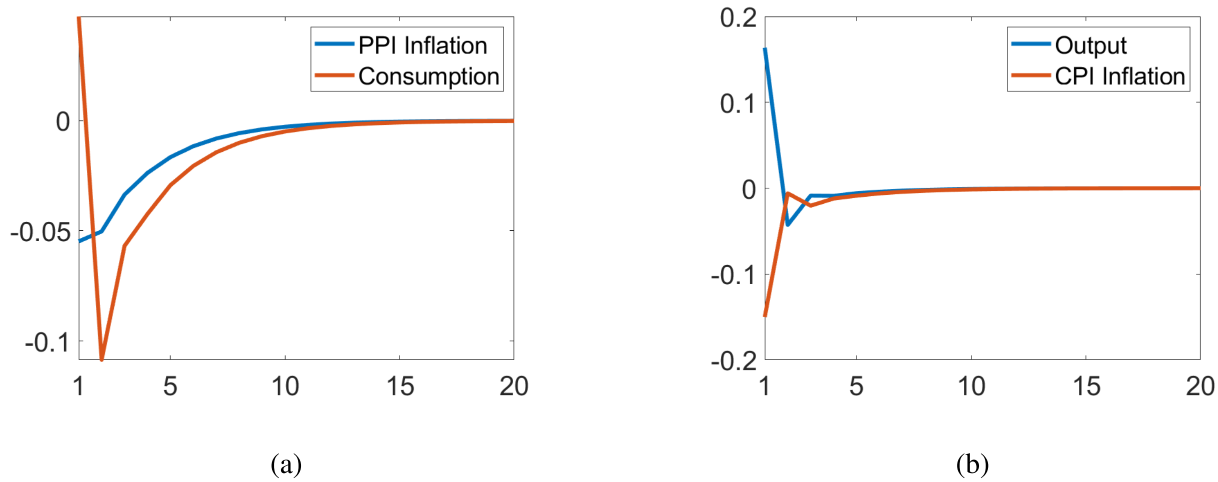
A.3.2 Alternative inflation target

When consumer price inflation enters a Taylor-rule type monetary policy, using the relationship between consumer price and producer price inflation in equation 14, 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 (17), 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 Figure A.1 to persistent tariff shocks shows an increase in consumption on impact.

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



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 (14), 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 $\mathbb{E}_t \begin{pmatrix} c_{t+1} \\ m_{t+1} \end{pmatrix} = \begin{pmatrix} B_{11} & -\frac{1}{\beta} \\ 1 & 0 \end{pmatrix} \begin{pmatrix} c_t \\ m_t \end{pmatrix} +$ 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

$$c_0 = \mu_{cpi,1} c_{-1} - \tau_0 \frac{\mu_{cpi,1}}{\sigma(1-\beta\rho\mu_{cpi,1})}(1+\beta(1-\rho)-\lambda-\beta\mu_{cpi,1}) \tag{A.31}$$

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 $c_0 > 0$.

A.4 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 (25).

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 $\mathbf{X}_{g,t} = (\pi_{H,t}, c_t, d^G_{t-1})'$. 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,

$$\mathbf{M}_g = \begin{bmatrix} \frac{1}{\beta} & -\frac{\lambda}{\beta}\tilde{\sigma} & 0 \\ \frac{1}{\tilde{\sigma}}(\phi_\pi - \frac{1}{\beta}) & 1+\frac{\lambda}{\beta} & 0 \\ \phi_\pi - \frac{1}{\beta} & 0 & \tilde{\gamma} \end{bmatrix} \tag{A.32}$$

$\mathbf{M}_g$ 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 3.

B 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 B.1); 2) writing down the competitive equilibrium and finding the subsidy to achieve an efficient non-stochastic steady state (Section B.2); 3) writing down the welfare loss along with constraints expressed as the wedge from the FB (Section B.3); and 4) deriving the planner's optimal monetary policy with commitment (Section B.5).

B.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

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

Putting equation (B.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 (30). 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

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

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 (B.2) implies that

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

Equation (30) implies that the steady state labor supply

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

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

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

Therefore the optimal labor supply is

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

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

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

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

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

In summary, equations (B.5)-(B.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 (B.4) and (B.8). The symmetric steady state consists of $Y = Y^* = (1-\nu)(C^* + X) + \nu Y^*$, equation (B.3), and equation(B.8). The solution is

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

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

B.2 Competitive equilibrium

The flexible price competitive equilibrium is identical to the one in Section A.2 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 5 *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 5.

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

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

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

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

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 (B.11) and combining it with equations (CE-1), the market clearing condition returns

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

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

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

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

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

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

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

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

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

B.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 $\bar{\omega} N_t C_t^{\alpha}(1+\psi_x)^{-\alpha} = (1-\alpha) Y_t d_t$ and $\bar{\omega} X_t C_t^{-(1-\alpha)}(1+\psi_x)^{1-\alpha} = \alpha Y_t d_t$. 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 (30), the objective function is

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

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

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

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

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

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

Omitting N and arranging terms yields the objective function in Proposition 4.

B.4 Deriving the Ramsey problem

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

B.5 Deriving results the optimal monetary policy in Section 4

The social planner's Lagrangian is

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

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

C Incomplete market model with production networks

This section lays out an incomplete market small open-economy model. The equilibrium is defined as follows. The model consists of $6 + 3 \times M$ variables: i_t, c_t, n_t, $\mathbb{E}_t(\Delta e_{t+1})$, b_t^*, π_t, $\boldsymbol{\pi_{H,t}}$, $\boldsymbol{s_t}$, and $\boldsymbol{p_t}$. The following equations define the equilibrium. I assume that the Taylor rule targeting weight on sectoral PPI is uniform across sectors. Moreover, I assume that tariffs are uniform across sectors.

Uncovered interest parity (with deviations) (1 equation):

$$i_t^* - i_t + \mathbb{E}_t(\Delta e_{t+1}) = \omega b_t^* \tag{C.21}$$

The definition of nominal exchange rate (M equations):

$$\mathbb{E}_t(\Delta e_{t+1})\mathbf{1} = \mathbb{E}_t(\pi_{t+1})\mathbf{1} + \mathbb{E}_t(\boldsymbol{\pi_{H,t+1}} - \Delta \boldsymbol{s_{t+1}}) \tag{C.22}$$

Aggregate production function (1 equation):

$$k_n n_t = \boldsymbol{K_s}^\top \boldsymbol{s_t} + \boldsymbol{K_\tau}^\top \mathbf{1}\tau_t + \boldsymbol{K_p}^\top \boldsymbol{p_t} + k_c c_t \tag{C.23}$$

Phillips curve (M equations):

$$\boldsymbol{\pi_{H,t}} = \beta \mathbb{E}_t(\boldsymbol{\pi_{H,t+1}}) + \lambda(-(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{p_t} - \nu \boldsymbol{s_t} + \nu\tau_t\mathbf{1} + \varphi n_t \boldsymbol{\alpha_0} + \sigma c_t \boldsymbol{\alpha_0}) \tag{C.24}$$

Balance of payments (1 equation):

$$\beta b_t = b_{t-1} + h_n n_t + h_c c_t + \boldsymbol{H_s}^\top \boldsymbol{s_t} + \boldsymbol{H_p}^\top \boldsymbol{p_t} + h_\tau \tau_t \tag{C.25}$$

IS curve (1 equation):

$$0 = \mathbb{E}_t(\sigma \Delta c_{t+1}) - \frac{1}{\sigma}(i_t - \mathbb{E}_t(\pi_{t+1})) \tag{C.26}$$

The definition of sectoral price index (1 equation):

$$\boldsymbol{\beta^c}^\top \boldsymbol{p_t} = 0 \tag{C.27}$$

The definition of sectoral producer price inflation and CPI inflation (M equations):

$$\boldsymbol{\pi_{H,t}} - \pi_t \mathbf{1} = \Delta \boldsymbol{p_t} + \nu \Delta \boldsymbol{s_t} - \nu \Delta \tau_t \mathbf{1} \tag{C.28}$$

Monetary policy (1 equation):

$$i_t = \phi_\pi \times \mathbf{1}^\top \pi_{H,t} \tag{C.29}$$

The main text focuses on the *flexible price equilibrium*, which is summarized by the following system of equations. Using the matrices defined below, I solve the model using the Blanchard-Khan method.

Consumption share: $\boldsymbol{\beta^c} \boldsymbol{p_t} = 0$

Risk sharing: $\mathbb{E}_t(\sigma \Delta c_{t+1} \mathbf{1} - \Delta \boldsymbol{p_{t+1}} + \nu \Delta \tau_{t+1} \mathbf{1} + (1-\nu) \Delta \boldsymbol{s_{t+1}}) = -\omega b^* \mathbf{1}$

Balance of payments: $\beta b_t^* - b_{t-1}^* = h_n n_t + h_c c_t + \boldsymbol{H_s}^\top \boldsymbol{s_t} + \boldsymbol{H_p}^\top \boldsymbol{p_t} + h_\tau \tau_t$

Aggregate production: $k_n n_t = \boldsymbol{K_s}^\top \boldsymbol{s_t} + k_\tau \tau_t + \boldsymbol{K_p}^\top \boldsymbol{p_t} + k_d c_t$

Define the matrix related to firms' input-labor expenditure switching by allowing heterogeneous sectoral elasticities of substitution between labor and inputs summarized in the vector $\boldsymbol{\theta^L}$.

$$\check{\boldsymbol{k}}_{\boldsymbol{n}} = \mathbf{1} \otimes (\boldsymbol{\theta^L} - \mathbf{1})) \odot \boldsymbol{A}^\top \operatorname{diag}(\boldsymbol{\alpha_0})$$

It is useful to write the input-output matrix $\boldsymbol{\Omega}$ in Table 2 as $\boldsymbol{\Omega}^{-1} = \tilde{\boldsymbol{\Omega}}^{-1}(\boldsymbol{I} - \boldsymbol{A}^\top)$.

$$k_n = 1 + \varphi(1 - \mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{\alpha_0})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c}) + \varphi\nu \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \check{\boldsymbol{k}}_{\boldsymbol{n}} \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

$$k_d = 1 - \nu \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{\Psi}^\top \boldsymbol{\beta^c} - \sigma(1 - \mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{\alpha_0})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c}) - \sigma\nu \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \check{\boldsymbol{k}}_{\boldsymbol{n}} \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

$$h_n = \nu\varphi \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{A}^\top \operatorname{diag}(\boldsymbol{\alpha_0})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c} + \nu\varphi \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \check{\boldsymbol{k}}_{\boldsymbol{n}} \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

$$h_c = \nu\sigma \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} (\check{\boldsymbol{k}}_{\boldsymbol{n}} + \boldsymbol{A}^\top \operatorname{diag}(\boldsymbol{\alpha_0}))\boldsymbol{\Psi}^\top \boldsymbol{\beta^c} - \nu \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

$$k_\tau = \nu\eta(1 - \nu) \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

$$h_\tau = \nu \mathbf{1}^\top \boldsymbol{\Psi}^\top \boldsymbol{\beta^c} + \nu(\eta - \eta\nu - 1) \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{\beta^c} + \nu^2 \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{A}^\top \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

$$\boldsymbol{K_s}^\top = -\nu\eta(2 - \nu)(\mathbf{1}^\top \boldsymbol{\Omega}^{-1}) \odot (\boldsymbol{\Psi}^\top \boldsymbol{\beta^c})^\top$$

$$\boldsymbol{H_s}^\top = \nu(1 - 2\eta + \nu\eta)(\mathbf{1}^\top \boldsymbol{\Omega}^{-1}) \odot (\boldsymbol{\Psi}^\top \boldsymbol{\beta^c})^\top - \nu^2(\mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \boldsymbol{A}^\top) \odot (\boldsymbol{\Psi}^\top \boldsymbol{\beta^c})^\top$$

$\boldsymbol{K_p}^\top$ can be constructed by separating $\boldsymbol{p_t}$ from the terms below

$$-\mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}((\boldsymbol{I} - \boldsymbol{A})\boldsymbol{p_t})\boldsymbol{\Psi}^\top \boldsymbol{\beta^c} + \nu \mathbf{1}^\top \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{p}_t)\boldsymbol{\Psi}^\top \boldsymbol{\beta^c} - \nu \mathbf{1}^\top \tilde{\boldsymbol{\Omega}}^{-1} \left(\sum_{k=1}^{M} \boldsymbol{\mathcal{S}_k}^\top p_{k,t} \right) \boldsymbol{\Psi}^\top \boldsymbol{\beta^c}$$

For each sector k, the matrix from input-labor substitution is

$$\boldsymbol{\mathcal{S}_k} = [0, ..., \text{column k of } \boldsymbol{A}, .., 0]$$
$$+ \boldsymbol{A} \odot \left(\left[0, ..., -(\boldsymbol{\theta^L} - \theta^z \mathbf{1}) \odot \boldsymbol{\alpha_0} \text{ as kth column}, ..., 0\right] + (\theta^Z - 1)((\text{kth column of} \boldsymbol{A}) \otimes \mathbf{1}^\intercal) \right)$$

Similarly, $\boldsymbol{H_p}^\intercal$ can be constructed by separating $\boldsymbol{p_t}$ from the terms below

$$-\nu \mathbf{1}^\intercal \tilde{\boldsymbol{\Omega}}^{-1} \operatorname{diag}((\boldsymbol{I} - \boldsymbol{A})\boldsymbol{p_t}) \boldsymbol{\Psi}^\intercal \boldsymbol{\beta^c} + \nu \mathbf{1}^\intercal \boldsymbol{\Omega}^{-1} \operatorname{diag}(\boldsymbol{p}_t) \boldsymbol{\Psi}^\intercal \boldsymbol{\beta^c} + \nu \mathbf{1}^\intercal \tilde{\boldsymbol{\Omega}}^{-1} \left(\sum_{k=1}^{M} \boldsymbol{\mathcal{S}_k}^\intercal p_{k,t} \right) \boldsymbol{\Psi}^\intercal \boldsymbol{\beta^c}$$

D Connections to large open economies

D.1 Inputs qualitatively alter outcomes across alternative monetary policy regimes

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 3.1.2 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

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

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.

D.2 Log-linearized equilibrium for the two country model

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.

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

$$\pi^*_{F,t} = \beta \mathbb{E}_t(\pi^*_{F,t+1}) + \lambda(mc^*_t - p^*_{F,t})$$

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

$$\sigma c^*_t + \varphi n^*_t = w^*_t$$

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

$$mc^*_t = (1-\alpha)w^*_t$$

$$n_t + \alpha w_t = y_t$$

$$n^*_t + \alpha w^*_t = y^*_t$$

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

$$x^*_t - (1-\alpha)w^*_t = y^*_t$$

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

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

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

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

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

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

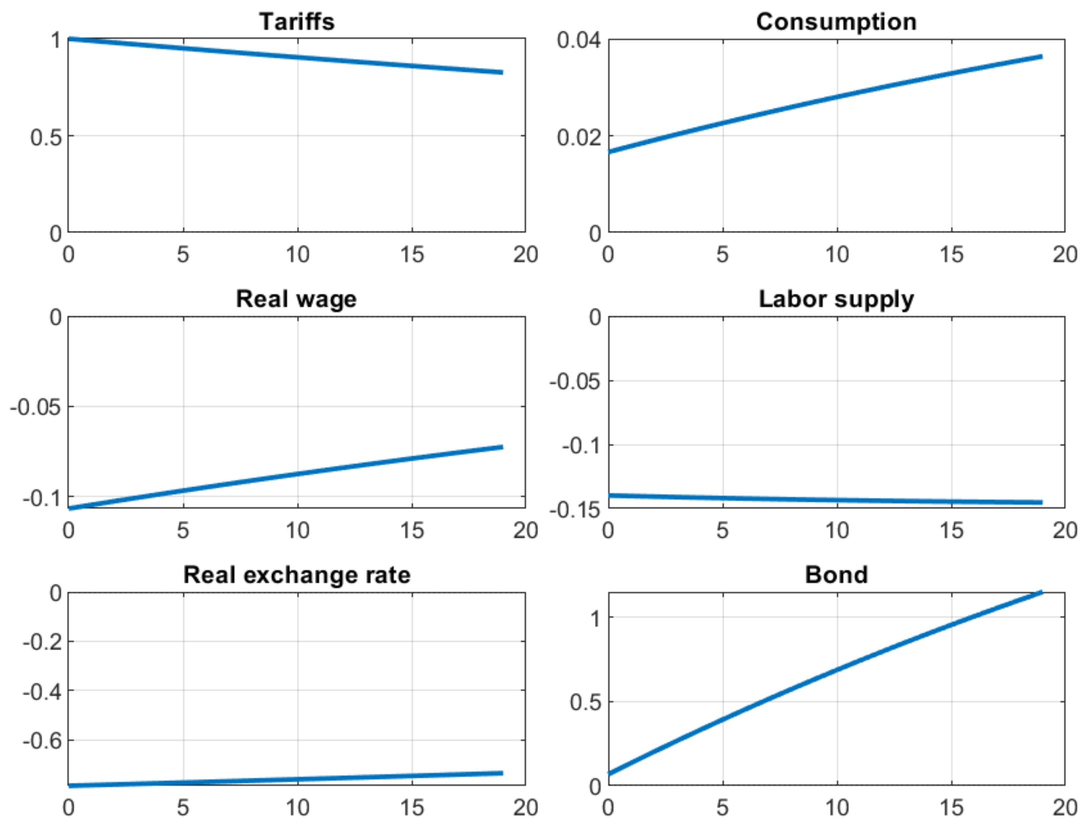
$$c^*_t = \mathbb{E}_t(c^*_{t+1}) - \frac{1}{\sigma}(i^*_t - \mathbb{E}_t(\pi^*_{t+1}))$$

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

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

E Addition figures

Figure E.2: Trade policy in a calibrated model (heterogeneous sectoral elasticities)



Notes: This figure shows the impulse response to 1% tariff shocks. All variables, except for the graph labeled "Bond", are in percent deviations from the free trade steady state. "Bond" plots b_t^*, the home country's net foreign asset position denominated in foreign currency as a share of steady-state consumption expenditure. Section 2.3 describes a one-sector roundabout economy. The table below lists the calibrated and fixed parameters.

	calibrated to the U.S.	1-sector roundabout
trade openness ν	Yes (0.08)	0.08
consumption share $\boldsymbol{\beta^c}$	Yes	n/a
$\boldsymbol{A}$ or α	Yes	0.6
trade elasticity η	1.5	
elasticity of sub. b/w labor & inputs θ^L	Yes	n/a
elasticity of sub. b/w inputs θ^Z	0.1	n/a
ρ	0.99	
σ	2	
φ	1	

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