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Welfare Implications of Tariffs under Alternative Nominal Rigidities

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ABSTRACT

Tariff is one of the major protection policies in international trade and has been a long-lasting issue in international economics. This paper uses a two-country dynamic general equilibrium model to examine the effects of the tariff on the world economy under alternative nominal rigidities: producer-currency pricing (PCP) and local-currency pricing (LCP) where the exchange rate pass-through and expenditure-switching effects are absent. This study finds that the effects of the tariff on the output and welfare do vary with the price setting strategies. A tariff is expansionary for the imposer's economy under both PCP and LCP. The tariff's impact on its trade partner is contractionary under LCP, but absent under PCP. The difference primarily comes from the exchange rate pass-through effect that differs under PCP and LCP. The alternative nominal rigidities also result in different effects on welfare. While a tariff improves the welfare of the domestic households under PCP, it worsens the welfare of the foreign country under LCP.

Keywords: Keyword：Tariff, Nominal Rigidity, Exchange Rate Pass-Through, Expenditure Switching Effect

JEL Classifications: F13; F41; E42

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1. Introduction

One of the primary protection policies is the imposition of tariffs. In recent years, many cases are going on among major countries[2]. While this is a widely used policy tool, the welfare evaluation of the trade policy is important to the authorities. This is a long-lasting issue in the literature, but whether the tariff is beneficial to the country which levies the policy still remains controversial. Early studies reach certain consensus though. (Mundell (1961), Boyer (1977), Chan (1978) and Eichengreen (1981)) As surveyed by Krugman (1982), the tariff is contractionary under a flexible exchange rate regime, but expansionary when the exchange rate is fixed. However, these studies are based on ad hoc assumptions of behavior and the policy is examined in a small open economy. Not too many endeavors have been devoted to evaluate this issue with intertemporal optimization in the past decades. The absence of micro-foundations implies the failure of the welfare assessment of the protection. Sen and Turnovsky (1989) are the first who use an intertemporal optimization framework to study the effects of unanticipated permanent, anticipated temporary, and anticipated permanent tariffs on a small open economy. They find that both output and employment are suppressed by the tariff in the short and long run. The role of capital accumulation is emphasized, which is the main factor that drives current account movements.

Nevertheless, a small open economy framework neglects the transmission mechanism of shocks across countries. As for now, the only study using a two-country dynamic general equilibrium model to study tariffs' effects is Fender and Yip (2000). The two-country framework permits the evaluation of tariff's impacts on the foreign country. Their model consists of imperfect competition and nominal rigidity. The role of monopolistic competitions which lead to inefficient outcomes is stressed. It shows that the tariff decreases both output and employment. As in traditional models, the impacts of a permanent tariff on welfare face tradeoffs, mainly from its impacts on output and consumption through terms of trade movements. In a monopolistically competitive environment, however, the elasticity of

[2] For example, in 2004, the European Union (EU) imposed a retaliate tariff on U.S. exports for the export tax subsidy applied by the U.S. government to U.S. producers. In 2006, the EU placed anti-dumping tariffs on goods exported from China. The producers of the EU seem to be the only winner, while retailers and consumer groups opposed to the move.

substitution among goods is crucial to the tariff's net effect on the welfare.

Thus, the objective of this study is to examine the effects of tariffs on the global economy with a two-country dynamic general equilibrium model with monopolistic competition and nominal rigidity. Equipped with the micro-foundation, the model provides a great platform for welfare analyses of policies. Different Fender and Yip (2000), this research centers on the tariff's effect under alternative nominal rigidities. In contrast to the producer-currency pricing (PCP) setting under Fender and Yip (2000), as traditional models specify, this study emphasizes the exchange rate pass-through and expenditure-switching effects that are absent under the alternative price stickiness, local-currency pricing (LCP). The importance of the pricing strategies is revealed by Devereux and Engel (2003). They show that the currency for the pricing setting has important implication for optimal exchange rate regime. The optimal exchange rate regime under PCP is flexible, while a fixed exchange rate regime is optimal under LCP.[3,4] Following Devereux and Engel (2003), empirical findings also support LCP for firms that actively conduct international trades.

In addition to its implication for exchange rate flexibilities, the degree of exchange rate pass-through, which determines how much the tariff is passed upon the import prices, certainly has important implications for the macroeconomic fundamentals and welfare. In particular, while the LCP behavior prevails in the world, how tariffs may impact on the global economy is critical for policy makers.

To examine tariffs' effects qualitatively for the policy analysis, we use the model in Obstfeld (2006) where analytical solutions are available and introduce permanent tariffs for the imports in the home and foreign countries respectively. In this model, nontradable goods are present and all the prices are predetermined one period ahead. While relative tariff rates cause exchange rate movements, the absence of exchange rate pass-through under LCP leads to different impacts on the home and foreign outputs and

[3] Nevertheless, their result is challenged by Obstfeld (2006), who argues that the result in Devereux and Engel (2003) comes from the symmetric reactions of consumption to idiosyncratic shocks when nontradable goods are absent. In an economy with nontradable goods, the monetary authorities in these two countries set divergent interest rate rules and thus nominal exchange rate flexibilities are needed for the asset market to achieve the equilibrium where the uncovered interest parity holds.

[4] Moreover, Devereux, Engle and Stoggard (2003) consider endogenous pricing strategies instead. They find that PCP is the optimal pricing strategy when exchange rate fluctuations are small while LCP is the optimal under greater exchange rate fluctuations.

welfare from the PCP case.

This paper is structured as follows. Section 2 outlines the specifications of the model. In Section 3, we conduct the analysis of the tariff's implications for a flexible-price economy. Section 4 then discusses the different prices and consumptions under PCP and LCP. Section 5 and 6 analyze the impacts of a tariff on the production and welfare. Finally, we present our conclusion in Section 7 and discuss areas for future research.

2. The model

2.1 Production

There are two countries, home and foreign. Each country produces both tradable and nontradable goods. Y_H and Y_N denote traded and nontraded goods produced in the home country, while Y_F and Y_N^* denote traded and nontraded goods in the foreign country. For each type of goods, the good market structure is monopolistic competition, with a lot of firms producing similar but slightly different goods and competing with each other in the market. Labor is the only input in the production process. Production functions follow the form:

$$Y_{H,t} = A_t L_{H,t}, \quad Y_{N,t} = A_t L_{N,t} \tag{1a}$$

where A_t is an autocorrelated country-specific productivity shock. H and N indicate home tradable and nontradable goods respectively. The foreign production functions follow the analogous form and are indexed by asterisks.

$$Y_{F,t}^* = A_t^* L_{F,t}^*, \quad Y_{N,t}^* = A_t^* L_{N,t}^* \tag{1b}$$

The real shock in the economy is characterized by technological innovation. The logarithm of productivity shocks, indicated by lower-case a_t and a_t^*, evolve with the following AR(1) process:

$$a_t = (1-\rho_a)a + \rho_a a_{t-1} + \varepsilon_{a,t}, \;\; \varepsilon_{a,t} \sim N(0, \sigma_a^2) \tag{2a}$$

$$a_t^* = \left(1-\rho_a^*\right) a^* + \rho_a^* a_{t-1}^* + \varepsilon_{a,t}^*, \;\; \varepsilon_{a^*,t} \sim N(0, \sigma_{a^*}^2) \qquad (2b)$$

The productivity shock is the only exogenous shock in the economy. Because the productivity shock follows a lognormal distribution, all the endogenous variables in the economy are lognormally distributed as well.

2.2 Consumption

There is a continuum of varieties for each type of good. Home goods are indexed from $j \in (0,1)$ while foreign goods are indexed from $j \in (1,2)$. Consumers in each country consume a variety of goods, composed of home and foreign tradable goods and domestic nontradable goods. For any individual i in the home country, the composite consumption index is in the Cobb-Douglas form:

$$C = \frac{C_T^{\gamma} C_N^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \qquad (3)$$

C_T and C_N are indices of traded and nontraded consumption and γ is the share of spending on tradable goods in total expenditure PC. Tradable consumption is composed of equal share of home and foreign tradable goods, C_H and C_F:

$$C_T = 2C_H^{1/2} C_F^{1/2} \qquad (4)$$

where

$$C_H = \left[\int_0^1 C_T(j)^{(\theta-1)/\theta} \mathrm{d}j\right]^{\theta/(\theta-1)}, \;\; C_F = \left[\int_1^2 C_T(j)^{(\theta-1)/\theta} \mathrm{d}j\right]^{\theta/(\theta-1)}, \;\; C_N = \left[\int_0^1 C_N(j)^{(\theta-1)/\theta} \mathrm{d}j\right]^{\theta/(\theta-1)}$$

and θ is the price elasticity of substitution among goods and $\theta>1$. The home aggregate price index for the composite consumption is

$$P = P_T^{\gamma} P_N^{1-\gamma}, \;\; P_T = \left(1+\tau\right)^{1/2} P_H^{1/2} P_F^{1/2} \qquad (5)$$

where

$$P_H = \left[\int_{i=0}^{1} P_T(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}, \ P_F = \left[\int_{i=1}^{2} P_T(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}, \ P_N = \left[\int_{i=0}^{1} P_N(i)^{1-\theta} di \right]^{\frac{1}{1-\theta}}$$

and τ is the home tariff on the goods imported from abroad. Therefore, home demand for each commodity can be derived as

$$C_T(h) = \left[\frac{P_T(h)}{P_H} \right]^{-\theta} C_H, \ C_T(f) = \left[\frac{P_T(f)}{P_F} \right]^{-\theta} C_F, \ C_N(h) = \left[\frac{P_N(h)}{P_N} \right]^{-\theta} C_N \quad (6)$$

Home demand functions for home and foreign goods are

$$C_H = \frac{1}{2} \left[\frac{P_H}{P_T} \right]^{-1} C_T, \ C_F = \frac{1}{2} \left[\frac{(1+\tau) P_F}{P_T} \right]^{-1} C_T$$

and home demand functions for traded and nontraded goods are

$$C_T = \gamma \left[\frac{P_T}{P} \right]^{-1} C, \ C_N = (1-\gamma) \left[\frac{P_N}{P} \right]^{-1} C$$

The parameter τ is the constant tariff associated with the protectionism policy of the home government. Variables in the foreign country are in analogous forms and indicated by asterisks.

2.3 The Utility Function

Consumers face the following intertemporal maximization problem as follows:

$$\max \ \sum_{t=0}^{\infty} \sum_{s_{t+1}} \beta^t E_0 \left(\frac{1}{1-\rho} C_t^{i1-\rho} - \kappa L_t^i \right) \quad (7a)$$

$$\text{s.t.} \quad P_t C_t^i + \sum_{s_{t+1}} B(s_{t+1}|s_t) D^i(s_{t+1}) \le P_t W_t L_t^i + D_t^i + P_{H,t}^i Y_{H,t}^i + \varsigma_t P_{H,t}^{*\ i} Y_{H,t}^{*\ i} + P_{N,t}^i Y_{N,t}^i + T_t \quad (7b)$$

The utility of individual i depends on consumption of the composite good, C_t^i, and the disutility from labor supply. β is the subjective discount factor and κ is the factor determining the disutility caused by the labor supplied. $1/\rho$ is the elasticity of substitution and we assume $\rho > 1$[5]. Real money holding does not enter the utility function because we use the interest rate rule as the monetary policy, rather than the control over the money supply in the economy. ς_t is the nominal exchange rate measured by the home currency price of the foreign currency.

We assume that asset markets are complete. That is, there is a complete set of state-contingent securities $D(s_t)$ in the budget constraint.[6] $B(s_{t+1}|s_t)$ is the home-currency price of the state-contingent security toward each future state s_{t+1}. The individual household receives wages from labor and collects revenues from the sale of good produced. Because output in the commodity market is determined by demand, Y indicates the amount of the good sold and the market demand for the good. The government transfers all the tariff revenue T_t to consumers.[7] W_t is the nominal wage for each unit of labor supplied, L_i. $Y^i_{H.t}$, $Y^i_{N,t}$ and $Y^{*i}_{H.t}$ denote the demand functions of the goods produced by home producer. Since all the consumers are assumed symmetric, we will drop the superscript i throughout the paper.

According to the maximization problem as specified above, the Euler equation is obtained as follows:

$$\frac{C_t^{-\rho}}{P_t} = \beta\left(1+i_t\right)E_t\left(\frac{C_{t+1}^{-\rho}}{P_{t+1}}\right) \tag{8}$$

where the definition of the nominal interest rate i_t is defined as follows: $1/\left(1+i_t\right)=\sum_{s_{t+1}} B\left(s_{t+1}|s_t\right)$. Note that the nominal interest rate in this model is the policy determined by the government and thus is exogenous to consumers' optimization.

Because consumers in the home and foreign countries face the same asset prices, the risk-sharing

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[5] The range of the elasticity of intertemporal substitution varies in a wide range. Most of the empirical studies support that the elasticity is smaller than unity, which implies $\rho > 1$. While most of the papers assume $\rho > 0$ (for example, Obstfeld (2006), Devereux and Engel (2003)), the assumption of $\rho > 1$ in this paper is primarily for analytical simplicity.

[6] Because all the exogenous shocks are lognormal, there will be a continuum of states. The specification of discrete states here can be extended to continuous states directly.

[7] As explained in Obstfeld and Rogoff (1998), the Cobb-Douglas preference implies the current account balance is zero if the initial debt is zero. However, if the tariff is imposed, the current account is not necessarily balanced unless the tariff revenue is returned to consumers to subsidize higher consumption expenditure caused by the tariff.

condition in the complete asset markets holds for all states[8]:

$$\frac{C_t^{-\rho}}{P_t} = \frac{C_t^{*-\rho}}{\varsigma_t P_t^*} \tag{9}$$

ς_t is the nominal exchange rate, defined as the home-currency price of one foreign currency. Since the purchasing power parity does not hold in our model due to the existence of nontradable goods and tariffs, this condition implies that consumptions do not generally equal across countries.

. Following the monetary policies adopted in Obstfeld (2006), the interest rate rules in these two countries are as follows:[9]

$$\ln\left(1+i_t\right) = \overline{i} + \omega p_t \tag{10a}$$

$$\ln\left(1+i_t^*\right) = \overline{i} + \omega p_t^* \tag{10b}$$

The monetary authority in each country adjusts the nominal interest rate in reaction to the domestic price levels and shocks from both countries. The foreign monetary policy follows an analogous form.[10, 11]

3. Flexible prices

To understand how sticky prices would affect the economy, we have to know how the economy works under flexible nominal prices. Assume that the central bank does not respond to productivity shocks so that the nominal interest rate rule is simplified as $1+i_t = \overline{i} + \omega p_t$ in the flexible-price case.

The tradeoff between labor supply and consumption is:

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[8] The derivation of this equation is in the appendix.

[9] Amato and Laubach (2004) find that a simple interest rate rule can nearly lead to the optimal allocation for any degree of habit formation. They adopt an inertial interest rate rule where the interest rate reacts to the past interest rate, the inflation rate and the output. The optimal monetary policy suggests a super-inertia interest rate rule that, in which the current interest rate reacts more than one hundred percent to its past value. The coefficient incorporating the nominal interest rate's reaction to the inflation rate is 2.37 when there is no habit formation. Both of these two responses of the interest rate decrease with the degree of habit formation.

[10] Following Obstfeld (2006), we assume there is no nominal shock to the interest rate rule. This case can be extended easily.

[11] Kollmann (2002) calibrates a dynamic general equilibrium model with a small open economy framework to find the optimal monetary policy rule. His finding supports the inflation targeting policy rule and the response of the central bank to a one-percent of the price level increase is 3. Bergin, et al. (2007) finds the similar inflation targeting rule and the parameter in reaction to the inflation rate is 5.0.

$$\frac{W_t}{P_t}C_t^{-\rho}=\frac{W_t^*}{P_t^*}C_t^{*-\rho}=\kappa \tag{11}$$

Substituting this equation back into Eq. (9), we can see that $W_t=\xi_t W_t^*$. In a monopolistic competition market, firms will set the price as a fixed markup over the marginal cost for the home and foreign countries; that is, $P_{H,t}=\frac{\theta}{\theta-1}\frac{W_t}{A_t}$ and $P_{F,t}=\frac{\theta}{\theta-1}\frac{W_t^*}{A_t^*}\xi_t$ respectively. Therefore, combined with the relative wage, relative price is simply the relative productivity across countries:

$$\frac{P_{H,t}}{P_{F,t}}=\frac{P_{H,t}^*}{P_{F,t}^*}=\frac{A_t^*}{A_t}$$

The combination of Eq. (11) and the composite price index yields the consumptions in these two countries respectively:

$$C_t=\left[\frac{\theta-1}{k\theta}A_t^{1-\frac{\gamma}{2}}A_t^{*\frac{\gamma}{2}}\left(1+\tau\right)^{-\frac{\gamma}{2}}\right]^{\frac{1}{\rho}},\quad C_t^*=\left[\frac{\theta-1}{k\theta}A_t^{\frac{\gamma}{2}}A_t^{*1-\frac{\gamma}{2}}\left(1+\tau^*\right)^{-\frac{\gamma}{2}}\right]^{\frac{1}{\rho}} \tag{12}$$

Eq. (12) shows that shocks are shared across countries. The home consumption increases with positive home and foreign shocks because higher productivity lowers both the domestic and foreign prices. On the contrary, higher tariff increases the domestic import price level and thus reduces the consumption. However, the imposition of the tariff affects the consumption in the domestic economy only. The share of the tradable goods in the overall consumption determines the magnitude of these effects.

Because all the variables follow lognormal distribution, take logarithms for the Euler equation Eq. (8) under flexible prices. Substitute the interest rate rule, consumptions in Eq. (12) and solve the price level recursively, then we can write the price level in terms of expected future consumption growth and variances of endogenous variables, which are assumed constant over time:

$$p_t=\frac{\rho_a-1}{1+\omega-\rho_a}\left[\left(1-\frac{\gamma}{2}\right)a_t+\frac{\gamma}{2}a_t^*\right]+\frac{1}{\omega}\left(\log\beta+\bar{i}+\frac{\rho^2}{2}\sigma_c^2+\frac{1}{2}\sigma_p^2+\rho\sigma_{cp}\right) \tag{13}$$

All lower cases denote the logarithm of the variables. Because both the exchange rate and prices can adjust freely, none of the tariff influences the home aggregate price level. However, relative tariff drives exchange rate movements. The combination of consumption and price level, Eq. (12), (13) and the risk-sharing condition, Eq. (9) yields the nominal exchange rate:

$$\xi_t = \frac{\omega(1-\gamma)}{1+\omega-\rho_a}\left(a_t - a_t^*\right) + \Gamma_{\xi,t}^{FP} \tag{14}$$

where

$$\Gamma_{\xi,t}^{FP} = -\frac{\gamma\left(\tau-\tau^*\right)}{2}$$

Here we make use of the fact that $\log\left(1+\tau\right) \simeq \tau$ when τ is small. This equation holds under the assumption that $E_{t-1}\Lambda_{c,t}^{FP} = E_{t-1}\Lambda_{c,t}^{*FP}$. It is shown that higher home productivity reduces home prices relative to foreign and thus the nominal exchange rate depreciates in reaction to the relative productivity movement. On the other hand, greater home tariff leads to the nominal exchange rate depreciation to diminish the magnitude of the domestic demand shift from import to the home goods due to the tariff.

Following past studies, we are interested in whether the tariff policy is contractionary or expansionary. In the monopolistic competition market, because the productions of each country consist of the goods sold to the domestic and foreign markets, the home production can be obtained from the world demand for home goods, Eq. (6), combined with relative prices:

$$Y_t = Y_{H,t} + Y_{N,t} + Y_{H,t}^* \tag{15}$$

Substituting prices from Eq. (11), the home tradable prices and consumptions in Eq. (12) with Eq. (15) yields:

$$\begin{aligned} Y_t = &\left(1-\frac{\gamma}{2}\right)\left(\frac{\theta-1}{\kappa\theta}\right)^{\frac{1}{\rho}} \exp\left\{\left(\frac{2-\gamma(1-\rho)}{2\rho}\right)a_t + \frac{\gamma(1-\rho)}{2\rho}a_t^* + \frac{\gamma(\rho-1)}{2\rho}\tau\right\} \\ &+ \frac{\gamma}{2}\left(\frac{\theta-1}{\kappa\theta}\right)^{\frac{1}{\rho}} \exp\left\{\left(\frac{2\rho-\gamma(\rho-1)}{2\rho}\right)a_t + \frac{(2-\gamma)(1-\rho)}{2\rho}a_t^* + \left(\frac{\gamma(\rho-1)-2\rho}{2\rho}\right)\tau^*\right\} \end{aligned} \tag{16}$$

where

$$\frac{\partial Y_t^{FP}}{\partial \tau} = \left(\frac{\gamma(\rho-1)}{2\rho}\right)Y_{H,t}^{FP} > 0,$$

$$\frac{\partial Y_t^{FP}}{\partial \tau^*} = \left(\frac{\gamma(\rho-1)-2\rho}{2\rho}\right)Y_{F,t}^{FP} < 0.$$

The home tariff is expansionary for its domestic output when $\rho > 1$, but the foreign tariff is contractionary for the home production. While the current home tariff has a direct negative effect on the aggregate consumption by raising up the aggregate price level, it also causes the home demand to shift toward the home produced goods due to the deterioration of the home terms of trade. The substitution effect in the latter dominates and thus the overall home production benefits from the protection policy. On the other hand, the foreign tariff reduces the foreign aggregate consumption as well as the import from home firms to the foreign market, and thus leads to lower home export. Note that, the future tariff plan does not influence the production.

The welfare under flexible prices can be evaluated by the expected utility:

$$E_0\left(\frac{1}{1-\rho}C_t^{i1-\rho}-\kappa L_t^i\right)$$

Where $L_t = Y_t / A_t$.

4. Optimal Pricings and Equilibriums under Alternative Nominal Rigidities

The optimal pricings under PCP and LCP are listed in Table 1. The results are essentially same as those in Devereux and Engel (2003), except that the aggregate price level in the equation contains the tariff. Prices are predetermined one period ahead before the profit is realized. Producers choose optimal prices by maximizing expected profits. The first-order derivation of a home firm with respect to the price of the goods sold in the domestic economy is as follows:

$$E_{t-1}\left\{\frac{C_t^{-\rho}}{P_t}\left[\frac{\partial P_{H,t}^i Y_{H,t}^i}{\partial P_{H,t}^i}\right]-\kappa\frac{\partial L_t}{\partial Y_{H,t}^i}\frac{\partial Y_{H,t}^i}{\partial P_{H,t}^i}\right\}=0$$

Other firms follow the same pricing process. However, the price setting for export firms varies with PCP and LCP. Under PCP, producers choose optimal prices in their own currency to maximize expected profits as the traditional pricing adopted by Fender and Yip (2000). Prices for goods sold in the foreign country are converted into the foreign-currency prices by using exchange rates, thus the law of one price holds for tradable goods. Under LCP, producers preset prices in consumers' currency so there is no exchange rate pass-through onto export prices. Therefore, the law of one price may not hold.

Table 1: Optimal Pricings under PCP and LCP

PCP	LCP
$P_{H,t}^{PCP} = P_{N,t}^{PCP} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(P_t C_t / A_t\right)}{E_{t-1}\left(C_t^{1-\rho}\right)}$	$P_{H,t}^{LCP} = P_{N,t}^{LCP} = P_{H,t}^{PCP}$
$P_{H,t}^{*PCP} = P_{H,t}^{PCP} / \varsigma_t$	$P_{H,t}^{*LCP} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(P_t^* C_t^* / A_t\right)}{E_{t-1}\left(C_t^{*1-\rho}\right)}$
$P_{F,t}^{PCP} = \varsigma_t P_{F,t}^{*PCP}$	$P_{F,t}^{LCP} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(P_t C_t / A_t^*\right)}{E_{t-1}\left(C_t^{1-\rho}\right)}$
$P_{F,t}^{*PCP} = P_{N,t}^{*PCP} = \left(\frac{k\theta}{\theta-1}\right)\frac{E_{t-1}\left(P_t^* C_t^* / A_t^*\right)}{E_{t-1}\left(C_t^{*1-\rho}\right)}$	$P_{F,t}^{*LCP} = P_{N,t}^{*LCP} = P_{F,t}^{*PCP}$

In monopolistic competition markets, the production is determined by consumption demands. To examine the effects of the tariff on the output in the equilibrium, we need to know the price and consumption first. The explicit solutions of prices and consumption can be obtained by taking similar steps in the flexible-price case. Because all variables are lognormally distributed, we can easily derive $E_{t-1}C_t$ and $E_{t-1}C_t^*$ from prices in Table 1 by using the price indices in Eq. (5).

Under LCP, the logarithm of the combination of $P_{H,t}^{LCP}$ and $P_{F,t}^{LCP}$ yields $E_{t-1}c_t^{LCP}$ in terms of exogenous productivity shocks:

$$E_{t-1}c_t^{LCP} = \frac{-1}{\rho}\log\frac{\theta\kappa}{\theta-1} - \frac{\gamma}{2\rho}\log\left(1+\tau\right) + \frac{2-\gamma}{2\rho}\left(E_{t-1}a_t + \sigma_{ca}\right) + \frac{\gamma}{2\rho}\left(E_{t-1}a_t^* + \sigma_{ca^*}\right) + \Lambda_{Ec} \tag{17}$$

where Λ_{Ec} includes all the moments associated with the expectation under the lognormal distribution. Negative productivity shocks and higher tariff raise the aggregate price level and thus lead to lower consumption level. The share of tradable goods, γ, dictates these impacts. Use the fact that $E_t P_{t+1} = P_{t+1}$, then the log-linearized Euler equation for home households, Eq. (8), can be written as:

$$c_t = E_t c_{t+1} - \frac{1}{\rho}\left[\log\beta + \log(1+i_t) - (p_{t+1} - p_t) + \frac{\rho^2}{2}\sigma_c^2\right] \tag{18}$$

By taking the expectation one period ahead and substituting $E_t c_{t+1}$ from Eq. (17), we can derive the explicit solution of p_t which essentially contains the information available at the period $t-1$. Eq. (8) with the substitution of p_t and p_{t+1} generates c_t.

Under PCP, however, the exchange rate pass-through complicates the computation. The exchange rate can be driven by the tariff as well as macroeconomic discrepancies and thus affects the terms of trade and the international demands for tradable goods. The price and consumption in these two countries can not be solved separately, but we need to find the global equilibrium. Define $x_t^T = x_t + x_t^*$ and $x_t^D = x_t - x_t^*$ represent the sum and difference of the variable x_t and x_t^*. We can obtain $E_{t-1}c_t^T$ from the logarithm of the combination of $P_{H,t}^{PCP}$ and $P_{F,t}^{*PCP}$:

$$E_{t-1}c_t^T = \frac{1}{\rho}E_{t-1}a_t^T - \frac{\gamma}{2\rho}\ln(1+\tau_t)^T - \frac{2}{\rho}\ln\left(\frac{\kappa\theta}{\theta-1}\right) \tag{19}$$

Let $\overline{p}_t^{PCP} = (1-\gamma/2)\,p_{H,t}^{PCP} + (\gamma/2)\,p_{F,t}^{*PCP}$ so that the home aggregate price level p_t can be written as $(\gamma/2)\xi_t + \overline{p}_t + (\gamma/2)\log(1+\tau)$. By doing so, we can separate the predetermined part in the aggregate price level from the nominal exchange rate which fluctuates with innovations. Substitute the aggregate price level into the Euler equation, then we can obtain the dynamics of the aggregate price index similar to Eq. (18):

$$c_t^T = E_t\left(c_{t+1}^T\right) - \frac{1}{\rho}\left[2\log\beta + \log(1+i_t)^T - \left(p_{t+1}^T - p_t^T\right) + \frac{\rho^2}{2}\sigma_c^{2T}\right]$$

Following the similar steps in the LCP case, we can solve p_t^T and c_t^T. p_t^D and c_t^D can be derived by substituting the nominal exchange rate from the risk-sharing condition into $P_{H,t}^{PCP}$ and $P_{F,t}^{*PCP}$. The impacts of the tariff on the price and consumption are listed below where $\Gamma_{x,\tau}$ indicates the effect of τ

on the variable x and $\Gamma_{x,\tau}$ represents the impacts from τ^*.

Table 2: Macroeconomic impacts of tariffs in the home country

Prices	$\Gamma_{p,\tau}^{PCP} = \Gamma_{p,\tau}^{LCP} = 0$, $\Gamma_{p,\tau^*}^{PCP} = \Gamma_{p,\tau^*}^{LCP} = 0$
Consumptions	$\Gamma_{c,\tau}^{PCP} = \Gamma_{c,\tau}^{LCP} = \frac{-\gamma}{2\rho}\tau$, $\Gamma_{c,\tau^*}^{PCP} = \Gamma_{c,\tau^*}^{LCP} = 0$
Nominal exchange rate	$\Gamma_{\xi,\tau}^{PCP} = \Gamma_{\xi,\tau}^{LCP} = -\frac{\gamma}{2}\tau$, $\Gamma_{\xi,\tau^*}^{PCP} = \Gamma_{\xi,\tau^*}^{LCP} = \frac{\gamma}{2}\tau^*$

Interestingly, the impacts of tariff are identical under LCP and PCP, however, the adjustment mechanism behind differs. Since prices are predetermined, the permanent tariffs reduce expected consumptions as well as the prices. Under PCP, the exchange rate movements caused by the tariff discrepancy offsets the ex ante terms of trade and thus the law of one price holds ex post. While the exchange rate pass-through is absent under LCP, the expected consumption drops directly with the permanent tariff and thus LCP firms' ex ante pricing react more to the tariff than PCP firms.

5. Welfare Implication of the Tariff under PCP

Because the law of one price holds under PCP and the government refunds the tariff revenue to consumers, the current account balance remains zero under the assumption of Cobb-Douglas preferences and zero initial debt.[12] The balanced current account states that the condition $PC = P_H Y_H + P_N Y_N = P_H Y$ holds for all periods. Therefore, the home output under PCP can be written as:

[12] The refund of tariff revenues assures the purchasing power of domestic households, even with the presence of tariff, and thus the zero current account balance which holds in Obstfeld and Rogoff also holds here.

$$
\begin{aligned}
Y_t^{PCP} &= \left(C_t^{PCP}\right)^{\frac{\rho\gamma}{2(1-\gamma)}+1}\left(C_t^{*PCP}\right)^{\frac{\rho\gamma}{2(1-\gamma)}}\left(1+\tau\right)^{\frac{\gamma(2-\gamma)}{4(1-\gamma)}}\left(1+\tau^*\right)^{\frac{\gamma^2}{4(1-\gamma)}} \\
&= \exp\left\{\left(\frac{\rho\gamma}{2(1-\gamma)}+1\right)c_t - \left(\frac{\rho\gamma}{2(1-\gamma)}\right)c_t^* - \left(\frac{\gamma^2}{4(1-\gamma)}\right)\tau^* + \left(\frac{\gamma(2-\gamma)}{4(1-\gamma)}\right)\tau\right\}
\end{aligned}
\tag{20}
$$

Here we let $\log(1+\tau)\approx\tau$. Thus, the impact of tariffs on the home output is:

$$
\frac{\partial Y_t^{PCP}}{\partial\tau} = \left(\frac{\gamma(\rho-1)}{2\rho}\right)Y_t^{PCP} > 0,
$$

$$
\frac{\partial Y_t^{PCP}}{\partial\tau^*} = 0
$$

The sign of $\partial Y_t^{PCP}/\partial\tau$ is positive as $\rho>1$, while the output is independent of the foreign tariff. The home production benefits from the deterioration of the terms of trade caused by the home tariff. Apparently, the effect of the foreign tariff on the home export is diminished by the exchange rate adjustment.

Proposition 1**:** Under PCP, the home tariff is expansionary for the home country while the foreign tariff stays independent of the home production.

The expected utility can be obtained from the consumption and the expected labor supply which is essentially determined by the production level for monopoly firms. Substituting the optimal pricing into the expected labor supply, the expected utility under PCP is mainly a function of home consumption:

$$
\begin{aligned}
W_t^{PCP} = E_{t-1}U_t^{PCP} &= \left[\frac{1}{1-\rho}-\frac{\theta-1}{\theta}\right]E_{t-1}\left(C_t^{PCP}\right)^{1-\rho} \\
&= \left[\frac{1}{1-\rho}-\frac{\theta-1}{\theta}\right]\exp\left\{(1-\rho)E_{t-1}c_t^{PCP} + \frac{(1-\rho)^2}{2}\sigma_{c^{PCP}}^2\right\}
\end{aligned}
\tag{21}
$$

Therefore, the tariffs influence the welfare solely through the consumption:

$$\frac{\partial W_t^{PCP}}{\partial \tau} = \left(\frac{\gamma(\rho - 1)}{2\rho} \right) W_t^{PCP} < 0 \text{ [13]},$$

$$\frac{\partial W_t^{PCP}}{\partial \tau^*} = 0$$

Different from its effect on the output, the home tariff places a negative impact on the home welfare. There is a tradeoff between consumption and labor supply in the utility evaluation. While higher consumption raises the utility level, greater labor supply which generates higher income reduces the utility level. Because the home tariff increases the home production, the negative effect of higher labor supply on the utility dominates the welfare gain from higher consumption. The foreign tariff does not influence the home welfare as it does to the home production and consumption for the same reason.

Proposition 2**:** the home tariff lowers the home welfare, while the home welfare is independent of the foreign tariff's impact.

6. Welfare Implication of the Tariff under LCP

Under nominal rigidity, the production is determined by demand. Therefore, the home output under LCP can be written as follows with the substitution the LCP optimal pricing into the output in Eq. (16):

$$Y_t^{LCP} = \left(1 - \frac{\gamma}{2}\right)^{\frac{\gamma}{2}} \left(\frac{P_{H,t}}{(1+\tau_t) P_{F,t}} \right)^{-\frac{\gamma}{2}} C_t + \frac{\gamma}{2} \left(\frac{P_{F,t}^*}{(1+\tau_t^*) P_{H,t}^*} \right)^{1-\frac{\gamma}{2}} C_t^*$$

Substituting the optimal pricing into the output, then the home production can be written as:

$$\begin{aligned} Y_t^{LCP} = & \left(1 - \frac{\gamma}{2}\right)\left(\frac{\theta - 1}{\kappa\theta}\right) \exp\left\{ \left[c_t^{LCP} - \rho E_{t-1} c_t^{LCP} \right] + E_{t-1} a_t + \Lambda_{YH}^{LCP} \right\} \\ & + \frac{\gamma}{2}\left(\frac{\theta - 1}{\kappa\theta}\right) \exp\left\{ -\tau_t^* + \left[c_t^{*LCP} - \rho E_{t-1} c_t^{*LCP} \right] + E_{t-1} a_t^* + \Lambda_{YF}^{LCP} \right\} \end{aligned}$$

where Λ_{YH} and Λ_{YF} represent the related moments. The impacts of tariffs on the home production are

[13] Here, we let $\Gamma_{U,\tau} = (1-\rho)\Gamma_{c,\tau}$ instead of $(1-\rho)\Gamma_{c,\tau}$ because the impacts of the tariff on the welfare is not solely determined by the sign of $(1-\rho)$.

$$\frac{\partial Y_t^{LCP}}{\partial \tau} = \left(\frac{\gamma(\rho-1)}{2\rho}\right) Y_{HT,t}^{LCP} > 0, \tag{22}$$

$$\frac{\partial Y_t^{LCP}}{\partial \tau^*} = \left[\left(\frac{\gamma(\rho-1)}{2\rho} - 1\right)\right] Y_{F,t}^{LCP} < 0$$

where $Y_{HT,t}^{LCP}$ denotes the home goods sold in the domestic economy, $Y_{H,t}^{LCP} + Y_{H*,t}^{LCP}$. The home tariff raises the production in the home country. Instead of being a portion of the total home output, the home tariff affects the home production through the domestic consumption of the home goods, while the foreign tariff ‘s impact is solely from the foreign consumption. Since the exchange rate movements do not affect tradable prices, the ex ante terms of trade movement due to the imposition of the tariff remains ex post. The foreign tariff improves the home terms of trade, reduces the demand for the home export and finally results in lower home production.

Proposition 3: The home tariff is expansionary for the home production while the foreign tariff has a negative effect on the home output.

Following the same steps, the welfare under LCP is:

$$\begin{aligned} W_t^{LCP} &= E_{t-1} U_t^{LCP} \\ &= \left[\frac{1}{1-\rho} - \left(1-\frac{\gamma}{2}\right)\left(\frac{\theta-1}{\theta}\right)\right] \exp\left\{(1-\rho) E_{t-1} c_t^{LCP} + \frac{(1-\rho)^2}{2}\sigma_{c^{LCP}}^2\right\} \\ &\quad - \frac{\gamma}{2}\left(\frac{\theta-1}{\theta}\right)\exp\left\{-\tau^* + (1-\rho) E_{t-1} c_t^{*LCP} + \frac{(1-\rho)^2}{2}\sigma_{c^{*LCP}}^2\right\} \end{aligned} \tag{23}$$

The tariffs impacts on the welfare can be stated as follows:

$$\frac{\partial W_t^{LCP}}{\partial \tau} = \frac{\gamma(\rho-1)}{2\rho} W_{H,t}^{LCP} < 0,$$

$$\frac{\partial W_t^{LCP}}{\partial \tau^*} = -\left(\frac{\gamma(\rho-1)}{2\rho} + 1\right) W_{F,t}^{LCP} > 0$$

While the home tariff hurts the home welfare, the home country benefits from the foreign tariff. Similar to the PCP case, the positive effect of the home tariff on the labor supply places a negative effect on the home welfare which dominates the positive effect of higher consumption on the utility. As we can see, the home tariff's impact on the home production is relatively limited under LCP than PCP as it influences only part of the consumption and labor supply. Moreover, the foreign tariff now acts to improve the home welfare by reducing the home export and labor supply.

Proposition 4: The home tariff diminishes the home welfare, while the foreign tariff is beneficial. The effect of the home tariff is small under LCP than PCP.

7. Conclusion

The objective of this paper is to investigate the effects of tariffs on an economy under alternative pricing behaviors, PCP and LCP, which incur different exchange rate pass-through and expenditure-switching effects. While most of past studies use static models to examine the tariff's effect, this study conducts the issue of the trade protection policy in a two-country dynamic general equilibrium model.

The analytical solutions shed light on the importance of the exchange rate pass-through in the macroeconomic and welfare implications of the tariff. While the tariff has identical effects on prices and consumption under PCP and LCP, different mechanisms arise. Under PCP, the exchange rate adjustment offsets the ex ante price discrepancy and thus the law of one price holds. As a consequence, the home tariff decreases the home production while the foreign tariff does not and its effects are removed by the exchange rate movements. The lower labor supply associated with the lower production improves the home welfare. The effects of the foreign tariff on the home output and welfare are absent. On the other hand, the exchange rate fluctuations do not affect the ex post terms of trade under LCP. Therefore, firms decrease the prices directly with the imposition of the home tariff which results in lower consumption demand. It thus causes the home production contraction and welfare improvement.

Many interesting issues can be analyzed under this framework. As discussed in Mundell (1961), the exchange rate regimes, flexible or fixed, may lead to different effects of the tariff on the economy. This result may differ under the dynamic general equilibrium setting. Lastly, while the analytical solution in the model can elucidate the effects of protection policy on the economy, this model is subject to certain assumptions and thus fails to capture some important aspects of this issue. For example, we may calibrate a more general specification of the model to observe the dynamic adjustment that macroeconomic variables respond to a temporary protection.

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計畫成果自評

1. 研究內容與原計畫相符程度：

本研究內容與原計畫主題相符，唯使用之研究方式不同。原計畫預計採用校對模擬方式 (calibration) 針對關稅問題進行動態分析，而本研究內容則以一理論模型之分析解來作關稅政策之評估。採用後者的主因是，分析解更便於提供政策制定者評估相關變數變動時對於政策效果之影響

2. 達成預期目標情況：

本研究約達成原計畫預計目標之 95%

3. 研究成果之學術或應用價值：

本研究是以一兩國模型架構，於不同的名目僵固性 (producer-currency pricing (PCP) 與 local-currency pricing (LCP)) 之下探討關稅政策對於總體經濟與福利的影響分別為何。過往研究普遍僅採取其中一種名目僵固性 (PCP) 來進行貿易政策之分析；然而近年來，實證研究發現，LCP 的現象遠較 PCP 普遍；相關理論研究亦證實，不同的名目僵固性對於最適貨幣政策與匯率制度具有重要的影響。因此本研究於學術上具有顯著貢獻。除此之外，本研究成果可作為政府單位制定貿易政策之參考。

4. 是否適合在學術期刊發表或申請專利：

本研究預計於國際期刊上發表 1-2 篇文章。

5. 主要發現或其他有關價值等：

本研究主要是在探討匯率轉嫁 (exchange rate pass-through) 的程度對於貿易政策之影響。在 PCP 之下，關稅可完全轉嫁至貿易財價格，使得匯率的變動得以減緩關稅對於價格與消費的影響。另一方面，LCP 下，匯率無法轉嫁。本研究發現，不論是在 LCP 或是 PCP 之下，本國關稅對於本國的產出皆具有正面效果，並對福利造成負向的影響；但在 LCP 下，本國關稅對於本國經濟的影響較小。另一方面，外國關稅在 PCP 的環境裡不會影響本國產出與福利，外國關稅在 LCP 下卻會使得造成本國產出的下降以及福利的提昇(因為勞動供給減少)。此研究結果與過往僅在 PCP 的設定下進行的關稅政策評估所得之結果有所不同，並可提供貿易政策之政策制定者重要的訊息： 在一普遍採取 LCP 的經濟體中，關稅政策的施行對於本國經濟所造成的影響較小。

Macroeconomic Implications of the Trade Protection Policy under Local-Currency Pricing

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報告論文

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Abstract

The imposition of a tariff is the most widely used protection policy in international trades and has been a long-lasting issue in international economics. This paper uses a two-country dynamic general equilibrium model to examine the effects of the tariff on the world economy under local-currency pricing (LCP). Because prices are predetermined ahead of the time the consumption takes place, we emphasize the importance of the timing of the policy announcement and the information set for the expectation. The analytical solutions available in this model show that the information discrepancy between the producer and consumer is critical to the tariff's impact on the aggregate consumption and production. Three alternative policy plans are considered. While the anticipated home policy shock causes contractionary impacts of the trade policy on the domestic output, whether the unanticipated permanent and temporary policy shocks are expansionary or contractionary depends upon how risk averse the agents in the economy are. In all cases, the foreign tariff reduces the home productions.

Keywords: Keyword：Tariff, Nominal rigidity, Local-currency pricing

JEL Classifications: F13; F41; E42

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1. Introduction

One of the primary tools of trade protection policies is the imposition of import tariffs. In recent years, many cases are going on among the major countries. For example, in 2004, the European Union (EU) imposed a retaliate tariff on U.S. exports for the export tax subsidy applied by the U.S. government to U.S. producers. In 2006, the EU placed anti-dumping tariffs on goods exported from China. The producers of the EU seem to be the only winner, while retailers and consumer groups opposed to the move. Early trade literature shows that tariffs are contractionary (Krugman (1982)), such that prices go up and lower quantities are caused. The imposition of tariffs thus may turn to hurt domestic consumers' welfare. Evaluating the influences of the trade policy on the economy, in particular, on the welfare, is an important job for the authorities.

This has long been an important issue in international macroeconomics, though not too many endeavors devoted to it with intertemporal optimization. There are consensus in the early studies, as surveyed by Krugman (1982), that monetary polices are contractionary in an economy with a flexible exchange rate regime while expansionary under a fixed exchange rate regime. However, these studies are based on ad hoc assumptions of behavior and a small open economy. The absence of micro-foundations implies the failure of welfare assessments of policies. The small open economy model also neglects the transmission mechanism of shocks across countries. Rare studies in the past two decades discuss the macroeconomic effects of tariffs based on intertemporal utility optimization and a two-country framework (Sen and Turnovsky (1989), Fender and Yip (2000)).

The effects of a tariff under alternative exchange rate regimes have long been discussed in literature. This issue was initiated by Mundell (1961). He uses a static model with nominal rigidity and argues that the output declines with the imposition of the tariff under flexible exchange rates, while increases under fixed exchange rates. The depressing effect under flexible exchange rates comes from the Laursen-Metzler effect, which suggests that the tariff induces higher saving while suppressing consumption. Because predetermined consumer prices were kept constant under fixed exchange rate, the tariff increases the import prices, improves the home terms of trade, and thus increases the world demand for home tradable goods as well as the domestic nominal income.

After the collapse of the Bretton Woods System, researchers have paid much attention to trade policies under flexible exchange rates and more endeavors were devoted to this issue, such as Boyer (1977), Chan (1978) and Eichengreen (1981) among others. While Mundell uses a static model, Eichengreen (1981) uses a dynamic model to analyze the short-run and long-run effects of a tariff under flexible exchange rates. He finds that a tariff can be expansionary in the short run, contrary to Mundell's argument, but contractionary in the long run. In general, the imposition of a tariff faces trade-offs: the direct effect on the welfare from the improvement of the terms of trade, which induce greater world demand for home goods, and the indirect effect from the appreciation of home currency. The studies based on Mundell's framework were surveyed by Krugman (1982) who concludes the consensus that mostly coincide with the combination of Eichengreen and Mundell's propositions.

However, these studies lack micro-foundations and thus fail to measure social welfare appropriately. Sen and Turnovsky (1989) use an intertemporal optimization framework to study the effects of unanticipated permanent, anticipated temporary, and anticipated permanent tariffs on the economy and, in particular, on the current account balances. They find that a tariff is contractionary both in the short run and long run. Both output and employments are suppressed. Their study emphasizes the role of capital accumulation, the main factor that drives the current account movements. While their study is based on a small open economy, the shock transmission mechanism is neglected.

Thus, the objective of this study is to examine the effects of the tariff on the economy in a two-country dynamic general equilibrium model with monopolistic competition and nominal rigidity. The monopoly power embodied in each monopoly firm justifies its ability to keep the prices unchanged for some periods in face of shocks. Equipped with micro-foundations, this class of model has been used for many international macroeconomic issues and policy evaluations in the past decade, after it was initiated by Obstfeld and Rogoff (1995). While most of the studies based on the model examine exchange rate regimes and international business cycles, relatively scarce studies focus on trade related issues. Bacchetta and Wincoop (2000) examine the relationship between exchange rate flexibility and trade, and find that exchange rate fluctuations do not affect trades when the utility is separable. The influences of exchange rate regimes on trade and welfare depend upon preferences and how the exchange rate regime (the international monetary policy independence) is formulated.

The only study using a two-country dynamic general equilibrium model to study tariffs' effects is Fender and Yip (2000). They stress the role that monopolistic competition plays in international macroeconomy, which has resulted in inefficient outcomes. Their model shows that the tariff decreases both output and employment. As in standard models, the impacts of a permanent tariff on welfare face tradeoffs, mainly from its impacts on output and consumption through terms of trade changes. Due to the monopolistically competitive environment, the elasticity of substitution among goods is crucial in the tariff's net effect on the welfare. The steady-state welfare is increased when the elasticity of substation is high such that the demand for the home good increases more when import prices are raised due to the tariff. Moreover, the two-country model permits the evaluation of tariff's impacts on the foreign country, which are ambiguous in their model. Thus far, this is the only study conducting tariff issues based on NOEM models. As pointed out by Fender and Yip (2000), it is very difficult to find the related studies using similar approach in literature.

Unlike Fender and Yip (2000), this research centers on the tariff's effect under an alternative nominal rigidity, named local-currency pricing (LCP). There are two pricing strategies in the literature. One is producer-currency pricing (PCP), and the other is local-currency pricing (LCP). In PCP, firms predetermine nominal prices for the goods they sell in their own currency. Thus nominal exchange rate fluctuations will have complete pass-through effects on the consumer prices.. In LCP, however, export firms preset prices in the currency of consumers. As a result, nominal exchange rate fluctuations do not affect the final prices at all and the purchasing power parity does not necessarily hold in general, which is different from all existing studies on tariffs. Devereux and Engel (2003) have shown that the pricing strategy has important implications for the optimal exchange rate regime. They find that a flexible exchange rate regime is optimal under PCP, while a fixed exchange rate is optimal under LCP.[2] Nevertheless, their result is challenged by Obstfeld (2006), who argues that the result in Devereux and Engel (2003) is based upon the symmetric reactions of consumption to idiosyncratic shocks when

[2] Moreover, Devereux, Engle and Stoggard (2003) consider endogenous pricing strategies instead. They find that PCP is the optimal pricing strategy when exchange rate fluctuations are small while LCP is the optimal under greater exchange rate fluctuations.

nontradable goods are absent. In an economy with nontradable goods, the monetary authorities in these two countries set divergent interest rate rule and thus the nominal exchange rate flexibility is needed for the asset market to achieve the equilibrium where the identity holds. While the exchange rate flexibility matters in the trade policy as past studies suggest, the degree of exchange rate pass-through, which determines how much the tariff is passed upon the import prices, would have important implications for consumption, output and welfare. Thus, in contrast to the PCP case in Fender and Yip (2000) and past studies, this paper examines the tariff's implications under the alternative price setting, LCP.

To achieve the goal of this study specifically, we include the tariff in the highly tractable model in Obstfeld (2006) where analytical solutions are available. In this model, nontradable goods are present and all the prices are predetermined one period ahead from firms' profit-maximization decision. We use the stochastic tariff to characterize the policy shock, emphasizing the importance of the expectation under nominal rigidity. Since prices are preset by firms, prices may not be able to react to any unanticipated policy shock. Moreover, with the absence of exchange rate flexibility under LCP, the only adjustment mechanism falls on the goods market. We focus our discussion on tariff's implications for the aggregate price level, consumption and productions.

The result shows that the timing of the expectation formation is critical to the implications of policy shocks for the economy. Because firms determine the prices one period ahead of the time the goods are sold, the analytical solutions show that the information discrepancy between firms and consumers is a crucial determinant of consumption and output. Three cases with different policy shocks are discussed: anticipated permanent tariff, unanticipated permanent tariff and unanticipated temporary tariff. The comparison of the first two cases, in particular, discloses the point we address above: if the policy is not known when the prices are determined, but announced later when the goods are sold, prices fail to adjust in time and thus the tariff is added up directly to the import prices, leading to higher aggregate price level and lower consumption. In this case, however, whether the trade protection policy is expansionary or contractionary to the output is determined by the relative size of the subjective risk aversion and the monetary authority's response to the aggregate price level.

This paper is structured as follows. Section 2 outlines the specifications of the model. In Section 3, we discuss the tariff's implications for the benchmark economy under flexible prices. Section 4 then conducts the model under LCP. Analytical solutions that are available under this framework disclose the critical role that the information plays. Three policy shocks are discussed in Section 5. Finally, we present our conclusion in Section 6 and discuss areas for future research.

2. The model

2.1 Production

There are two countries, home and foreign. Each country produces both tradable and nontradable goods. Y_H and Y_N denote traded and nontraded goods produced in the home country, while Y_F and Y_N^* denote traded and nontraded goods in the foreign country. For each type of goods, the good market structure is monopolistic competition, with a lot of firms producing similar but slightly different goods and competing with each other in the market. Labor is the only input in the production process. Production functions follow the form:

$$Y_{H,t} = A_t L_{H,t}, \quad Y_{N,t} = A_t L_{N,t} \tag{1a}$$

where A_t is an autocorrelated country-specific productivity shock. H and N indicate home tradable and nontradable goods respectively. The foreign production functions follow the analogous form and are indexed by asterisks.

$$Y_{F,t}^* = A_t^* L_{F,t}^*, \quad Y_{N,t}^* = A_t^* L_{N,t}^* \tag{1b}$$

The real shock in the economy is characterized by technological innovation. The logarithm of productivity shocks, indicated by lower-case a_t and a_t^*, evolve with the following AR(1) process:

$$a_t = (1-\rho_a)a + \rho_a a_{t-1} + \varepsilon_{a,t}, \;\; \varepsilon_{a,t} \sim N(0,\sigma_a^2) \tag{2a}$$

$$a_t^* = (1-\rho_a^*)a^* + \rho_a^* a_{t-1}^* + \varepsilon_{a,t}^*, \;\; \varepsilon_{a^*,t} \sim N(0,\sigma_{a^*}^2) \tag{2b}$$

The productivity shock is the only exogenous shock in the economy. Because the productivity shock follows a lognormal distribution, all the endogenous variables in the economy are lognormally distributed as well.

2.2 Consumption

There is a continuum of varieties for each type of good. Home goods are indexed from $j \in (0,1)$ while foreign goods are indexed from $j \in (1,2)$. Consumers in each country consume a variety of goods, composed of home and foreign tradable goods and domestic nontradable goods. For any individual i in the home country, the composite consumption index is in the Cobb-Douglas form:

$$C = \frac{C_T^{\gamma} C_N^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \tag{3}$$

C_T and C_N are indices of traded and nontraded consumption and γ is the share of spending on tradable goods in total expenditure PC. Tradable consumption is composed of equal share of home and foreign tradable goods, C_H and C_F:

$$C_T = 2C_H^{1/2} C_F^{1/2} \tag{4}$$

where

$$C_H = \left[\int_0^1 C_T(j)^{(\theta-1)/\theta} \mathrm{d}j\right]^{\theta/(\theta-1)}, \quad C_F = \left[\int_1^2 C_T(j)^{(\theta-1)/\theta} \mathrm{d}j\right]^{\theta/(\theta-1)}, \quad C_N = \left[\int_0^1 C_N(j)^{(\theta-1)/\theta} \mathrm{d}j\right]^{\theta/(\theta-1)}$$

and θ is the price elasticity of substitution among goods. The home aggregate price index for the composite consumption is

$$P = P_T^{\gamma} P_N^{1-\gamma}, \quad P_T = (1+\tau)^{1/2} P_H^{1/2} P_F^{1/2} \tag{5}$$

where

$$P_H = \left[\int_{i=0}^{1} P_T(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}, \quad P_F = \left[\int_{i=1}^{2} P_T(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}, \quad P_N = \left[\int_{i=0}^{1} P_N(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$$

and τ is the rate of tariff on the imported goods from abroad. Therefore, home demand for each commodity can be derived as

$$C_T(h) = \left[\frac{P_T(h)}{P_H}\right]^{-\theta} C_H, \quad C_T(f) = \left[\frac{P_T(f)}{P_F}\right]^{-\theta} C_F, \quad C_N(h) = \left[\frac{P_N(h)}{P_N}\right]^{-\theta} C_N$$

Home demand functions for home and foreign goods are

$$C_H = \frac{1}{2}\left[\frac{P_H}{P_T}\right]^{-1} C_T, \quad C_F = \frac{1}{2}\left[\frac{P_F}{P_T}\right]^{-1} C_T$$

and home demand functions for traded and nontraded goods are

$$C_T = \gamma\left[\frac{P_T}{P}\right]^{-1} C, \quad C_N = (1-\gamma)\left[\frac{P_N}{P}\right]^{-1} C$$

Consumptions and prices in the foreign country are in analogous forms and indicated by asterisks.

2.3 The Utility Function

Consumers face the following intertemporal maximization problem as follows:

$$\max \sum_{t=0}^{\infty}\sum_{s_{t+1}} \beta^t E_0\left(\frac{1}{1-\rho} C_t^{i1-\rho} - \kappa L_t^i\right) \tag{6a}$$

$$\text{s.t.} \quad P_t C_t^i + \sum_{s_{t+1}} B(s_{t+1}|s_t) D^i(s_{t+1}) \le P_t W_t L^i + D_t^i + P_{H,t}^i Y_{H,t}^i + \varsigma_t P_{H,t}^{*\,i} Y_{H,t}^{*\,i} + P_{N,t}^i Y_{N,t}^i + T_t \tag{6b}$$

The utility of individual i depends on consumption of the composite good, C_t^i, and the disutility from labor supply. β is the subjective discount factor and κ is the factor determining the disutility caused by the labor supplied. ρ is the coefficient of relative risk aversion. Real money holding does not enter the utility function because we use the interest rate rule as the monetary policy, rather than the control over the money supply in the economy. ς_t is the nominal exchange rate measured by the home currency price of the foreign currency.

We assume that asset markets are complete. That is, there is a complete set of state-contingent securities $D(s_t)$ in the budget constraint.[3] $B(s_{t+1}|s_t)$ is the home-currency price of the state-contingent security toward each future state s_{t+1}. The individual household receives wages from labor and collects revenues from the sale of good produced. Because output in the commodity market is determined by demand, Y indicates the amount of the good sold and the market demand for the good. T_t is the transfer from the government. The government uses the tariff revenue to finance the lump-sum transfer to the consumers

[3] Because all the exogenous shocks are lognormal, there will be a continuum of states. The specification of discrete states here can be extended to continuous states directly.

W_t is the nominal wage for each unit of labor supplied, L_i. $Y^i_{H.t}$ denotes the demand function faced by the monopolistic-competitive producer i of home tradable goods, which can be described by:

$$Y^i_{H,t} = \frac{\gamma}{2}\left(\frac{P^i_{H,t}}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-1}\left(\frac{P_{T,t}}{P_t}\right)^{-1} C_t, \tag{7a}$$

The demand function for each type of goods follows the analogous form:

$$Y^i_{N,t} = (1-\gamma)\left(\frac{P^i_{N,t}}{P_{N,t}}\right)^{-\theta}\left(\frac{P_{N,t}}{P_t}\right)^{-1} C_t, \tag{7b}$$

$$Y_{F,t} = \frac{\gamma}{2}\left(\frac{(1+\tau_t)P^i_{F,t}}{(1+\tau_t)P_{F,t}}\right)^{-\theta}\left(\frac{(1+\tau_t)P_{F,t}}{P_{T,t}}\right)^{-1}\left(\frac{P_{T,t}}{P_t}\right)^{-1} C_t\,. \tag{7c}$$

The tariff τ_t involves the trade policy of the home government. It can be anticipated if the policy has been announced befor it is in effect, but unanticipated if the tariff is not known until it is impoced. Here, we treat τ_t as a random variable and $(1+\tau_t)$ follows the lognormal distribution. In Section 5, we will discuss how alternative tariff policies may have different effects on the economy.

Since all the consumers are symmetric, we will drop the superscript i throughout the paper. According to the maximization problem as specified above, the Euler equation is as follows:

$$\frac{C_t^{-\rho}}{P_t} = \beta(1+i_t)E_t\left(\frac{C_{t+1}^{-\rho}}{P_{t+1}}\right) \tag{8}$$

where the definition of the nominal interest rate i_t is defined as follows: $1/(1+i_t) = \sum_{s_{t+1}} B(s_{t+1}|s_t)$. Note that the nominal interest rate in this model is the policy determined by the government and thus is exogenous to consumers' optimization.

Because consumers in the home and foreign countries face the same asset prices, the risk-sharing condition in the complete asset markets holds for all time and states[4]:

[4] The derivation of this equation is in the appendix.

$$\frac{C_t^{-\rho}}{P_t} = \frac{C_t^{*-\rho}}{\varsigma_t P_t^*} \tag{9}$$

Since the purchasing power parity does not necessarily hold in our model, this condition implies that consumptions may not generally equal across countries.

. Following the monetary policies adopted in Obstfeld (2006), the interest rate rules in these two countries are as follows:[5]

$$\ln\left(1+i_t\right) = \bar{i} + \omega p_t + \phi_H \varepsilon_{a,t} + \phi_F \varepsilon_{a^*,t} \tag{10a}$$

$$\ln\left(1+i_t^*\right) = \bar{i} + \omega p_t^* + \phi_H^* \varepsilon_{a,t} + \phi_F^* \varepsilon_{a^*,t} \tag{10b}$$

The monetary authority in each country adjusts the nominal interest rate in reaction to the domestic price levels and shocks from both countries. ϕ_H and ϕ_F are the home monetary policy parameters determining how the home monetary authority reacts to shocks. The foreign monetary policy follows an analogous form.[6]

3. Flexible prices

To understand how sticky prices would affect the economy, we have to know how the economy works under flexible nominal prices. Assume that the central bank does not respond to productivity shocks so that the nominal interest rate rule is simplified as $1+i_t = \bar{i} + \omega p_t$ in the flexible-price case.

The tradeoff between the labor supply and consumption is:

$$\frac{W_t}{P_t} C_t^{-\rho} = \frac{W_t^*}{P_t^*} C_t^{*-\rho} = \kappa \tag{11}$$

Substituting this equation back into Eq. (9), we can see that $W_t = \xi_t W_t^*$. In a monopolistic competition market, firms will set the price as a fixed markup over the marginal cost for the home and foreign countries;

[5] Amato and Laubach (2004) find that a simple interest rate rule can nearly lead to the optimal allocation for any degree of habit formation. They adopt an inertial interest rate rule where the interest rate reacts to the past interest rate, the inflation rate and the output. The optimal monetary policy suggests a super-inertia interest rate rule that, in which the current interest rate reacts more than one hundred percent to its past value. The coefficient incorporating the nominal interest rate's reaction to the inflation rate is 2.37 when there is no habit formation. Both of these two responses of the interest rate decrease with the degree of habit formation.

[6] Following Obstfeld (2006), we assume there is no nominal shock to the interest rate rule. This case can be extended easily.

that is, $P_{H,t} = \frac{\theta}{\theta-1}\frac{W_t}{A_t}$ and $P_{F,t} = \frac{\theta}{\theta-1}\frac{W_t^*}{A_t^*}\xi_t$ respectively. Therefore, combined with the relative wage, relative price is simply the relative productivity across countries:

$$\frac{P_{H,t}}{P_{F,t}} = \frac{P_{H,t}^*}{P_{F,t}^*} = \frac{A_t^*}{A_t}$$

The combination of Eq. (11) and the composite price index yields the consumptions in these two countries respectively:

$$C_t = \left[\frac{\theta-1}{k\theta} A_t^{1-\frac{\gamma}{2}} A_t^{*\frac{\gamma}{2}} \left(1+\tau_t\right)^{-\frac{\gamma}{2}}\right]^{\frac{1}{\rho}}, \quad C_t^* = \left[\frac{\theta-1}{k\theta} A_t^{\frac{\gamma}{2}} A_t^{*1-\frac{\gamma}{2}} \left(1+\tau_t^*\right)^{-\frac{\gamma}{2}}\right]^{\frac{1}{\rho}} \tag{12}$$

Eq. (12) shows that shocks are shared across countries. The home consumption increases with positive home and foreign shocks because higher productivity lowers both the domestic and foreign good prices. On the contrary, higher tariff increases the domestic import price level and thus reduces the consumption. However, the imposition of the tariff affects the consumption in the domestic economy only. The share of the tradable goods in the overall consumption determines the magnitude of these effects.

Because all the variables follow lognormal distribution, take logarithms for the Euler equation Eq. (8) under flexible prices. Substitute the interest rate rule and solve the price level recursively, then we can write the price level in terms of expected future consumption growth and variances of endogenous variables, which are assumed constant over time:

$$p_t = \sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t} \rho\left[E_t\left(c_{s+1}-c_s\right)\right] - \frac{1}{\omega}\left[\log\beta + \bar{i} + \frac{\rho^2}{2}\sigma_c^2 + \frac{1}{2}\sigma_p^2 + \rho\sigma_{cp}\right] \tag{13}$$

All lower cases denote the logarithm of the variables. Substitute consumption functions Eq. (12) into Eq. (13), we will see that the price level can be written as:

$$p_t = \frac{\rho_a - 1}{1+\omega-\rho_a}\left[\left(1-\frac{\gamma}{2}\right)a_t + \frac{\gamma}{2}a_t^*\right] + \Gamma_{p,t}^{FP} + \frac{1}{\omega}\left(\log\beta + \bar{i} + \frac{\rho^2}{2}\sigma_c^2 + \frac{1}{2}\sigma_p^2 + \rho\sigma_{cp}\right) \tag{14}$$

where

$$\Lambda_{p,t}^{FP} = -\frac{\gamma}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t} E_t\left(\log\left(1+\tau_{s+1}\right) - \log\left(1+\tau_s\right)\right).$$

Same as consumption, the home aggregate price level is influenced by the domestic tariff only. However, the impact of the tariff on the price level, $\Lambda_{p,t}^{FP}$, involves not only current tariff rate but also the expected future tariff policy changes. While current tariff shock causes higher price level, expected tariff increase lowers the aggregate price level. It is because lower consumption is caused by higher price level in the future, forcing the monopolistic firms to reduce prices.

The moment terms in the parenthesis are primarily associated with variances of consumption and the covariance between consumption and price and are assumed to be identical across countries. Because the tariff affects consumption, its variation would also impact the level of price and other macroeconomic variables. However, throughout the paper we neglect the effects caused by the policy fluctuations because the trade protection policy is not subject to frequent adjustments.

The trade policy also drives exchange rate movements. Substitute the consumption and price level, Eq. (12) and (14), into the risk-sharing condition Eq. (10), we can derive the nominal exchange rate:

$$\xi_t = \frac{\omega(1-\gamma)}{1+\omega-\rho_a}\left(a_t - a_t^*\right) + \Lambda_{\xi,t}^{FP} \tag{15}$$

where

$$\Lambda_{\xi,t}^{FP} = -\frac{\gamma}{2}\left\{\left(\log\left(1+\tau_t\right) - \log\left(1+\tau_t^*\right)\right) + \sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t} E_t\left(\log\left(\frac{1+\tau_{s+1}}{1+\tau_s}\right) - \log\left(\frac{1+\tau_{s+1}^*}{1+\tau_s^*}\right)\right)\right\}$$

This equation holds because $E_{t-1}\Lambda_{c,t}^{FP} = E_{t-1}\Lambda_{c,t}^{*FP}$. Both relative productivity shock current and future relative tariff rates cause the nominal exchange rate movements. Higher home productivity reduces home prices relative to foreign and thus the nominal exchange rate depreciates in reaction to the relative productivity movements. On the other hand, greater home tariff leads to the nominal exchange rate depreciation to diminish the magnitude of the domestic demand shift from import to the home goods due to the tariff.

Following past studies, we are interested in whether the tariff policy is contractionary or expansionary. In the monopolistic competition market, because the productions of each country consist of the goods sold to the domestic and foreign markets, the home production can be obtained from the world demand for home goods, Eq. (7), combined with relative prices:

$$
\begin{aligned}
Y_t &= Y_{H,t} + Y_{N,t} + Y_{H,t}^{*} \\
&= \left(1-\frac{\gamma}{2}\right)\left(\frac{P_{H,t}}{P_t}\right)^{-1} C_t + \frac{\gamma}{2}\left(\frac{\left(1+\tau_t^{*}\right)P_{H,t}^{*}}{P_t^{*}}\right)^{-1} C_t^{*} \\
&= \left\{\left(1-\frac{\gamma}{2}\right)\left(1+\tau_t\right)^{\frac{\gamma}{2}}\left(\frac{A_t^{*}}{A_t}\right)^{-\frac{\gamma}{2}} C_t + \frac{\gamma}{2}\left(1+\tau_t^{*}\right)^{\frac{\gamma}{2}-1}\left(\frac{A_t^{*}}{A_t}\right)^{1-\frac{\gamma}{2}} C_t^{*}\right\} \\
&= \left(1-\frac{\gamma}{2}\right)\left(\frac{\theta-1}{\kappa\theta}\right)^{\frac{1}{\rho}} A_t^{\frac{2-\gamma(1-\rho)}{2\rho}} A_t^{*\frac{\gamma(1-\rho)}{2\rho}} \exp\left[\Lambda_{Y,t}^{FP,H}\right] + \frac{\gamma}{2}\left(\frac{\theta-1}{\kappa\theta}\right)^{\frac{1}{\rho}} A_t^{1-\frac{\gamma(\rho-1)}{2\rho}} A_t^{*\frac{(2-\gamma)(1-\rho)}{2\rho}} \exp\left[\Lambda_{Y,t}^{FP,F}\right]
\end{aligned}
\tag{16}
$$

where

$$
\Lambda_{Y,t}^{FP,H} = \frac{\gamma(\rho-1)}{2\rho}\log\left(1+\tau_t\right),
$$

$$
\Lambda_{Y,t}^{FP,F} = \left(\frac{\gamma(\rho-1)-2\rho}{2\rho}\right)\log\left(1+\tau_t^{*}\right).
$$

Because $\rho > 1$, we can see that current home tariff is expansionary, but the foreign tariff is contractionary for the home production. While the current home tariff has a direct negative effect on the aggregate consumption by raising up the aggregate price level, it also causes the home demand to shift toward the home produced goods due to the improvement of the home terms of trade. The substitution effect in the latter dominates and thus the overall home production benefits from the protection policy. On the other hand, the foreign tariff reduces the foreign aggregate consumption as well as the import from home firms to the foreign market, and thus leads to lower home export. Note that, the future tariff plan does not influence the production. In Section 5, we will propose three trade policies and examine the impacts of different tariff structures on the economy.

4. Local-currency pricing (LCP)

4.1 Aggregate price level and consumption

Now we assume firms preset prices in the currency of the country where the goods are sold. Use the price index and the optimal monopolistic prices for the home and foreign tradable goods sold in the home country are:

$$P_{H,t}^{i} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(P_t C_t / A_t\right)}{E_{t-1}\left(C_t^{1-\rho}\right)}, \tag{17a}$$

$$P_{F,t} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{-1} P_t C_t / A_t^{*}\right)}{E_{t-1}\left(\left(1+\tau_t\right)^{-1} C_t^{1-\rho}\right)} \tag{17b}$$

The derivation of the optimal pricing is provided in the appendix. Because all agents in this economy are symmetric, the subscript i can be dropped and $P_{H,t}^{i} = P_{H,t}$. Substitute the aggregate price index into the optimal pricing, these two equations can be rewritten as

$$\left(\frac{P_{H,t}}{P_{F,t}}\right)^{\frac{\gamma}{2}} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{\frac{\gamma}{2}} C_t / A_t\right)}{E_{t-1}\left(C_t^{1-\rho}\right)}, \tag{18a}$$

$$\left(\frac{P_{H,t}}{P_{F,t}}\right)^{\frac{\gamma}{2}-1} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{\frac{\gamma}{2}-1} C_t / A_t^{*}\right)}{E_{t-1}\left(\left(1+\tau_t\right)^{-1} C_t^{1-\rho}\right)} \tag{18b}$$

The combination of the logarithms of these two equations yields the expected consumption:

$$E_t c_{t+1} = \frac{-1}{\rho}\log\frac{\theta\kappa}{\theta-1} - \frac{\gamma}{2\rho}E_t \log\left(1+\tau_{t+1}\right) + \frac{2-\gamma}{2\rho}\left(E_t a_{t+1} + \sigma_{ca}\right) + \frac{\gamma}{2\rho}\left(E_t a_{t+1}^{*} + \sigma_{ca^*}\right) + \Gamma_{Ec} \tag{19}$$

where Γ_{Ec} includes all the moments associated with the expectation under the lognormal distribution. Throughout this paper, we use Γ to indicate those moment terms without further explanations.

To solve the aggregate price level, let $\overline{P}_t$ denote the preset prices before the imposition of tariff, $P_{H,t}^{1-\frac{\gamma}{2}} P_{F,t}^{\frac{\gamma}{2}}$, and rewrite the aggregate price level as $P_t = \left(1+\tau_t\right)^{\frac{\gamma}{2}} \overline{P}_t$. Take the logarithm of the Euler equation and write it in terms of the dynamics of $\overline{p}_t$ and τ_t:

$$c_t = E_t c_{t+1} - \frac{1}{\rho}\left[\log\beta + \log\left(1+i_t\right) - \left(\overline{p}_{t+1} - \overline{p}_t\right) - \frac{\gamma}{2}\left(E_t \log\left(1+\tau_{t+1}\right) - \log\left(1+\tau_t\right)\right) + \Gamma_c{}'\right] \tag{20}$$

Because $\overline{p}_t = E_{t-1}\overline{p}_t$, we can write $\overline{p}_t$ from Eq. (20) and take the expectation back from date $t-1$. Combining with the home interest rate rule, $\overline{p}_t$ can be written as:

$$\overline{p}_t = \frac{1}{1+\omega}\left\{E_{t-1}\overline{p}_{t+1} + \frac{\gamma}{2}E_{t-1}\left[\log\left(1+\tau_{t+1}\right) - \left(1+\omega\right)\log\left(1+\tau_t\right)\right] + \rho\left(E_{t-1}c_{t+1} - E_{t-1}c_t\right) + \Gamma_{\overline{p}}{}'\right\}$$

Using Eq. (19) and substituting $\overline{p}_t$ recursively, we can solve $\overline{p}_t$ as:

$$\overline{p}_t = \frac{\gamma\rho_a\left(2-\gamma\right)\left(\rho_a-1\right)}{1+\omega-\rho_a}\left[\frac{a_{t-1}}{2\gamma}+\frac{a_{t-1}^*}{2\left(2-\gamma\right)}\right]-\frac{\gamma\omega}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}E_{t-1}\log\left(1+\tau_s\right)+\Gamma_p$$

Thus, the aggregate price index p_t is:

$$p_t = \frac{\gamma\rho_a\left(2-\gamma\right)\left(\rho_a-1\right)}{1+\omega-\rho_a}\left[\frac{a_{t-1}}{2\gamma}+\frac{a_{t-1}^*}{2\left(2-\gamma\right)}\right]+\Lambda_{p,t}^{LCP}+\Gamma_p \tag{21}$$

where

$$\Lambda_{p,t}^{LCP} = \frac{\gamma}{2}\left(\log\left(1+\tau_t\right)-\frac{\omega}{1+\omega}E_{t-1}\log\left(1+\tau_t\right)\right)-\frac{\gamma\omega}{2\left(1+\omega\right)}\sum_{s=t+1}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}E_{t-1}\log\left(1+\tau_s\right)$$

This equation is identical to the aggregate price level in Obstfeld (2006), except the impact from the tariff. Unanticipated current tariff shock raises the overall price level. However, similar to the flexible-price case, an announced policy that remains the same over time does not affect the price level. It is because unanticipated policy shocks do not appear in the predetermined part of the aggregate price level, $\overline{p}_t$. However, if the policy is known, firms will respond by setting lower prices to retain the sale that they may lose. Therefore, the prices under unanticipated policy shocks may be too high and thus reduce the consumption further.

We can derive c_t by substituting p_t into Eq. (20):

$$c_t = \frac{\gamma\rho_a}{1+\omega-\rho_a}\left[\left(\frac{2-\gamma}{2\rho}\right)a_t+\left(\frac{\gamma}{2\rho}\right)a_t^*\right]+\frac{1}{\rho}\left(\phi_H u_t+\phi_H^* u_t^*\right)+\Lambda_{c,t}^{LCP}+\Gamma_c \tag{22}$$

where

$$\Lambda_{c,t}^{LCP} = -\frac{\gamma\left(1+\omega\right)}{2\rho}\left(\log\left(1+\tau_t\right)-\frac{\omega}{1+\omega}E_{t-1}\log\left(1+\tau_t\right)\right)-\frac{\gamma\omega}{2\rho}\sum_{s=t+1}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[E_t\log\left(1+\tau_s\right)-E_{t-1}\log\left(1+\tau_s\right)\right]$$

Similar to Obstfeld (2006), positive productivity shock lowers the price and thus leads to greater consumption. For the impacts of the tariff on consumption, $\Lambda_{c,t}^{LCP}$, the term in the first parenthesis is the unanticipated current tariff shock which has the negative effect on consumption because of the higher price that it results in. The term in the latter parenthesis, however, reveals the renewed information about the tariff policy at time t. This is the essential difference between the flexible-price and LCP cases: under LCP, prices are predetermined and thus the information used for the expectation does matter. The difference between the expected tariff from $t-1$ to t characterizes the information discrepancy between the decisions made by the firm and the consumer. While firms preset prices at the period $t-1$, consumers make the consumption decisions at time t, considering his consumption path over time. A policy announced at the period t, but unknown at the period $t-1$ will be taken into account by consumers, leading to lower consumption. Note that, exchange rate movements do not affect consumption under LCP as all prices are predetermined, contrary to past studies and the flexible-price economy in this study.

4.2 Output

Same as the flexible-price economy, the output in the monopolistic competition market is derived from the consumption demands:

$$
\begin{aligned}
Y_t &= \left(1-\frac{\gamma}{2}\right)(1+\tau_t)^{\frac{\gamma}{2}}\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\frac{\gamma}{2}} C_t + \frac{\gamma}{2}(1+\tau_t^*)^{\frac{\gamma}{2}-1}\left(\frac{P_{H,t}^*}{P_{F,t}^*}\right)^{\frac{\gamma}{2}-1} C_t^* \\
&= \left(1-\frac{\gamma}{2}\right)\left(\frac{\kappa\theta}{\theta-1}\right)^{-1}(1+\tau_t)^{\frac{\gamma}{2}} C_t \left(\frac{E_{t-1}\left((1+\tau_t)^{\frac{\gamma}{2}} C_t / A_t\right)}{E_{t-1}\left(C_t^{1-\rho}\right)}\right)^{-1} + \frac{\gamma}{2}\left(\frac{\kappa\theta}{\theta-1}\right)^{-1}(1+\tau_t^*)^{\frac{\gamma}{2}-1} C_t^* \left(\frac{E_{t-1}\left((1+\tau_t^*)^{\frac{\gamma}{2}-1} C_t^* / A_t^*\right)}{E_{t-1}\left((1+\tau_t^*)^{-1} C_t^{*1-\rho}\right)}\right)^{-1} \\
&= \left(1-\frac{\gamma}{2}\right)\left(\frac{\kappa\theta}{\theta-1}\right)^{-1}\exp\left\{\frac{\gamma}{2}\left[\log(1+\tau_t) - E_{t-1}\log(1+\tau_t)\right] + \left[c_t - \rho E_{t-1}c_t\right] + E_{t-1}a_t\right\} \\
&\quad + \frac{\gamma}{2}\left(\frac{\kappa\theta}{\theta-1}\right)^{-1}\exp\left\{\left(\frac{\gamma}{2}-1\right)\left[\log(1+\tau_t^*) - \frac{\gamma}{\gamma-2}E_{t-1}\log(1+\tau_t^*)\right] + \left[c_t^* - \rho E_{t-1}c_t^*\right] + E_{t-1}a_t^*\right\} + \Gamma_Y
\end{aligned}
\tag{23}
$$

Because the home tariff does not affect foreign consumption and home export, the impacts of home tariff on home production is from its sale in the domestic market while the foreign tariff has the impact on the home output through the home export. Therefore, the logarithm of the impacts of the tariffs from the home and foreign countries on the home production are as follows:

$$\Lambda_{Y,t}^{LCP,H} = \frac{\gamma}{2}\left[\log\left(1+\tau_t\right) - E_{t-1}\log\left(1+\tau_t\right)\right] + \Lambda_{c,t}^{LCP}$$

$$\Lambda_{Y,t}^{LCP,F} = \left(\frac{\gamma}{2}-1\right)\left[\log\left(1+\tau_t^*\right) - \frac{\gamma}{\gamma-2}E_{t-1}\log\left(1+\tau_t^*\right)\right] + \Lambda_{c,t}^{*LCP}$$

The unexpected tariff shock places an immediate effect on the relative price and consumption. The combination of these two effects shows that if the tariff protection policy under LCP is contractionary or expansionary depends upon the response of the central bank to the price level relative to the subjective coefficient of relative risk aversion. If the former is greater, the tariff is contractionary, following most of past studies. However, if the latter is greater, the imposition of the protection policy is expansionary, same as the flexible-price case. It is because, the increase in the interest rate following the high price level lowers the consumption further and thus reduces the production.

5. Alternative tariff policies

In this section, we will discuss the impacts of alternative trade protection policies on the economy. Three cases will be examined.

5.1 Anticipated permanent tariff

Consider first, the imposition of the tariff on the imported goods is announced before it is executed at the period t. Thus the trade protection policy, that is known for all market participants in the economy, follows:

$$\tau_s = \tau\,,\ \ \tau_s^* = \tau^*\,,\ \ \forall s \geq t\,.$$

Since the policy is known to the public, the expectation of the tariff is:

$$E_{t-1}\tau_s = \tau\,,\ \ E_{t-1}\tau_s^* = \tau^*\,,\ \ \forall s \geq t$$

Proposition 1.

The imposition of an anticipated permanent tariff has the same effect on the aggregate price level and consumption under flexible prices and LCP. However, under flexible prices, the tariff is expansionary for the domestic output of the tariff imposer and contractionary for the foreign output, but contractionary for both the home and foreign outputs under LCP.

Macroeconomic variables under the imposition of anticipated permanent tariffs are listed in Table 1.

Table 1: Macroeconomic variables under anticipated permanent tariffs

	Flexible prices	**LCP**
Price	$\Lambda_{p,t}^{FP}=0$ $\Lambda_{p,t}^{*FP}=0$	$\Lambda_{p,t}^{LCP}=0$ $\Lambda_{p,t}^{*LCP}=0$
Consumption	$\Lambda_{c,t}^{FP}=-\frac{\gamma}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{c,t}^{*FP}=-\frac{\gamma}{2\rho}\log\left(1+\tau^{*}\right)$	$\Lambda_{c,t}^{LCP}=-\frac{\gamma}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{c,t}^{*LCP}=-\frac{\gamma}{2\rho}\log\left(1+\tau^{*}\right)$
Output	$\Lambda_{Y,t}^{FP,H}=\frac{\gamma\left(\rho-1\right)}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{Y,t}^{FP,F}=\frac{\left(\gamma-2\right)\rho-\gamma}{2\rho}\log\left(1+\tau^{*}\right)$	$\Lambda_{Y,t}^{LCP,H}=-\frac{\gamma}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{Y,t}^{LCP,F}=-\frac{\left(2\rho+\gamma\right)}{2\rho}\log\left(1+\tau^{*}\right)$

As shown in Table 1, anticipated permanent tariff does not influence the aggregate price level, but lowers the consumption in both the flexible-price and LCP cases with same magnitude. However, its impacts on the output vary with different price flexibilities. Under flexible prices, the protection policy successfully increases the home output, while suppresses foreign output. Nevertheless, both the home and foreign productions are lowered by the tariff under LCP.

The difference in these two cases results from the expenditure-switching effect caused by exchange rates. A higher tariff improves the home terms of trade and thus leads to lower home demand for foreign goods. Under flexible prices, the nominal exchange rate is shown as below:

$$\Lambda_{\xi,t}^{FP} = -\frac{\gamma}{2}\left[\log\left(1+\tau\right) - \log\left(1+\tau^{*}\right)\right]$$

A higher home tariff, relative to that of the foreign, causes the nominal exchange rate to appreciate, followed by lower home demand. Therefore, the home nominal wage decreases while the foreign wage goes up. However, the exchange rate fluctuation absorbs part of the direct impact of the tariff on the home and foreign wages, and thus the aggregate price level stays unchanged. The lower real wage makes the worker substitute leisure for consumption. Overall, the lower home price raises the home demand for the home products and thus the tariff is expansionary to the home production, even if the consumption is lowered by the tariff. As discussed in the previous section, the foreign tariff places a negative effect on the home production because lower foreign consumption caused by the tariff reduces the home export.

On the other hand, for a LCP economy, the timing of the expectation formation does not matter for an announced permanent policy. Because the policy is known to the public when the expectation is made, the imposition of the tariff has been included in the predetermined prices. The absence of unanticipated policy shock leaves the aggregate price level unchanged. Moreover, when consumers consider the consumption path over the life time, permanent identical tariff rate does not drive the intertemporal price changes, no matter when the expectation is formed. It turns out that the consumption reacts to the current tariff only.

Since the expenditure-switching effect is absent under LCP and the exchange rate movement is not passed through onto the import prices, the predetermination of the prices does not have to consider the exchange rate movement. Preset prices simply adjust with the full information about the imposition of the policy. As a result, relative price, $p_{H,t}$ to $p_{F,t}$, completely offsets the direct impact of the tariff on the aggregate price level. Therefore, the sale of the home goods sold in the domestic economy is completely affected by the decline of the aggregate consumption, but not the relative price movement. The protection policy is contractionary to the home output consequently.

5.2 Unanticipated permanent tariff

Suppose that, a permanent tariff is imposed at time t without prior announcement. Thus, the tariff structure is as follows:

$$\tau_s = \tau_s^* = 0, \ \forall s < t;$$

$$\tau_s = \tau, \ \tau_s^* = \tau^*, \ \forall s \geq t.$$

Before the policy is known to the public, the expectation for the tariff policy is:

$$E_{t-1}\tau_{t+k} = 0, \ E_{t-1}\tau_{t+k}^* = 0, \ \forall k \geq 0;$$

$$E_t\tau_{t+k} = \tau, \ E_t\tau_{t+k}^* = \tau^*, \ \forall k \geq 0.$$

Proposition 2.

The impacts of the unanticipated permanent tariff on the flexible-price macroeconomic equilibrium are identical to those of anticipated permanent tariff. The unanticipated permanent tariff has greater impacts on the aggregate price level and consumption than the anticipated permanent tariff does, while its impact on the output is determined by the size of the subjective risk aversion relative to the response of the monetary authority to the price index.

Macroeconomic variables under the imposition of unanticipated permanent tariffs are listed in Table 2.

Table 2: Macroeconomic variables under unanticipated permanent tariffs

	Flexible prices	**LCP**
Price	$\Lambda_{p,t}^{FP} = 0$	$\Lambda_{p,t}^{LCP} = \frac{\gamma}{2}\log(1+\tau)$
	$\Lambda_{p,t}^{*FP} = 0$	$\Lambda_{p,t}^{*LCP} = \frac{\gamma}{2}\log(1+\tau^*)$

Consumption	$\Lambda_{c,t}^{FP} = -\frac{\gamma}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{c,t}^{*FP} = -\frac{\gamma}{2\rho}\log\left(1+\tau^{*}\right)$	$\Lambda_{c,t}^{LCP} = -\frac{\gamma\left(2+\omega\right)}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{c,t}^{*LCP} = -\frac{\gamma\left(2+\omega\right)}{2\rho}\log\left(1+\tau^{*}\right)$
Output	$\Lambda_{Y,t}^{FP,H} = \frac{\gamma\left(\rho-1\right)}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{Y,t}^{FP,F} = \frac{\gamma\left(\rho-1\right)}{2\rho}\log\left(1+\tau^{*}\right)$	$\Lambda_{Y,t}^{LCP,H} = \frac{\gamma\left(\rho-2-\omega\right)}{2\rho}\log\left(1+\tau\right)$ $\Lambda_{Y,t}^{LCP,F} = \frac{\left(\gamma-2\right)\rho-\gamma\left(2+\omega\right)}{2\rho}\log\left(1+\tau^{*}\right)$

Because the flexible-price equilibrium reacts to the current policy that is in effect, it does not matter when the policy is announced. So the macroeconomy is completely identical under the anticipated and unanticipated permanent tariff system.

However, the timing of the policy announcement is critical for a LCP economy because prices are determined in advance. At time $t-1$, the firm does not know the policy is going to be imposed. Therefore, firms do not take into account the decline of consumption caused by the tariff and preset prices higher than those in the case with anticipated tariff shock. Consequently the predetermined prices for the period t do not reflect the tariff and thus the rate of the tariff on the import goods is completely reflected onto the aggregate price level.

Nevertheless, consumers have different information when they make the consumption decision in the period t. At time t, they observe that import prices are too high after the imposition of the tariff and thus decide to consume less. In addition, the high interest rate that the monetary authority responds to current high price adds fuel to the decline of consumption. On the other hand, the new information about the policy increase consumers' expected inflation from the period t and $t+1$. The intertemporal substitution results in higher current consumption relative to the future. Overall, the policy's impact on consumption reflects the different information set that the firms and consumers use for their decisions. Since the first two effects dominates, consumption decreases after the imposition of the tariff. The magnitude of the downturn of consumption is enlarged by the information discrepancy between the firms and consumers, compared to that under the anticipated policy.

However, the tariff has different implications for the home outputs. While the foreign tariff has the negative effect on the home production, the home tariff's impact on the home output is ambiguous and depends upon relative magnitude of the risk aversion to the response of the central bank to the aggregate price level. If consumers are very risk averse ($\rho > 2+\omega$), the tariff is expansionary while contractionary otherwise. Consumers who are more risk averse save more for the uncertainty in the future by reducing her current consumption further. The precautionary saving lessens the policy's impact on output via consumption. As a result, the home production is boosted by the domestic trade protection policy if people are more risk averse.

5.3 Unanticipated temporary tariff

If a temporary unanticipated tariff is imposed at time t, then the policy follows:

$$\tau_s = \tau\,,\ \ \tau_s^* = \tau^*\,,\ \ t \le s < T\ ;$$

$$\tau_s = \tau_s^* = 0\,,\quad s \ge T\ .$$

And the expectation of the trade policy is:

$$E_{t-1}\tau_{t+k} = 0\,,\ \ E_{t-1}\tau_{t+k}^* = 0\,,\ \ k \ge 0\,;$$

$$E_t\tau_{t+k} = \tau\,,\ \ E_t\tau_{t+k}^* = \tau^*\,,\ \ 0 \le k < \left(T-t\right);$$

$$E_t\tau_{t+k} = 0\,,\ \ E_t\tau_{t+k}^* = 0\,,\ \ k \ge \left(T-t\right).$$

Proposition 3.

Most of the responses of the macroeconomic equilibrium to the unanticipated temporary policy are smaller than those to the permanent policy, in both the flexible-price and LCP economies.

Macroeconomic variables under the imposition of unanticipated temporary tariffs are listed in Table 3.

Table 3: Macroeconomic variables under unanticipated temporary tariffs

	Flexible prices	LCP
Price	$\Lambda_{p,t}^{FP}=\frac{\gamma}{2(1+\omega)^{T-t}}\log(1+\tau)$ $\Lambda_{p,t}^{*FP}=\frac{\gamma}{2(1+\omega)^{T-t}}\log(1+\tau^{*})$	$\Lambda_{p,t}^{LCP}=\frac{\gamma}{2}\log(1+\tau)$ $\Lambda_{p,t}^{*LCP}=\frac{\gamma}{2}\log(1+\tau^{*})$
Consumption	$\Lambda_{c,t}^{FP}=-\frac{\gamma}{2\rho}\log(1+\tau)$ $\Lambda_{c,t}^{*FP}=-\frac{\gamma}{2\rho}\log(1+\tau^{*})$	$\Lambda_{c,t}^{LCP}=-\frac{\gamma}{2\rho}\left[2+\omega-\left(\frac{1}{1+\omega}\right)^{T-t-1}\right]\log(1+\tau)$ $\Lambda_{c,t}^{*LCP}=-\frac{\gamma}{2\rho}\left[2+\omega-\left(\frac{1}{1+\omega}\right)^{T-t-1}\right]\log(1+\tau^{*})$
Output	$\Lambda_{Y,t}^{FP,H}=\frac{\gamma(\rho-1)}{2\rho}\log(1+\tau)$ $\Lambda_{Y,t}^{FP,F}=\frac{\gamma(\rho-1)-2\rho}{2\rho}\log(1+\tau^{*})$	$\Lambda_{Y,t}^{LCP,H}=\frac{\gamma}{2\rho}\left[\rho-2-\omega+\left(\frac{1}{1+\omega}\right)^{T-t-1}\right]\log(1+\tau)$ $\Lambda_{Y,t}^{LCP,F}=\left[\frac{(\gamma-2)\rho-\gamma(2+\omega)}{2\rho}+\frac{\gamma}{2\rho}\left(\frac{1}{1+\omega}\right)^{T-t-1}\right]\times\log(1+\tau^{*})$

Similarly, the flexible-price consumption and production stay the same in face of anticipated or unanticipated policies because the economy is affected by the current policy only. Following past studies, the temporary tariff lowers its effect on the aggregate price level, reflecting the tariff rate difference between the time $T-1$ and T when the policy expires. As we can expect, the magnitudes of the wage and exchange rate adjustment will also be smaller. For the same reason that the policy change occurs at the time T, the reaction of the macroeconomic equilibrium in an LCP economy under the temporary policy is also smaller than that under the permanent policy.

6 Conclusion

The objective of this paper is to investigate the effects of the tariff on an economy under which firms take the local-currency pricing as the pricing strategy. While most of past studies use static models to examine the tariff's effect, this study conducts the issue of the trade protection policy in a two-country dynamic general equilibrium model. Different from the pricing strategies that past studies use, we adopt LCP under which firms preset prices in the consumer's currency and thus there is no exchange rate pass-through. The absence of the flexible exchange rate adjustment mechanism causes higher impact of an unanticipated policy on the economy.

The analytical solutions that are available in this model shed light on the importance of the information in the predetermination of prices. Thus, the timing of the policy announcement is important. In particular, the information discrepancy between consumers and firms is critical to the consumption decision. It is because prices are determined one period ahead of the time the consumption is made. If an unanticipated policy shock occurs and prices can not adjust in time, consumption will respond more to the policy as consumers would expect the upward price change in the future.

Moreover, we consider the effects of the tariff under three policy plans. In particular, we focus on the long-lasting issue: whether the trade protection policy is expansionary or contractionary. We find that, the tariff is contractionary for the home output under the anticipated permanent policy shock. However, the effect of the unanticipated policy shock on the output is primarily determined by the degree of risk aversion. If people are more risk averse, they will decrease consumption and save more for the uncertainty in the future. The risk-aversion behavior thus diminishes the negative effect of the tariff on consumption as well as that on output. Therefore, the home production will benefit from the improvement of the terms of trade due to the tariff. Not surprisingly, the imposition of the foreign tariff hurts the home economy. Because the foreign protection policy causes lower foreign consumption by raising the price level (if the policy is unanticipated), the home export is reduced.

Many interesting issues can be analyzed under this framework. As discussed in Mundell (1961), the exchange rate regimes, flexible or fixed, may lead to different effects of the tariff on the economy. This result may differ under the dynamic general equilibrium setting. Moreover, past studies examine this issue in a producer-currency pricing economy. It would be interesting if we can make the comparison between our result and that under PCP. Lastly, while the analytical solution in the model is able to elucidate the effects of different trade policies on the economy, this model is subject to certain assumptions and thus fails to capture some important aspects of this issue. For example, we may calibrate a more general specification of the model to observe the dynamic adjustment that macroeconomic variables respond to the policy.

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APPENDIX

Appendix 1: Derivation of prices and consumption under LCP

The demand function for each type of good is:

$$Y_{H,t}^{i}=\frac{\gamma}{2}\left(\frac{P_{H,t}^{i}}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-1}\left(\frac{P_{T,t}}{P_{t}}\right)^{-1}C_{t},$$

$$Y_{H,t}^{*}=\frac{\gamma}{2}\left(\frac{\left(1+\tau_{t}^{*}\right)P_{H,t}^{*\ i}}{\left(1+\tau_{t}^{*}\right)P_{H,t}^{*}}\right)^{-\theta}\left(\frac{\left(1+\tau_{t}^{*}\right)P_{H,t}^{*}}{P_{T,t}^{*}}\right)^{-1}\left(\frac{P_{T,t}^{*}}{P_{t}^{*}}\right)^{-1}C_{t}^{*},$$

$$Y_{N,t}^{i}=\left(1-\gamma\right)\left(\frac{P_{N,t}^{i}}{P_{N,t}}\right)^{-\theta}\left(\frac{P_{T,t}}{P_{t}}\right)^{-1}C_{t},$$

$$Y_{F,t}=\frac{\gamma}{2}\left(\frac{\left(1+\tau_{t}\right)P_{F,t}^{i}}{\left(1+\tau_{t}\right)P_{F,t}}\right)^{-\theta}\left(\frac{\left(1+\tau_{t}\right)P_{F,t}}{P_{T,t}}\right)^{-1}\left(\frac{P_{T,t}}{P_{t}}\right)^{-1}C_{t}.$$

Here, prices for each type of goods are determined one period ahead, but the tariff is not known until the policy is announced.

Substituting the budget constraint into the expected utility function with the demand function for each type of goods, and then taking the first-order derivative with respect to $P_{H,t}^{i}$, $P_{N,t}^{i}$, $P_{H,t}^{*\ i}$, we can derive the optimal pricing strategies preset one period ahead. For instance, the first-order condition with respect to $P_{H,t}^{i}$ is:

$$E_{t-1}\left\{\frac{C_{t}^{-\rho}}{P_{t}}\left[\frac{\partial P_{H,t}^{i}Y_{H,t}^{i}}{\partial P_{H,t}^{i}}\right]-\kappa\frac{\partial L_{t}}{\partial Y_{H,t}^{i}}\frac{\partial Y_{H,t}^{i}}{\partial P_{H,t}^{i}}\right\}=0$$

Substitute the demand function and production function into this equation, then $P_{H,t}^{i}$ can be written as:

$$P_{H,t}^{i}=\left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(P_{t}C_{t}/A_{t}\right)}{E_{t-1}\left(C_{t}^{1-\rho}\right)} \tag{A.1}$$

Since all the firms are symmetric, the superscript i can be dropped throughout the paper. Moreover, the home nontradable producer will set price in the same way as the home tradable firm does. Therefore, $P_{H,t}^{i}=P_{H,t}=P_{N,t}$.

Likewise, the first-order condition with respect to $P_{F,t}^{i}$ is:

$$E_{t-1}\left\{\frac{C_t^{*-\rho}}{P_t^{*}\varsigma_t}\left[\frac{\partial P_{F,t}^{i}Y_{F,t}^{i}}{\partial P_{F,t}^{i}}\right]-\kappa\frac{\partial L_t^{*}}{\partial Y_{F,t}^{i}}\frac{\partial Y_{F,t}^{i}}{\partial P_{F,t}^{i}}\right\}=0$$

Thus, the foreign tradable goods sold in the home country is priced at:

$$P_{F,t}=\left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{-1}P_tC_t\,/\,A_t\right)}{E_{t-1}\left(\left(1+\tau_t\right)^{-1}P_t\,C_t\,C_t^{*-\rho}\,/\,P_t^{*}\varsigma_t\right)}$$

Substitute the risk-sharing condition, $\frac{C_t^{-\rho}}{P_t}=\frac{C_t^{*-\rho}}{\varsigma_t P_t^{*}}$. As a result, $P_{F,t}$, can be written as:

$$P_{F,t}=\left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{-1}P_t\,C_t\,/\,A_t^{*}\right)}{E_{t-1}\left(\left(1+\tau_t\right)^{-1}C_t^{1-\rho}\right)} \qquad \text{(A.2)}$$

The tradable goods sold in the foreign country can be priced in the similar way:

$$P_{H,t}^{*}=\left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t^{*}\right)^{-1}P_t^{*}C_t^{*}\,/\,A_t\right)}{E_{t-1}\left(\left(1+\tau_t^{*}\right)^{-1}C_t^{*1-\rho}\right)} \qquad \text{(A.3)}$$

Since

$$P_t=P_{H,t}^{1-\frac{\gamma}{2}}P_{F,t}^{\frac{\gamma}{2}}$$

Eq. (A.1) and (A.2) can be written as

$$\left(\frac{P_{H,t}}{P_{F,t}}\right)^{\frac{\gamma}{2}}=\left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{\frac{\gamma}{2}}C_t\,/\,A_t\right)}{E_{t-1}\left(C_t^{1-\rho}\right)}, \qquad \text{(18a)}$$

$$\left(\frac{P_{H,t}}{P_{F,t}}\right)^{\frac{\gamma}{2}-1}=\left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}\left(\left(1+\tau_t\right)^{\frac{\gamma}{2}-1}C_t\,/\,A_t^{*}\right)}{E_{t-1}\left(\left(1+\tau_t\right)^{-1}C_t^{1-\rho}\right)} \qquad \text{(18b)}$$

From Eq. (18a) and (18b), we can obtain:

$$1=\left(\frac{\theta\kappa}{\theta-1}\right)^{\frac{1}{\gamma(2-\gamma)}}\frac{E_{t-1}\left(\left(1+\tau_t\right)^{\frac{\gamma}{2}}C_t/A_t\right)^{\frac{1}{2\gamma}}E_{t-1}\left(\left(1+\tau_t\right)^{\frac{\gamma}{2}}C_t/A_t\right)^{\frac{1}{2(2-\gamma)}}}{E_{t-1}\left(C_t^{1-\rho}\right)^{\frac{1}{2\gamma}}E_{t-1}\left(\left(1+\tau_t\right)^{-1}C_t^{1-\rho}\right)^{\frac{1}{2(2-\gamma)}}} \tag{A.5}$$

Since shocks are lognormally distributed and so do all the variables, Eq. (A.5) yields Eq. (19):

$$E_t c_{t+1}=\frac{-1}{\rho}\log\frac{\theta\kappa}{\theta-1}-\frac{\gamma}{2\rho}E_t\log\left(1+\tau_{t+1}\right)+\frac{2-\gamma}{2\rho}\left(E_t a_{t+1}+\sigma_{ca}\right)+\frac{\gamma}{2\rho}\left(E_t a_{t+1}^*+\sigma_{ca^*}\right)+\Lambda$$

where $x_t=\log\left(X_t\right)$.

Appendix 2：Derivation of prices and consumption under flexible prices

From the Euler equation, Eq.(8), and substitute P_t recursively, we can write P_t in terms of expected consumption growth:

$$p_t=\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\rho\left[E_t\left(c_{s+1}-c_s\right)\right]-\frac{1}{\omega}\left[\log\beta+\bar{i}+\frac{\rho^2}{2}\sigma_c^2+\frac{1}{2}\sigma_p^2+\rho\sigma_{cp}\right] \tag{13}$$

Substitute consumption, Eq.(12), into equation above, we can obtain p_t :

$$p_t=\frac{\rho_a-1}{1+\omega-\rho_a}\left[\left(1-\frac{\gamma}{2}\right)a_t+\frac{\gamma}{2}a_t^*\right]+\Gamma_{p,t}^{FP}+\frac{1}{\omega}\left(\log\beta+\bar{i}+\frac{\rho^2}{2}\sigma_c^2+\frac{1}{2}\sigma_p^2+\rho\sigma_{cp}\right) \tag{14}$$

where

$$\Lambda_{p,t}^{FP}=-\frac{\gamma}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}E_t\left(\log\left(1+\tau_{s+1}\right)-\log\left(1+\tau_s\right)\right).$$

The foreign aggregate price level follows the analogous form:

$$p_t^*=\frac{\rho_a-1}{1+\omega-\rho_a}\left[\frac{\gamma}{2}a_t+\left(1-\frac{\gamma}{2}\right)a_t^*\right]+\frac{1}{\omega}\left(\log\beta+\bar{i}+\frac{\rho^2}{2}\sigma_{c^*}^2+\frac{1}{2}\sigma_{p^*}^2+\rho\sigma_{cp^*}\right)$$

The combination of the logs of Eq.(9), (12), (14) and its foreign analogy, yields the nominal exchange rate:

$$\xi_t=\frac{\omega(1-\gamma)}{1+\omega-\rho_a}\left(a_t-a_t^*\right)+\Lambda_{\xi,t}^{FP} \tag{15}$$

where

$$\Lambda_{\xi,t}^{FP}=-\frac{\gamma}{2}\left\{\left(\log\left(1+\tau_t\right)-\log\left(1+\tau_t^*\right)\right)+\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}E_t\left(\log\left(\frac{1+\tau_{s+1}}{1+\tau_s}\right)-\log\left(\frac{1+\tau_{s+1}^*}{1+\tau_s^*}\right)\right)\right\}$$