行政院國家科學委員會專題研究計畫 期末報告

小型開放經濟體系下之政府公債與最適貨幣政策及財政政策

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報 告 附 件 ：出席國際會議研究心得報告及發表論文

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中 華 民 國 102 年 10 月 31 日

中 文 摘 要 ： 最近的歐洲債務危機顯示了貨幣政策與財政政策之間的緊密關係。本研究的目的即在於探
討在一小型開放經濟體系中之政府公債，特別是 debt-GDP 比例的設定對於總體經濟的影響。我們藉由一個具有三種市場不完全機制（獨占性競爭、名目僵固性與所得稅）的小型開放動態隨機一般均衡（DSGE）
模型來探討在不同的經濟開放程度之下，debt-GDP 比例的施行是否會有不同的總體經濟效果。研究結果發現， debt-GDP 比例的改變將使政府財政政策(稅與政府支出)產生相應變動。在一開放程度較低的國家，其對於國內經濟會有較大的影響，而造成較劇烈的總體經濟變動。

中文關鍵詞： 財政政策，公債比重，開放經濟

英 文 摘 要 ： The objective of this research is to examine the public debts in a small open economy, in line with the recent debate on the European debt crisis. We use a small-open-economy dynamic stochastic general equilibrium (DSGE) model with three types of market distortions including monopolistic competition, nominal rigidity, and distortionary income tax to examine the macroeconomic effects of the debt-GDP ratio in countries with different degrees of economic openness. The numerical analyses show that the increase in the debt-GDP ratio in a less open economy will result in more drastic changes in government spending and thus will be less likely to stabilize the responses of macroeconomic variables in response to the technology shock.

英文關鍵詞： fiscal policy, debt-GDP ratio, open economy

行政院國家科學委員會補助專題研究計畫 √ 成 果 報 告 □期中進度報告

（計畫名稱）

小型開放經濟體系下之政府公債與最適貨幣政策及財政政策

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計畫參與人員：楊馥菁、劉世夫、林學宏

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中　華　民　國 102 年 10 月 31 日

Macroeconomic Implications of Debt Policy in a Small Open Economy

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October 2013

ABSTRACT

The objective of this research is to examine the public debts in a small open economy, in line with the recent debate on the European debt crisis. We use a small-open-economy dynamic stochastic general equilibrium (DSGE) model with three types of market distortions including monopolistic competition, nominal rigidity, and distortionary income tax to examine the macroeconomic effects of the debt-GDP ratio in countries with different degrees of economic openness. The numerical analyses show that the increase in the debt-GDP ratio in a less open economy will result in more drastic changes in government spending and thus will be less likely to stabilize the responses of macroeconomic variables in response to the techonology shock.

Keywords: fiscal policy, debt-GDP ratio, open economy

JEL Classifications: E61; E62; E63

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1. Introduction

The government debt has become the primary concerns of the world since 2009 when some countries in the Euro area such as Greece, Ireland and Italy, encountered rapid and significant rises in public debts, as shown by Figure 1. The sovereign risks that occurred to the European countries has been largely attributed to the absence of exchange rate adjustment for individual member countries. Due to the absence of exchange rate devaluation, it is difficult to offset the adverse impacts of negative shocks on the countries in the Euro area. As a result, the exports, and thus the outputs, decline upon adverse shocks. In the lack of control of monetary policy, bailout projects became the primary measures to survive from the economic downturns. Unavoidably, the rise in the government expenditure and the decline in the tax revenue resulted in high deficits and accumulated a tremendous amount of public debts. This crisis is a vivid example to demonstrate the close relationship between the monetary and fiscal policies.

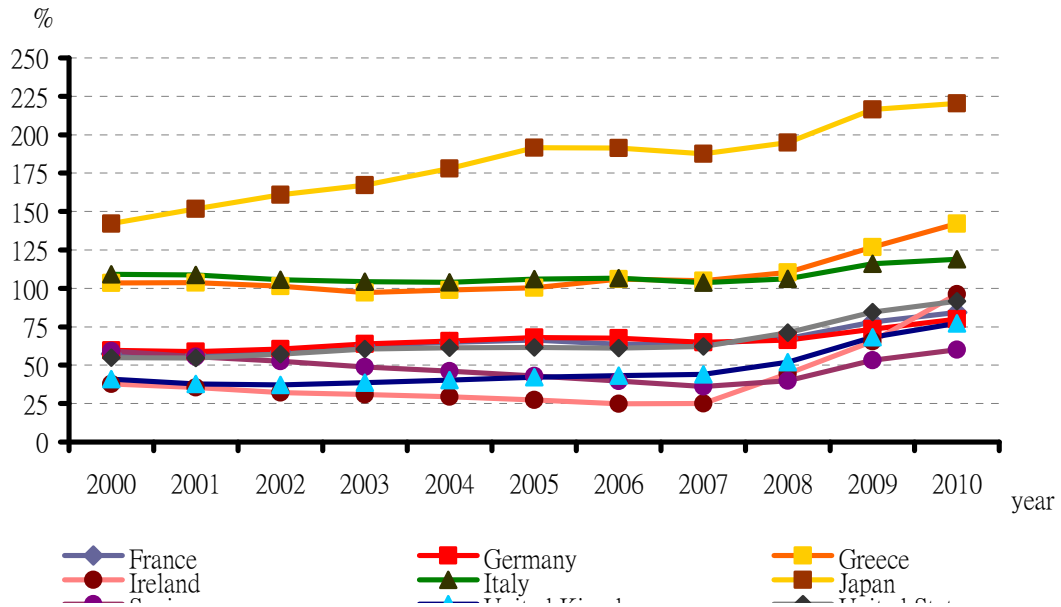
The interature has shown that the fiscal policy, particularly the debt, is closely related to the monetary policy. Active siscal policies can affect prices and inflation. In the case of fiscal dominance where the government uses the active fiscal policy and passive monetary policy, the government sets up the taxes and spending without considering the binding intertemporal government budget constraint, but issuing debts for financing purposes. As a result, future seigniorage is required to offset the debt, and thereby raises prices and inflation.[2] Different from the Ricardian equivalence where the tax financing or debt financing are indifferent,[3] these policies are identified as the non-Ricardian fiscal policy, according to Woodford (1996).[4]

Furthermore, monetary policy can have direct effects on the public debts. The interest rate and the price level, which are crucially affected by the monetary policy, can lead to revaluation of real debts. The recent DSGE models featuring market imperfections, particularly the nominal rigidity, have showed some important quantitative implications of the distortions for the public debts. Schmitt- Grohé and Uribe (2004) point out that the sluggish adjustment of prices may diminish the ability of the government's using the monetary policy to influence the prices. In their study in

[2] Earlier studies can be seen in Aiyagari and Gertler (1985), Sargent (1982) and Leeper (1991). A recent study by Aizenman and Marion (2011) shows that the large public debts of the US can be inflated away. Their analytical results show that a large nominal debt overhang can lead to inflation, and suggests that when economic growth is slowed, the US debt overhang may induce a persistent increase in inflation of about 5% that could significantly reduce the debt ratio under persistently slow economic growth.

[3] Please see Barro (1974, 1989), Woodford (1995, 2001).

[4] A theory which is directly related to the non-Ricardian fiscal policies is the fiscal theory of price level (FTPL). Under FTPL, it is shown that the fiscal policy is the primary determinant of price level, instead of the monetary policy according to the conventional wisdom (Sims (1994), Woodford (1995, 2001), Cochrane (1998)).



Source: The World Economic Outlook.

Figure 1: The debt-GDP ratio of European countries and Japan, 2000-2010.

2007, Schmitt-Grohé and Uribe stress the unrealistic simplifications of earlier studies on optimal monetary policy under DSGE models, particularly the absence of capital accumulation, the lump-sum tax and the balanced government budget because the design of optimal monetary policy should depend upon the fiscal regime. With the implementation of a distortionary tax, instead of stylized lump-sum tax, they show that the welfare-maximizing monetary and fiscal policies are passive.

However, Schmitt-Grohé and Uribe (2004, 2007) do not explicitly discuss the public debts, but simply use them to offset the fiscal gap between the government spending and tax due to unbalanced government budget. Leith and Wren-Lewis (2007) extend their model to examine the public debts for time consistency issue,[5] in line with various discussions on the debt-GDP ratio specified by the Stability and Growth Pack (SGP) of the European Monetary Union (EMU) when people doubt whether the authority can stick with the rule.[6] Their model is followed by Adam and Billi (2008) who emphasize the implications of endogenous government spending for public debts.

[5] Most of the studies assume the monetary and fiscal policies under commitment.
[6] The Stability and Growth Pack (SGP) of the EMU sets the rule that the deficit cannot exceed 3% of the GDP and the outstanding debt cannot exceed 60% of the GDP for the Euro countries. The early study on the time inconsistency problem can be seen in Woodford (1996).

[7]

Adam (2011) uses the model in Adam and Billi (2008) which features three types of distortions including nominal rigidity, distortionary tax and monopolistic competition to examine the dynamics of public debts under optimal monetary and fiscal policies by using the timeless Ramsey-optimal policy introduced by Schmitt- Grohé and Uribe (2004). He finds that there are various steady-state equilibriums associated with different values of initial debt-GDP ratio. In the steady state, the debt does not influence the optimal interest rate rule of the central bank, but will influence the real economy. In the short run, the government debt has important implications for the implementation of both the optimal monetary and fiscal policies as the stabilizer and thus both of the policies depend on the initial outstanding balance of debts. The responses of interest rate rises, and both the tax revenue and the debt-GDP ratio to shocks differ under different initial debt. The debt will converge gradually to zero, the optimal level. This implies the debt will decline if the initial debt is positive and will rise if the initial debt is negative. These issues are particularly important for countries holding massive public debts, such as the US and European countries for the government to maintain the adequate debt-GDP ratio, particularly under adverse shocks, and its relevance to the implementation of monetary and fiscal policies.

However, while the public debt issue has been examined under closed economies or a currency union, it has been rarely examined under an open economy. Past studies on the debt issue in open economies fall more heavily on the sovereign risk that emerging economies with high foreign debts instead of the examination of the public debt management.[8] Some studies try to endogenously generate the procyclical government spending for emerging economies, consistent with the empirical findings. For example, by using a small-open-economy DSGE model with incomplete markets, endogenous fiscal policy and sovereign default premium, Cuadra, Sanchezm and Sapriza (2010) endogenously determine the procyclical optimal public expenditures and tax rates. They do not explicitly examine the issue of public debts.

Thus, it would be interesting to investigate the implications of economic openness for the public debts. Due to the close relationship between the monetary policy and the public debt, intuitively, the exchange rate movement which is crucially affected by monetary policy should have critical effects on the real value of government debts, and thereby generate quantitatively different macroeconomic implications. In

[7] The recent debt crises have put the public debt issue to the center of fiscal policy again when the public debt management can be a real problem. For example, Devereux (2010) examines the public debt under the liquidity trap in a closed-economy DSGE model. He shows that the government spending financed by deficits while the bond rate reaches the zero lower bound on nominal interest rate can be far more expansionary than tax finance. Many others focus on the sovereign risk which is beyond the scope of our study. We assume that there is not default risk for the government bonds.

[8] Studies on the capital flight in the East Asian crisis.

particular, trade and financial openness which allow flows in goods and financial assets across countries may also have important implication for the debt-GDP ratio that a government should maintain. Therefore, we will use a small-open-economy DSGE framework with all three types of market imperfections and examine the questions that Adam (2011) brings up for a closed economy to investigate how the government of a small open economy should maintain an adequate debt-GDP ratio, with an emphasis on the implication of economic openness for the public debts and the government debts' effects on the real economy and exchange rate movements.

This paper is structured as follows. In Section 2, we will outline the model. We will run conduct numerical examinations for the steady states associated with different level of debt-GDP ratios in Section 3. In Section 4, we will examine the macroeconomic responses to different shocks under different implementation of debt-GDP ratios. Section 5 concludes.

2. Model

In this study, we will examine the public debt issue in a small-open-economy DSGE model. There are domestic and imported goods. The market for each type of goods is monopolistic competition. The households can conduct the transactions of assets on the international asset market, where the borrowing and lending are frictional. To examine this issue, we assume that the government implements the fiscal policy, determining the distortionary income tax rate, the government spending and the public debts, first two of which crucially rely on the level of debt-GDP ratio. The central bank controls the interest rate which functions two main ways in this economy. Firstly, the interest rate is the cost of government's borrowing. Secondly, controlling interest rate also crucially affect the price level which will also influence the real debts.

2.1 Goods market

There are two types of consumption goods in the domestic market: the home tradable and imported goods, each of which is monopolistically competitive. The representative household consumes the composite goods, which are composed of domestic goods C_t^d and imported goods C_t^f :

$$C_t = \left[\left(\alpha^d\right)^{1-\sigma} \left(C_t^d\right)^{\frac{\sigma-1}{\sigma}} + \left(1-\alpha^d\right)^{1-\sigma} \left(C_t^f\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \qquad (1)$$

where $0 < \alpha^d > 1$ represents the ratios of imported and domestic goods in aggregate consumption, C_t. σ is the intratemporal elasticity of substitution between domestic and imported goods. The associated demand functions for the domestic and imported goods are described below:

$$C_t^d(j) = \left(\frac{P_t^d(j)}{P_t^d}\right)^{-\nu} C_t^d, \quad C_t^f(j) = \left(\frac{P_t^f(j)}{P_t^f}\right)^{-\nu} C_t^f \tag{2}$$

$$C_t^d = \left(\alpha^d\right)\left(\frac{P_t^d}{P_t}\right)^{-\sigma} C_t, \quad C_t^f = \left(1-\alpha^d\right)\left(\frac{e_t P_t^f}{P_t}\right)^{-\sigma} C_t \tag{3}$$

where $C_t^d(j)$ and $C_t^f(j)$ stand for the domestic goods and imported goods of variety j. ν is the elasticity of substitution among differentiated goods. The composite consumption index and the corresponding prices are shown as follows:

$$C_t^i = \left[\int_0^1 C_t^i(j)^{\frac{\nu-1}{\nu}} dj\right]^{\frac{\nu 1}{\nu-1}}, \quad i = d, f \quad P_t^i = \left[\int_0^1 P_t^i(j)^{1-\nu} dj\right]^{\frac{1}{1-\nu}}, \quad i = d, f, \tag{4}$$

As a result, the aggregate price level can be written as:

$$P_t = \left[\alpha^d \left(P_t^d\right)^{1-\sigma} + \left(1-\alpha^d\right)\left(P_t^f\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{5}$$

where $P_t^d(j)$ and P_t^d are the home-currency prices of individual and aggregate domestic goods, respectively, $P_t^f(j)$ and P_t^f are the home-currency prices for the imported goods and P_t is the aggregate price index. We assume that the provision of public goods follow the same composition of goods.

The home firm produces goods sold in both the domestic and foreign markets. The export demand function $C_t^x(j)$ of variety j is assumed to resemble the domestic demand function, Eq. (2):

$$C_t^x(j) = \left(\frac{P_t^x(j)}{P_t^x}\right)^{-\nu} C_t^x \quad \text{and} \quad C_t^x = X_t\left(\frac{P_t^x}{P_t^*}\right)^{-\mu}, \quad \mu > 0, \tag{6}$$

where $P_t^x(j)$ is the firm's export price in the foreign currency, P_t^x is the aggregate price index of exported goods denominated in the foreign currency, and P_t^* is the

foreign price index. μ is the price elasticity of the aggregate exports. X_t is the demand for the exports from the small open economy.

2.2 Household problem

We assume that the infinitely-lived household maximizes the expected lifetime utility based on the consumption and government spending, and the disutility from the labor supply:

$$E_0\left[\sum_{t=0}^{\infty}\beta^t u\left[C_t, l_t, G_t\right]\right] \tag{7}$$

where $\beta \in (0,1)$ is the household's subjective discount factor. l_t is the labor supply for the production of goods and G_t is the public goods provision in the form of aggregate consumption goods. We assume that

$$u(C_t, l_t, G_t) = \log(C_t) - \omega_l \frac{l_t^{1+\varphi}}{1+\varphi} + \omega_g \log(G_t),$$

The budget constraint of the households can be described as follows. The representative household's income includes the net sale of capital goods, the receipt of financial assets, the wages for working in both sectors, as well as the revenue from the sales of products:

$$C_t + \frac{B_t}{P_t} + \frac{B_t^*}{P_t} = \frac{R_{t-1}B_{t-1}}{P_t} + \frac{R_{t-1}^{B^*}B_{t-1}^*}{P_t} + \left\{\frac{P_t^d}{P_t}A_t l_t - w_t l_t\right\} + w_t l_t(1-\tau_t) \tag{8}$$

Here, w_t is the real wage and l_t is the labor demanded for production. τ_t is the tax rate. B_t and B_t^* are the non-contingent domestic bond and foreign bond denominated in foreign currency respectively. R_{t-1}^B and $R_{t-1}^{B^*}$ are the nominal interest rates which B_{t-1} and B_{t-1}^* pay respectively. We assume that the producers take the producer-currency pricing for exports and thus the law of one price (LOOP) holds such that $P_t^d = e_t P_t^x$ where e_t is the nominal exchange rate, expressed in units of the domestic currency per one unit of foreign currency.

Utility-optimizing households obtain the following first-order conditions:

$$C_t^{-1} = \beta R_t C_{t+1}^{-1}, \tag{9}$$

$$w_t(1-\tau_t)C_t^{-1} = -\omega_l l_t^{\varphi}, \tag{10}$$

Following Kollmann (2002), we assume that the foreign bond rate, $R_t^{B^*}$, is equal to the world interest rate, R_t^*, plus a factor of $\eta\left(B_t^*/P_t^*\right)/\chi$, which characterizes the friction on the international financial market:

$$R_t^{B^*} = R_t^* - \frac{\eta\left(B_t^*/P_t^*\right)}{\chi}, \tag{11}$$

where η is the parameter which captures the degree of capital mobility. A lower η stands for higher capital mobility and χ is the steady-state export value, $\left(P^x/P^*\right)^{1-\mu}$.

2.3 Production and pricing

The firms produce goods by employing labor to satisfy the market demand:

$$Y_t = A_t l_t, \tag{12}$$

where A_t is the productivity which is subject to the random shock. G_t is the aggregate government spending.

We assume that firms adopt the Calvo's (1983) staggered pricing strategy. In each period, the probability of firms to change the price is $1-\lambda$. Therefore, the mean interval of price change is $1/(1-\lambda)$. At period t, the profit maximization problem of a typical firm j who can change the price is to choose $P_t^d(j)$ to maximize the profit within the period t and $t+z$ when the price remains valid. The optimal price that a typical firm sets is:

$$\tilde{P}_{t,t}^d = \frac{\nu}{\nu-1}\frac{\left\{\sum_{z=0}^{\infty}(\lambda)^z E_t \Lambda_{t,t+z} mc_{t+z}\right\}}{\left\{\sum_{z=0}^{\infty}(\lambda)^z E_t \Lambda_{t,t+z}\right\}}, \tag{13}$$

where $\Lambda_{t,t+z}$ is the subjective intertemporal elasticity of substitution which can be written as $\Lambda_{t,t+z} = \beta_z C_t / C_{t+z}$. mc_t is the marginal cost of production which can be written as w_t / A_t.

The price index for the domestic price will evolve following:

$$\left(P_t^d\right)^{1-\nu} = \lambda\left(P_{t-1}^d\right)^{1-\nu} + (1-\lambda)\left(\tilde{P}_{t,t}^d\right)^{1-\nu}. \tag{14}$$

We assume that the export are priced according to the producer-currency pricing

(PCP) fashion. Therefore, firms choose the optimal home-currency export price P_t^x, following the same way as P_t^d, and using the exchange rate to transfer into the foreign-currency price for exports sold abroad.

2.4 Government and monetary policies

The government budget constraint can be written as:

$$\frac{B_t}{P_t} + \tau_t w_t l_t = G_t + \frac{R_{t-1}}{\Pi_t}\frac{B_{t-1}}{P_{t-1}}, \tag{15}$$

where $\Pi_t = P_t / P_{t-1}$.

While the fiscal authority controls the implementation of public goods provision, tax rates, and the issuance of government bonds, the monetary authority controls the interest rate R_t, following the rule specified as below:

$$R_t = \alpha^R R_{t-1} + \left(1-\alpha^R\right)\left[\alpha_\pi^R\left(\pi_t - \overline{\pi}\right) + \alpha_y^R\left(y_t - \overline{y}\right) + \alpha_S^R\left(e_t - \overline{e}\right)\right], \tag{16}$$

2.5 Market clearing condition

The market clearing condition on the goods market can be written as:

$$Y_t = \alpha_d\left(\frac{P_t^d(j)}{P_t^d}\right)^{-\nu}\left(\frac{P_t^d}{P_t}\right)^{-\sigma}\left(C_t + G_t\right) + \left(\frac{P_t^x(j)}{P_t^x}\right)^{-\nu}\left(\frac{P_t^x}{P_t^*}\right)^{-\sigma} X_t \tag{17}$$

3 Calibration

3.1 Parameter values

Calibrations are conducted for numerical examination of the macroeconomic effects under different debt-GDP ratio. We assume a non-inflationary, deterministic steady state. In our model, due to the financial friction on the international capital market, the current account is equal to 0 in the steady state. The parameter values are calibrated to generate steady-state values consistent with Taiwan's data in the long run. The debt-GDP ratio is specified as 0.4 in the benchmark case, which is the current public debt status of Taiwan. The income tax is specified as 0.15, close to 13.6%, the

Table 1 : Parameter values

Parameters	Description	value
β	Subjective discount rate	0.99
τ	Income tax rate	0.15
α^H	Weight of home goods in aggregate consumption	0.7
η	Elasticity of export goods	5
υ^x 、 υ^d	Elasticity of substitution among differentiated goods	6
γ^T	Elasticity of substitution between home and foreign goods	5
σ_N	Elasticity of labor supply	1
ξ	Financial friction on the international capital market	0.0019
γ^N	Disutility of labor supply	7
α_m	Persistence of interest rate rule	0.6
α_p^m 、 α_y^m 、 α_S^m	Responses of interest rate rule to inflation, output gap, exchange rate	0.8, 0, 0.02

average tax rate of 2009 reported by the Ministry of Finance of Taiwan. The disutility of labor supply, γ^N, is specified 7 to generate the steady-state employment approximating 1/3, the working hours in Taiwan. The share of home goods in the aggregate consumption is assumed to be 0.7, to capture the home-bias in consumption. β is specified as 0.99, following the conventional setting. Following Kollmann (2002), the financial friction on the international capital market is assumed to be 0.0019.

3.2 Implication of trade openness for the debt-GDP ratio

In this section, we conduct dynamic analyses to examine whether or not the change in the debt-GDP ratio in countries with different trade openness can lead to different responses of the economy to technology shock. Through out, we assume the tax rate remain at the level of 0.15. The change in the debt-GDP ratio will reflect mostly on the government spending.

Figure 1 lists the responses of macroeconomic variables, in an economy with $\alpha^d = 0.1$, to a 1% technology shock under the debt-GDP ratio of 0.1 and 0.7 respectively. The AR(1) coefficient is assumed to be 0.85. The increase in the debt-GDP ratio will lead to a more drastic decline in the government spending, followed by significant increase in government spending, which causes the import to move in the same direction. The change in the debt policy does not lead to notable

change in other real variables.

Figure 2 examines the same debt-GDP ratios in a less open economy with $\alpha^d = 0.6$. The comparison between these two figures shows clearly how the different degree of economic openness can lead to different macroeconomic effects of the debt policy. The increase in the debt-GDP ratio leads to much larger and more volatile movements in real variables such as output and employment in response to the same technology shock, primarily caused by the movement of the government spending. In a less open economy, the impact of the fiscal policy change, falls more heavily on the domestic economy and thus results in more drastic movement in the domestic real economy.

4. Conclusion

In this study, we examine numerically the macroeconomic effects of the debt-GDP ratio in a small-open-economy DSGE model. The calibration results demonstrate that an increase in the debt-GDP ratio in a less open economy will have greater impact on the domestic economy. This does not result in significant change in exchange rate movement. In the future study, we may conduct more careful welfare examinations of the debt policies, following Adam (2011), in a small open economy.

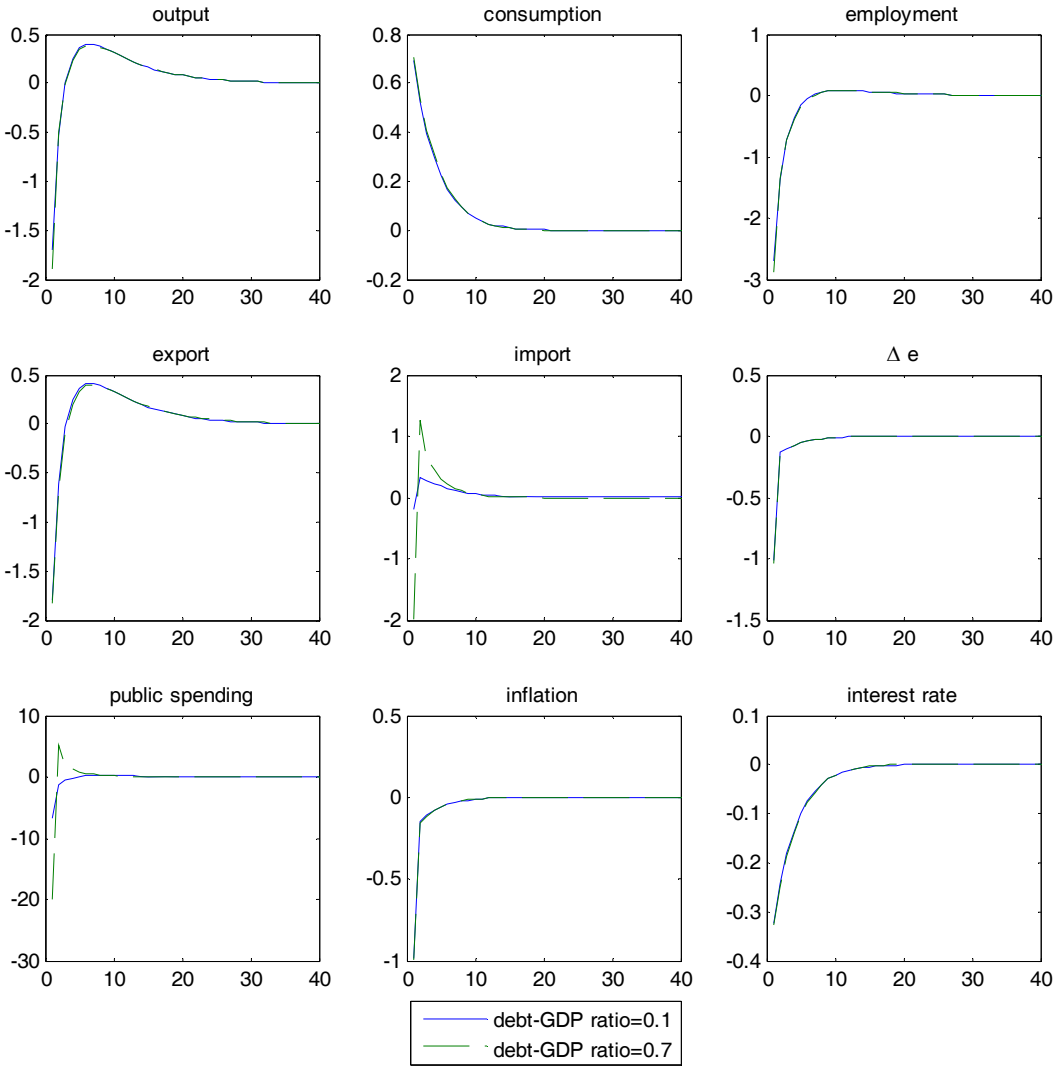


Figure 2: Different debt-GDP ratio in an economy with $\alpha^d = 0.1$

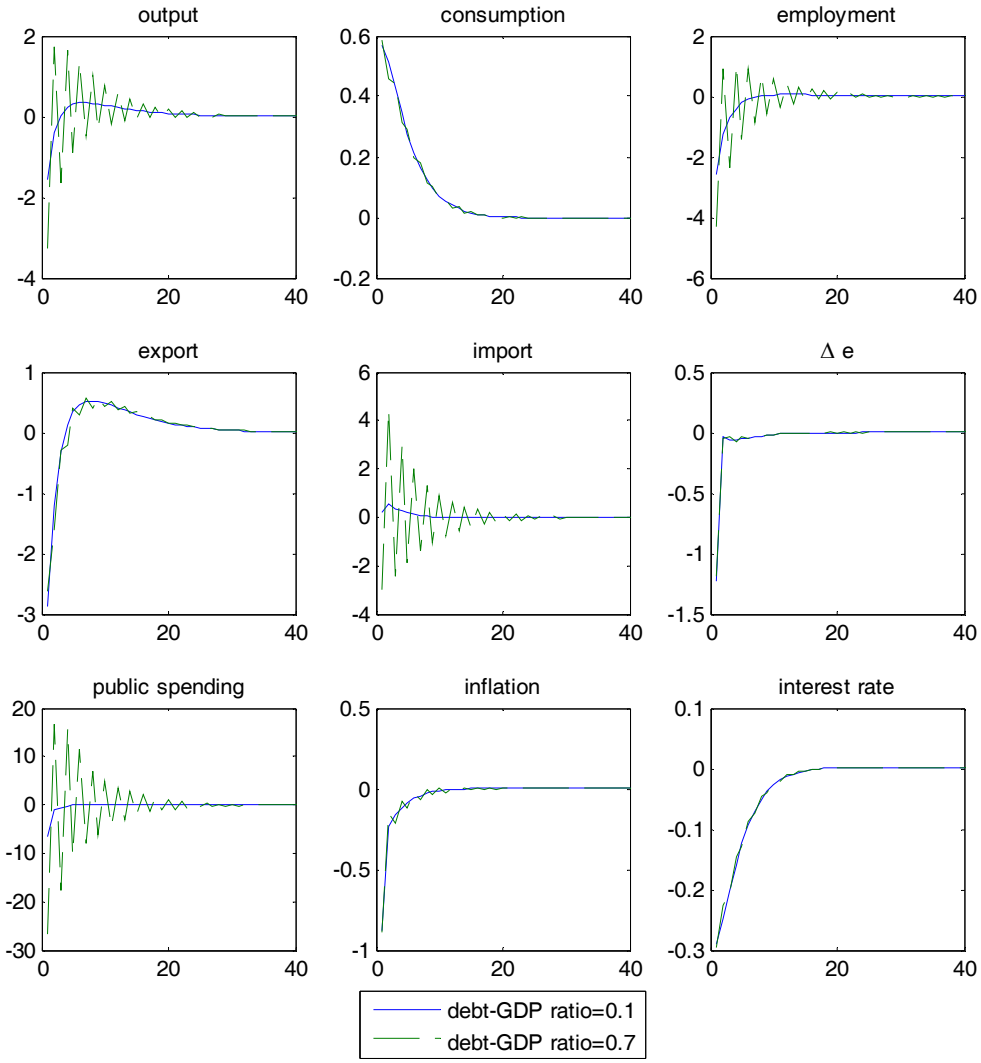


Figure 3: Different debt-GDP ratio in an economy with $\alpha^d = 0.6$

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國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：102 年 10 月 30 日

計畫編號	NSC 101 － 2410 － H － 004 － 016 －		
計畫名稱	Government debt and optimal monetary and fiscal policies in a small open economy		
出國人員 姓名	黃俞寧	服務機構 及職稱	政治大學經濟系副教授
會議時間	102 年 1 月 4 日至 102 年 1 月 6 日	會議地點	美國聖地牙哥
會議名稱	(中文) (英文) 2013 AEA Annual Meeting, Jan. 4-Jan. 6, 2013, San Diego, USA		
發表論文 題目	(中文) (英文) Exchange rate pass-through and the effects of tariffs on economic performance and welfare (with Stephen Turnovsky)		

一、參加會議經過

本人於當地時間 1 月 3 日下午抵達美國聖地牙哥，4 日下午報告本人與 Prof. Stephen Turnovsky 何著"Exchange rate pass-through and the effects of tariffs on economic performance and welfare"一文，會後與該場的 discussants 以及參與者針對相關議題進行了更深入的討論。該場報告亦有台大經濟系陳虹如教授，中研院經濟研究所廖珮如教授與曾在中研院經濟研究所服務的楊淑珺教授等人參與，主要皆是財政政策的總體經濟層面的探討，正是本人目前著手進行研究的方向之一，對於未來相關研究的進展甚有助益。

AEA meeting 向來有許多知名經濟學者針對重要議題進行座談，本人於次日亦參加了另外兩場針對貨幣政策與歐元區相關議題的會議：

1. International Policy Coordination in the Euro Area: Towards an Economic and Financial Federation
   主持者：JEAN-CLAUDE TRICHET (Banque de France)
   Discussants:
   DOMINICK SALVATORE (Fordham University)
   MARTIN FELDSTEIN (Harvard University)
   ROBERT MUNDELL (Columbia University)

KENNETH ROGOFF (Harvard University)
JOHN B. TAYLOR (Stanford University)
JEAN-CLAUDE TRICHET (Banque de France)

2. After the Crisis: What Did We Learn, and What Should We Teach, about Monetary Policy? (A2)
(Panel Discussion)
Panel Moderator: JANET YELLEN (Federal Reserve Board)
MARTIN EICHENBAUM (Northwestern University)
BENJAMIN M. FRIEDMAN (Harvard University)
MARK GERTLER (New York University)
MICHAEL WOODFORD (Columbia University)

參與座談者皆為一時之選，收穫甚豐。

1/4 下午，本人參加了 University of Washington 的校友聚會，欣逢許多於美國求學時代的教授與舊友。並與目前正在 UCLA Anderson Forecast Center 工作的 William Yu，與他交換了許多對於當前經濟以及未來前景的看法。此外，本人亦協助系上陳鎮洲老師藉由此次 meeting 為本系進行新聘教師的面談。

二、與會心得

整體而言，參與此次會議獲益良多。參與者多有舊識，除可敘舊之外，更可交換對於國內外學術界、與實務的看法。整體來說，因為此一會議與我的研究有高度相關，參與此一會議，不論是對於目前的學術研究或是未來的研究規劃，包括進一步的貨幣政策、財政政策分析，與目前已在進行的中國大陸研究，皆有相當的助益。目前我所發表的文章，已為 Journal of International Money and Finance 接受。

三、考察參觀活動(無是項活動者略)

四、建議

五、攜回資料名稱及內容

因為所有論文都有電子檔，因此並未攜回書面資料，需要時上網下載即可。

六、其他

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Exchange rate pass-through and the effects of tariffs on economic performance and welfare☆

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A B S T R A C T

We develop a stochastic two-country general equilibrium model, where prices are determined under conditions of monopolistic competition to examine the macroeconomic and welfare effects of tariffs on the world economy under alternative nominal rigidities: producer-currency pricing (PCP) and local-currency pricing (LCP) where the exchange rate pass-through is absent. We find that the significance of export pricing for the effects of tariffs depends critically upon whether tariffs are anticipated or unanticipated. In the former case both PCP and LCP yield the same outcome as do perfectly flexible prices, although the mechanism whereby this is achieved is different. In the latter case, the effects of unanticipated permanent tariffs are highly sensitive to the pricing scheme adopted by exporters, leading to a wide range of conflicting outcomes, involving tradeoffs among key parameters.

1. Introduction

The role of tariffs as a primary policy instrument of protection has a long history dating back to the 1930s and continuing through recent years.[1] As a result, the macroeconomic consequences of tariffs

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[1] As a recent example we note that in 2004, the European Union (EU) imposed a retaliatory 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 imported from China.

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have been extensively debated since they were first addressed by Mundell (1961). Mundell's analysis and the earliest extensions of his work were static, employing some variant of the Mundell-Fleming model; see e.g. Boyer (1977), Chan (1978), Krugman (1982). The general conclusion to emerge from this approach was that under flexible exchange rates, tariffs are contractionary, the key mechanism generating this being the Laursen-Metzler effect.[2] The first analysis of tariffs in a dynamic framework was Eichengreen (1981) who, using a currency substitution model, emphasized the intertemporal tradeoffs involved in a tariff. He argued that while the protection provided by a tariff may be expansionary in the short run, over time the increase in savings and current account surplus causes a gradual reversal, so that in the long run the tariff will be contractionary.

More recent analyses of tariffs have analyzed them in the context of a macrodynamic model based on intertemporal optimization. Sen and Turnovsky (1989) develop a one sector model and show how a tariff is contractionary both in the short run and in steady state, although it turns out that the long-run responses are sensitive to specifications of the utility function. Recognizing the diverse effects that tariffs may have on different parts of the economy, several papers have introduced tariffs into a multi-sector framework, thereby highlighting the role of the sectoral adjustments to the tariff; see Gavin (1991) and Turnovsky (1991). Brock and Turnovsky (1993) introduce tariffs into a two-sector specific factors model and focus particularly on the welfare aspects. Among the propositions they establish, they show that a uniform tariff levied on both consumption and investment goods will raise welfare in the short run but reduce it over time. More recently, Fender and Yip (2000) analyze the effects of tariffs in the two-country "new open economy model" pioneered by Obstfeld and Rogoff (1995, 1996). Their model features imperfect competition and nominal rigidity and shows that the tariff decreases both the output and employment. The impact of a permanent tariff on welfare faces tradeoffs, mainly from its impacts on output and consumption through the terms of trade movement.[3]

All the literature we have cited assumes either implicitly or explicitly that nominal export prices are set in terms of the currency of the country in which the goods are produced. That is, the literature assumes that export prices are set by producers in terms of their own currency, by employing producer-currency pricing (PCP), as it is known. Under PCP, producers adjust prices completely in accordance with exchange rate movements and thus there is complete exchange rate pass-through onto the prices paid by consumers in the importing country. Purchasing power parity therefore holds for all traded goods.

In practice, however, the empirical evidence supporting exchange rate pass-through implicit in PCP pricing is mixed. On the one hand, several studies have suggested the incomplete exchange rate pass-through onto prices, particularly in the short run. Early supporting evidence supporting this was provided by Mussa (1986) and Knetter (1989).[4] More recent evidence of sluggish prices and the failure of PPP using a wide range of data sets has been provided by others; see e.g. Engel (1993, 1999), Campa and Goldberg (2005), and Atkeson and Burstein (2008).[5] This evidence suggests that pricing in exporters' currency, and thereby implying complete exchange rate pass-through, is not the only way for invoicing trade, but rather that denomination in importers' currency is also a prevalent alternative. That is, exporters may adopt local-currency pricing (LCP), in which case purchasing power parity does not hold and there is no exchange-rate pass-through onto prices paid by importers.

[2] The Laursen-Metzler effect describes the mechanism whereby a deterioration in the terms of trade reduces real income, thereby reducing savings, and given the level of investment, leads to a deterioration in the current account.

[3] Other related references include Kimbrough (1982), Gardner and Kimbrough (1989), Engel and Kletzer (1990)), Ostry (1991), and Yip (1995). One characteristic of the literature is that there is no consensus regarding the theoretical effects of tariffs on key macroeconomic variables, a finding that tends to be confirmed empirically by Ostry and Rose (1992).

[4] An early study by Knetter (1989) comparing US and German export pricing finds producer prices of US firms to be insensitive to exchange rate movements and German producer prices to be more sensitive.

[5] There are many factors that may account for the failure of PPP. For example, Obstfeld and Rogoff (2000) argue that deviations from PPP may arise from the presence of nontraded goods in the aggregate price index, as well as from LCP. Moreover they argue that the observed correlations between terms of trade and exchange rate are more consistent with PCP than with LCP. They also cite direct empirical evidence suggesting that for most major economies the national currency remains the principal currency used for denominating national exports. However, they also acknowledge that the practice of invoicing exports in the importer's currency is increasing over time, except for the United States.

Some recent studies find contrasting degrees of exchange rate pass-through in the case of United States exports and imports. For example, Goldberg and Tille (2008) find that US firms denominate their exports in US dollars, while most US imports are also denominated in US dollars. In other words, US firms engage in PCP when it comes to their exports, while non US firms that export to the US often price in US dollars, and thus adopt LCP.[6] This finding is a manifestation of the role of the US dollar as the international currency for trade denomination, a consequence of which is the prevalence of both PCP and LCP in the pricing of exports.[7]

Recent work by Devereux and Engel (2003), Obstfeld (2008), and Engel (2011) has demonstrated how the pricing of exports has important consequences for monetary policy.[8,9] With tariffs impacting directly on the price of imports, the currency in which the underlying export price is determined by exporters clearly becomes important and relevant. Yet, despite the widespread use of LCP in practice, and the potential importance of exchange rate pass through in determining the impact of tariffs, there is no literature examining tariffs under this alternative, and widely adopted, pricing scheme where the prices that the consumers face do not immediately change with the exchange rates.[10] This is somewhat surprising in light of the fact that tariffs are a key factor driving long-run exchange rate movements, and that alternative degrees of exchange rate pass-through can be critical for policy makers.

The objective of this paper is to compare the macroeconomic consequences of a tariff under the two alternative pricing schemes, PCP and LCP. While the empirical evidence suggests that in practice the pricing of exports lies somewhere in between, focusing on these two polar extremes sharpens the contrast between them and facilitates the intuition. For this purpose, we employ a two-country DSGE model with monopolistic competition and nominal price rigidity, initially developed by Devereux and Engel (2003). We assume that both countries can impose a tariff and our objective is to evaluate its effects on both the domestic and the foreign economy. We focus particularly on the effects of the tariffs on equilibrium prices, consumption, and output, but also discuss the consequences for economic welfare.

Our approach is to begin with the case of perfectly flexible prices as a benchmark and then to characterize the general structure of the equilibrium under the two pricing schemes, taking account of their respective associated nominal rigidities. The main differences pertain to the updating of forecasts of future tariffs, made between time $t-1$, when prices are set, and time t, when the tariff is put into effect. The primary differences between the PCP and LCP schemes result from the fact that the lack of exchange rate pass-through in the latter case insulates large segments of the domestic economy from the foreign tariff.

We find that there is a sharp contrast between the effects of unanticipated and anticipated tariffs in terms of their sensitivity to the pricing of exports. In the case of *fully anticipated* tariffs, the pricing is

[6] Their result is also supported by Gopinath and Rigobon (2008), Gopinath et al. (2010), and others.

[7] The significance of the currency in which trade is denominated has attracted wide attention, and accordingly several recent studies have investigated the determinants of currency denomination for trading. For example, Bacchetta and van Wincoop (2005) find that less competitive firms in the foreign market (larger market share and fewer differentiated goods), are more likely to use their own currency for denomination. This may help explain the empirical findings of the US dollar as a widely adopted international currency in international trade denomination. Goldberg and Tille (2008, 2010) also examine various possible determinants in invoicing currencies.

[8] The importance of the pricing strategies is first revealed by Devereux and Engel (2003). They show that the currency in which the price is set has important implications for the optimal exchange rate regime. They show that a flexible exchange rate regime is optimal under PCP, while a fixed exchange rate regime is optimal under LCP. Obstfeld (2008) points out that this result of Devereux and Engel (2003) is due to the symmetric reactions of consumption to idiosyncratic shocks in the absence of nontradable goods. 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 uncovered interest parity holds.

[9] The implication of international currency for optimal monetary policy is also examined by Devereux et al. (2007). They construct a two-country dynamic stochastic general equilibrium (DSGE) model where US producers adopt PCP, while producers from the rest of the world employ LCP.

[10] Novy (2010) uses a two-country New Open Economy Model where some of the firms take PCP and others take LCP to examine the effects of the iceberg trade cost. He finds that the different degrees of exchange rate pass-through do not significantly alter the international correlation. Instead of emphasizing the business cycle properties, this study attempts to examine analytically the role of the exchange rate pass-through in the macroeconomic effects of the tariff.

essentially irrelevant, with the effects of tariffs being independent of how export prices are set. In that case, an increase in the domestic tariff under the alternative pricing schemes reduces overall domestic consumption by the same proportionate amount and has no effect on foreign consumption, though the mechanism by which this is accomplished is very different. Under PCP prices adjust completely in accordance with exchange rate movements, while under LCP they are the result of direct pricing decisions by exporters.

Second, for all forms of pricing a perfectly anticipated domestic tariff has both an expansionary effect on domestic output and a contractionary effect, with the former dominating if and only if the intertemporal elasticity of substitution is less than unity. On the other hand, the foreign tariff has an unambiguously contractionary effect on domestic output. This is because in all cases the Foreign tariff reduces Foreign demand for Home goods, although the precise mechanism whereby this occurs differs under the alternative pricing schemes.

In contrast, the effects of *unanticipated* permanent tariffs are highly sensitive to the pricing scheme adopted by exporters. With producers having pre-set the price in the period prior to the tariff, the aggregate domestic price index increases in response to either domestic or foreign tariffs under PCP, and while under LCP it also increases in response to a domestic tariff, the lack of exchange rate pass-through in that case insulates it against a foreign tariff. A parallel comparison applies to aggregate consumption. In all cases, the effects of unanticipated tariffs are sensitive to the intensity of monetary policy's response to the aggregate price level, which plays a potentially important role in determining whether tariffs are expansionary or contractionary. Again, because of the role of the exchange rate pass-through effect, it is possible for an unanticipated domestic tariff to be expansionary under LCP but contractionary under PCP, and conversely for a foreign tariff.

The final issue is welfare, which depends positively on consumption and negatively on output via employment and foregone leisure. Welfare effects can be assessed by combining the responses of consumption and output to tariff changes and, in the case of unanticipated tariffs their effects are also highly sensitive to pricing. The fact that tariff policy in one country impacts welfare abroad raises the potential for strategic tariff-setting, although that is not addressed here.

The remainder of the paper is structured as follows. Section 2 outlines the analytical framework, while in Section 3, we evaluate the effects of the tariff under flexible prices, viewed as a benchmark. We introduce the alternative specification of nominal rigidities, PCP and LCP, in Section 4 and characterize the general equilibrium price, exchange rate, and consumption responses to tariffs under alternative degree of exchange rate pass-through, while Section 5 focuses on the corresponding production responses. Section 6 discusses in detail the two polar cases of anticipated and unanticipated permanent tariff increases, including their welfare effects. Finally, we present our conclusions in Section 7. As will become evident, despite the simplicity of the model, its analysis involves substantial technical detail, which is provided in an Appendix available online.

2. The analytical framework

The analytical framework we employ is an adaptation of the framework of Obstfeld (2008) extended to include the imposition of tariffs.[11]

2.1. Production

There are two countries, Home and Foreign. Each country produces a continuum of both tradable and nontradable goods, where Y_H and Y_H^* denote the Home tradable goods sold in Home and Foreign, respectively, and Y_N denotes the Home nontraded goods. Analogously, Y_F, Y_F^*, and Y_N^* denote Foreign tradable goods sold in Home and Foreign, and the Foreign nontraded goods respectively. For each type of commodity, the goods market structure is monopolistically competitive. We index each agent in Home by i over the range [0,1] and assume that he produces one differentiated tradable good and one

[11] This framework is itself an adaption of Devereux and Engel (2003).

differentiated nontraded good, with his labor being the only input in the production process. Thus, agent i's production functions are specified by[12]

$$Y_{H,t}(i) = A_t L_{H,t}(i),\ Y^*_{H,t}(i) = A_t L^*_{H,t}(i),\ Y_{N,t}(i) = A_t L_{N,t}(i) \tag{1a}$$

where A_t is a country-specific productivity shock common to all producers in Home, and agent i's allocation of his total labor, $L_t(i)$, satisfies

$$\begin{aligned} L_t(i) &= L_{H,t}(i) + L^*_{H,t}(i) + L_{N,t}(i) \\ &= \frac{1}{A_t}\left[Y_{H,t}(i) + Y^*_{H,t}(i) + Y_{N,t}(i)\right] \end{aligned} \tag{1b}$$

Aggregating over Home agents yields the corresponding aggregate relationships in Home

$$Y_{H,t} = A_t L_{H,t},\ Y^*_{H,t} = A_t L^*_{H,t},\ Y_{N,t} = A_t L_{N,t} \tag{1c}$$

$$L_t = L_{H,t} + L^*_{H,t} + L_{N,t} \tag{1d}$$

Parallel conditions hold with respect to production in Foreign, where agents are indexed by i over the range [1,2] and the aggregate relationships in Foreign (denoted by asterisks) are

$$Y_{F,t} = A^*_t L_{F,t},\ Y^*_{F,t} = A^*_t L^*_{F,t},\ Y^*_{N,t} = A^*_t L^*_{N,t} \tag{2a}$$

$$L^*_t = L_{F,t} + L^*_{F,t} + L^*_{N,t} \tag{2b}$$

We denote the natural logarithms of the technology shocks in the two economies, A_t, A^*_t by a_t, a^*_t, where we assume the latter evolve in accordance with the following AR(1) processes:

$$a_t = (1-\eta)a + \eta a_{t-1} + \varepsilon_{a,t},\ \ \varepsilon_{a,t} \sim N\left(0, \sigma_a^2\right) \tag{3a}$$

$$a^*_t = (1-\eta)a^* + \eta a^*_{t-1} + \varepsilon_{a^*,t},\ \ \varepsilon_{a^*,t} \sim N\left(0, \sigma_{a^*}^2\right) \tag{3b}$$

Given the assumption on technology and preferences introduced below, the assumption of the lognormal distribution of productivity shocks implies that all endogenous variables in the economy are lognormally distributed as well.

2.2. Consumption

Consumers in each country consume a variety of goods, composed of Home and Foreign tradable goods and Home nontradable goods. Any individual i in Home consumes the composite consumption index, C, of the Cobb–Douglas form:

$$C_t = \frac{C^{\gamma}_{T,t} C^{1-\gamma}_{N,t}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \tag{4}$$

where C_T and C_N are the indexes of traded and nontraded consumption and γ is the share of spending on tradable goods in the total expenditure PC.

[12] The assumption of stochastic non-diminishing labor productivity, uniform across the traded and nontraded sectors (also adopted by Devereux and Engel, 2003; and Obstfeld, 2008) is made purely for simplicity and is of little consequence. This is because under monopolistic competition, equilibrium outputs are determined by consumption demand, so that (1a) and (1b) determine the corresponding demand for labor. The only aspect of our results that this specification impacts is the welfare effects which are dependent upon employment, and here the effects are quantitative rather than qualitative.

The inclusion of nontraded goods is important for several reasons. First, nontraded goods are quantitatively significant. Moreover, they help generate the home bias which is prevalent in practice, and which as Warnock (2003) and Obstfeld (2008) discuss, is important in determining the exchange rate movements and welfare implications of monetary policies. In this model, the inclusion of non-tradable goods helps characterize the asymmetric effects of tariffs' effects in the Home and Foreign countries. Without nontradable goods (or home bias), purchasing power parity will hold for both the flexible price and PCP cases, where the law of one price applies. This, together with the risk-sharing condition (13), will make consumption identical across countries at all times and will eliminate the terms of trade movement which is critical for the differential effects of tariff under alternative pricing schemes.

The tradable consumption sub-index is composed of an equal share of Home and Foreign tradable goods, C_H and C_F:

$$C_{T,t} = 2C_{H,t}^{1/2}C_{F,t}^{1/2} \tag{5}$$

where

$C_{H,t} = [\int_0^1 C_{H,t}(i)^{(\theta-1)/\theta}\mathrm{d}i]^{\theta/(\theta-1)}$, $C_{F,t} = [\int_1^2 C_{T,t}(i)^{(\theta-1)/\theta}\mathrm{d}i]^{\theta/(\theta-1)}$, $C_{N,t} = [\int_0^1 C_{N,t}(i)^{(\theta-1)/\theta}\mathrm{d}i]^{\theta/(\theta-1)}$ and θ is the elasticity of substitution in consumption between goods, with $\theta > 1$.

We assume that Home imposes a tariff τ_t on imports.[13] In this case, Home aggregate price index for the composite consumption good at time t is

$$P_t = P_{T,t}^{\gamma}P_{N,t}^{1-\gamma},\ P_{T,t} = P_{H,t}^{1/2}\left(P_{F,t}(1+\tau_t)\right)^{1/2} \tag{6}$$

where

$P_{H,t} = [\int_{i=0}^1 P_{H,t}(i)^{1-\theta}\mathrm{d}i]^{\frac{1}{1-\theta}}$, $P_{F,t} = [\int_{i=1}^2 P_{F,t}(i)^{1-\theta}\mathrm{d}i]^{\frac{1}{1-\theta}}$, $P_{N,t} = [\int_{i=0}^1 P_{N,t}(i)^{1-\theta}\mathrm{d}i]^{\frac{1}{1-\theta}}$ and $P_{H,t}(i)$, $P_{F,t}(i)$, and $P_{N,t}(i)$ are prices set by producer i with $P_{H,t}$, $P_{F,t}$ and $P_{N,t}$ being the prices of the corresponding sub-aggregates. The price of imports that Home consumers face, inclusive of the tariff, is $(1+\tau_t)P_{F,t}$. Throughout, we shall assume that the tariff is imposed permanently and show how its effects contrast sharply, depending upon whether it is anticipated or unanticipated.[14]

Assuming that agents choose to allocate among the differentiated goods so as to maximize the corresponding consumption aggregate, Home demand for each commodity can be written as

$$C_{H,t}(i) = \left[\frac{P_{H,t}(i)}{P_{H,t}}\right]^{-\theta}C_{H,t},\ C_{F,t}(i) = \left[\frac{P_{F,t}(i)}{P_{F,t}}\right]^{-\theta}C_{F,t},\ C_{N,t}(i) = \left[\frac{P_{N,t}(i)}{P_{N,t}}\right]^{-\theta}C_{N,t} \tag{7a}$$

Since all producers face identical conditions they set the same price and produce the same output. Home demand functions for Home and Foreign goods are

$$C_{H,t} = \frac{1}{2}\left[\frac{P_{H,t}}{P_{T,t}}\right]^{-1}C_{T,t},\ C_{F,t} = \frac{1}{2}\left[\frac{(1+\tau_t)P_{F,t}}{P_{T,t}}\right]^{-1}C_{T,t} \tag{7b}$$

and Home demand functions for traded and nontraded goods are

[13] We assume that the tariff is imposed on the producer price, $P_{F,t}$ so that consumers pay the tariff-inclusive price, $(1+\tau_t)P_{F,t}$. However, $P_{F,t}$ differs under the different pricing schemes. Specifically, $P_{F,t} = e_tP_{F,t}^*$, under both flexible prices and PCP, where $P_{F,t}^*$ adjusts freely under flexible prices, but is predetermined one period ahead under PCP. In the case of LCP, foreign firms predetermine $P_{F,t}$ in the Home currency. Whether or not the tariff is anticipated generates the difference in producer prices, and thereby the consumption price and consumption levels under flexible and predetermined prices.

[14] Temporary tariffs can be analyzed similarly and the contrasts are similar to those of permanent tariffs.

$$C_{T,t} = \gamma\left[\frac{P_{T,t}}{P_t}\right]^{-1} C_t,\ C_{N,t} = (1-\gamma)\left[\frac{P_{N,t}}{P_t}\right]^{-1} C_t \tag{7c}$$

Combining these equations, we can express aggregate Home demand for the three aggregates as

$$C_{H,t} = \frac{\gamma}{2}\left[\frac{P}{P_{H,t}}\right] C_t,\ C_{F,t} = \frac{\gamma}{2}\left[\frac{P_t}{(1+\tau_t)P_{F,t}}\right] C_t,\ C_{N,t} = (1-\gamma)\left[\frac{P_t}{P_{N,t}}\right] C_t \tag{8a}$$

Parallel to these equations, the Foreign demand for each good is

$$C^*_{H,t} = \frac{\gamma}{2}\left[\frac{P^*_t}{(1+\tau^*_t)P^*_{H,t}}\right] C^*_t,\ C^*_{F,t} = \frac{\gamma}{2}\left[\frac{P^*_t}{P^*_{F,t}}\right] C^*_t,\ C^*_{N,t} = (1-\gamma)\left[P^*_{N,t}\right] C^*_t \tag{8b}$$

where $P^*_{H,t}$, $P^*_{F,t}$, and $P^*_{N,t}$ are producer prices abroad, and we assume that Foreign imposes a permanent tariff τ^*_t on the imports from Home. With traded and nontraded producers facing identical production conditions, in each economy $P_{N,t} = P_{H,t}$; $P^*_{N,t} = P^*_{F,t}$, enabling the exact price index for the Home composite consumption good to be written

$$\frac{P_t}{P_{H,t}} = \left[(1+\tau_t)\frac{P_{F,t}}{P_{H,t}}\right]^{\frac{\gamma}{2}} \tag{9a}$$

with the corresponding Foreign price index being

$$\frac{P^*_t}{(1+\tau^*_t)P^*_{H,t}} = \left[\frac{P^*_{F,t}}{(1+\tau^*_t)P^*_{H,t}}\right]^{1-\frac{\gamma}{2}} \tag{9b}$$

2.3. The utility function

Agent i in the Home economy produces the ith tradable good and the ith nontraded good. He maximizes the following intertemporal utility function

$$\max \sum_{t=0}^{\infty} \beta^t E_0\left(\frac{1}{1-\rho}(C_t(i))^{1-\rho} - \kappa L_t(i)\right) \tag{10}$$

which depends on the consumption of the composite good, $C_t(i)$, specified in (4), and the disutility from labor supply, $L_t(i)$, parameterized by κ, where β is the subjective discount factor, and $1/\rho$ is the intertemporal elasticity of substitution (IES) and $\rho > 0$.[15] The maximization is subject to the flow budget constraint

$$P_t C_t(i) + B_{t+1}(i) = (1+R_t(i))B_t(i) + P_{H,t}(i)Y_{H,t}(i) + \varepsilon_t P^*_{H,t}(i)Y^*_{H,t}(i) + P_{N,t}(i)Y_{N,t}(i) + T_t(i) \tag{11}$$

where $B_t(i)$ is the agent's marketable wealth at time t, $R_t(i)$ is the return on his portfolio, ε_t is the nominal exchange rate measured in terms of Home-currency price of Foreign currency, and $T_t(i)$ are lump-sum transfers to agent i.

We assume that asset markets are complete. That is, there is a complete set of state-contingent securities in the budget constraint, which will permit complete risk-sharing.[16] The individual household receives income from the sale of the goods produced, which it uses to purchase the consumption bundle and to accumulate assets. Under monopolistic competition, the production of each good is determined by its demand, and thus $Y_{H,t}(i) = C_{H,t}(i)$, where $C_H(i)$ is determined by (8a) and analogously

[15] Although empirical estimates of the intertemporal elasticity of substitution extend over a broad range, they generally are less than unity, so that $\rho > 1$.

[16] 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.

for $Y_H^*(i), Y_N(i)$. It is assumed that the government redistributes the tariff revenues to individuals in a lump-sum fashion, T_t, so as to maintain a balanced budget.[17]

Optimizing over asset holdings, yields the familiar Euler equation for nominal bonds:

$$\frac{C_t^{-\rho}}{P_t} = \beta(1+r_t)E_t\left(\frac{C_{t+1}^{-\rho}}{P_{t+1}}\right) \tag{12}$$

where r_t is the nominal interest rate set by the monetary authorities in Home. Since consumers in Home and Foreign face the same asset prices, the risk-sharing condition for the complete asset markets holds for all states[18]

$$\frac{\mathcal{E}_t P_t^*}{P_t} = \frac{C_t^{\rho}}{C_t^{*\rho}} \tag{13}$$

The existence of nontradable goods and tariffs implies that purchasing power parity does not hold, so that (13) implies that, in general, consumption is not equalized across countries.

Finally, we need to specify monetary policy, and we do so by assuming that the central bank in each country adopts the following interest rate rule, targeting the logarithm of the overall domestic price level:

$$\ln(1+r_t) = \bar{r} + \omega p_t \tag{14a}$$

$$\ln(1+r_t^*) = \bar{r} + \omega p_t^* \tag{14b}$$

We assume $\omega > 0$ so that each central bank is adopting a price-stabilizing policy, raising (lowering) its interest rate in response to an increase (decrease) in the price level. The main advantage of adopting this specification is that it acknowledges the need to incorporate money in a framework involving nominal rigidities, while ascribing it a minimally intrusive role.[19]

2.4. Output

The key issue pertaining to tariff policy is to evaluate its effect on output and economic welfare. In the monopolistically competitive market, because the production of each country consists of the sum of goods sold on the domestic and foreign markets, total Home production can be obtained from the overall production of Home goods sold in Home and in Foreign,

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

where the components of (15) are obtained by summing over the relevant demand functions in (8a) and (8b). Thus Home output is given by

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

and combined with relative prices reported in (9a) and (9b), this expression can be rewritten as:

$$Y_t = \left(1-\frac{\gamma}{2}\right)\left[\frac{(1+\tau_t)P_{F,t}}{P_{H,t}}\right]^{\frac{\gamma}{2}}C_t + \frac{\gamma}{2}\left[\frac{P_{F,t}^*}{(1+\tau_t^*)P_{H,t}^*}\right]^{1-\frac{\gamma}{2}}C_t^* \tag{16}$$

The first term on the right-hand side are the goods sold domestically, $Y_{H,t} + Y_{N,t}$, while the second term is the sale in the Foreign country, $Y_{H,t}^*$. An analogous expression applies to Foreign output, Y_t^*. Thus, the differential output effects of tariffs under the alternative pricing schemes depend on how (i) they impact on consumptions in the two countries, and (ii) their effects on the tariff-adjusted relative price of the two goods.

[17] Assuming that the economy starts out with zero net assets, this also ensures that it remains intertemporally solvent.

[18] This equation is well documented in the literature; see e.g. Backus and Smith (2003), Devereux and Engel (2003).

[19] Obstfeld (2008) assumes that the interest rate can adjust with the productivity shocks and examines the optimal responses of the monetary policy to the shocks. Because this is not the focus of this study, we assume the interest rate rule simply responds to the aggregate price level.

3. Flexible prices

As a benchmark, we begin by determining the equilibrium under flexible prices. Optimizing (10) subject to (11), and the corresponding utility for Foreign, with respect to consumption and labor supply, we immediately derive the standard tradeoff between labor supply and consumption.[20]

$$\frac{W_t}{P_t}C_t^{-\rho} = \frac{W_t^*}{P_t^*}C_t^{*-\rho} = \kappa \tag{17}$$

Substituting this equation back into Eq. (13), yields the nominal wage parity condition, $W_t = \varepsilon_t W_t^*$.[21]

In a monopolistically competitive market, profit maximizing firms will set the price as a fixed markup over the marginal cost for the goods sold in the Home and Foreign economies. Thus, for the specific demand functions in (7) and (8), and production functions (1) and (2), Home producers will set $P_{H,t} = P_{N,t} = \varepsilon_t P_{H,t}^* = (\theta/(\theta-1))(W_t/A_t)$, while Foreign producers will set $P_{F,t}/\varepsilon_t = P_{F,t}^* = P_{N,t}^* = (\theta/(\theta-1))(W_t^*/A_t^*)$ respectively. Therefore, when combined with the wage parity condition, we see that the relative prices in the two economies satisfy:

$$\frac{P_{H,t}}{P_{F,t}} = \frac{P_{H,t}^*}{P_{F,t}^*} = \frac{A_t^*}{A_t} \tag{18}$$

Thus, with perfectly flexible prices, both countries face the same international relative prices, which will reflect only the relative productivity levels in these two countries, and are insulated from any impact of tariffs. Combining Equations (17) and (18), and the Home and Foreign composite price indexes, as defined by Equation (9), together with the price-setting relationships noted above, yields the equilibrium consumption in the two countries:

$$C_t^{FP} = \left[\frac{\theta-1}{\kappa\theta}A_t^{1-\frac{\gamma}{2}}A_t^{*\frac{\gamma}{2}}(1+\tau_t)^{-\frac{\gamma}{2}}\right]^{\frac{1}{\rho}},\quad C_t^{*FP} = \left[\frac{\theta-1}{\kappa\theta}A_t^{\frac{\gamma}{2}}A_t^{*1-\frac{\gamma}{2}}(1+\tau_t^*)^{-\frac{\gamma}{2}}\right]^{\frac{1}{\rho}} \tag{19}$$

where the superscript FP denotes "flexible price". Analogously in Section 4 below, we shall let PCP denote "producer currency pricing" and LCP denote "local currency pricing", respectively.

Equation (19) confirms Obstfeld's (2008) observation that due to the communality of the shocks across the traded and nontraded sectors, consumption depends disproportionately on the country's own productivity shock. From (19) we immediately obtain[22]

$$\frac{dC_t^{FP}}{C_t^{FP}} = -\frac{\gamma}{2\rho}\frac{d\tau_t}{(1+\tau_t)};\quad \frac{dC_t^{*FP}}{C_t^{*FP}} = -\frac{\gamma}{2\rho}\frac{d\tau_t^*}{(1+\tau_t^*)} \tag{20}$$

Each country's consumption is reduced by its current tariff only, the decline increasing with the importance of the traded good in overall consumption. In contrast, consumption is independent of the tariff imposed abroad. Intuitively, since the tariff revenue is refunded to households as lump-sum transfers, there is no income effect from the tariff payment. However, the tariff is imposed at the border after the firms of tradable goods set their prices. While producer prices will reflect only the productivity disparity across countries as shown by (18), the imposition of tariffs will directly affect prices that consumers face and consumption is reduced accordingly. We also note that with A_t and A_t^* being lognormal, C_t and C_t^* are lognormal, and from the basic properties of the lognormal distribution that the variance of C_t declines with the tariff.

Substituting the expression for relative prices, (18), into (16), the solution for Home output under flexible prices can be expressed as

[20] To do this, we rewrite the income earned from the sale of goods in terms of labor income and profit, as in Obstfeld and Rogoff (2000). Optimizing (10) subject to (11) re-expressed in this form immediately yields (17).

[21] We should emphasize that the wage parity holds because of the assumed identical disutility of labor supply across economies, coupled with complete risk sharing, as set out in (17). It does not reflect any assumptions of equally-sized countries, or equal tariffs. Indeed, tariffs are in general assumed to be set differentially across the two economies.

[22] For convenience we shall express the change in tariffs relative to the unit price inclusive of tariff, $d\tau/(1+\tau)$.

$$Y_t^{FP} = \left(1-\frac{\gamma}{2}\right)\left[\frac{(1+\tau_t)A_t}{A_t^*}\right]^{\frac{\gamma}{2}} C_t^{FP} + \frac{\gamma}{2}\left[\frac{A_t}{(1+\tau_t^*)A_t^*}\right]^{1-\frac{\gamma}{2}} C_t^{*FP} \tag{21}$$

and correspondingly for Foreign output. Substituting (19) into (21) yields a reduced form solution for Y_t that is expressed in terms of the exogenous shocks, tariffs, and parameters. Equilibrium employment is then obtained by combining (1c), (1d) and (15), namely $L_t^{FP} = Y_t^{FP}/A_t$.

The effects of Home and Foreign tariffs on the two components, $(Y_{H,t}+Y_{N,t})^{FP}$, $Y_{H,t}^{*FP}$ of total Home production, Y_t^{FP}, as decomposed in (15) can be readily shown to be:

$$\frac{\mathrm{d}(Y_{H,t}+Y_{N,t})^{FP}}{(Y_{H,t}+Y_{N,t})^{FP}} = \frac{\gamma(\rho-1)}{2\rho}\frac{\mathrm{d}\tau_t}{(1+\tau_t)} \tag{22a}$$

$$\frac{\mathrm{d}Y_{H,t}^{*FP}}{Y_{H,t}^{*FP}} = -\left(\frac{\rho(2-\gamma)+\gamma}{2\rho}\right)\frac{\mathrm{d}\tau_t^*}{(1+\tau_t^*)} < 0 \tag{22b}$$

with corresponding effects applying to Foreign production. As seen from (22a), the Home tariff is expansionary for Home output sold domestically when $\rho > 1$, but contractionary when $\rho < 1$. This is a reflection of two offsetting effects. While the Home tariff, by raising the aggregate price has a direct negative effect on the aggregate consumption (see Eq. (20)), by raising the price of imports it also causes Home demand to shift toward Home goods. The substitution effect in the latter dominates when $\rho > 1$ and, thus, the overall Home production benefits from the protection policy. On the other hand, the Foreign tariff is unambiguously contractionary for Home production, as shown by Equation (22b). This is because it reduces the Foreign aggregate consumption including imports from Home firms, and thus leads to lower Home exports. In both cases, the magnitudes of the marginal effects of the tariffs decline as the levels of the tariffs increase.

With prices being perfectly flexible, consumption and output are determined entirely by *contemporaneous* real quantities (productivity shocks and tariffs). Thus, whether tariffs are anticipated or not, or whether they are permanent or temporary is irrelevant. Consumption and output are also independent of nominal quantities, including monetary policy. Nevertheless, to understand the mechanism involved, and to compare the adjustments with cases characterized by nominal rigidity it is useful to solve for the relevant equilibrium prices. To do this, we return to the Euler Equation (12). With all the variables being lognormally distributed, we take logarithms of this equation. By substituting the interest rate rule (14) and Home and Foreign consumption from (19) into this equation, and solving the price level recursively, we can express the (logarithm of) the current price levels in terms of the current productivity shocks and the variances of the endogenous variables, which are assumed to be constant over time. The resulting equations for Home and Foreign aggregate price indexes are reported as (A.3) in the online Appendix. Taking differentials of these equations, we obtain

$$\frac{\mathrm{d}P_t^{FP}}{P_t^{FP}} = -\frac{\gamma}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\left[\frac{\mathrm{d}E_t\tau_{s+1}}{1+E_t\tau_{s+1}} - \frac{\mathrm{d}E_t\tau_s}{1+E_t\tau_s}\right] \tag{23a}$$

$$\frac{\mathrm{d}P_t^{*FP}}{P_t^{*FP}} = -\frac{\gamma}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\left[\frac{\mathrm{d}E_t\tau_{s+1}^*}{1+E_t\tau_{s+1}^*} - \frac{\mathrm{d}E_t\tau_s^*}{1+E_t\tau_s^*}\right] \tag{23b}$$

where $E_t\tau_s$ denotes the prediction (expectation) formed at time t of the tariff to be in effect at time s. Throughout, we assume that agents correctly observe the current tariff, a condition that is formally stated by $E_t\tau_t = \tau_t$.

Using the aggregate price index, while noting that in equilibrium, $p_{N,t} = p_{H,t}$, and analogously abroad, the producer prices (in logarithms) of the Home goods and imports from Foreign can be written in terms of the aggregate price level:

$$p_{H,t} = -\frac{\gamma}{2}\ln(1+\tau_t) - \frac{\gamma}{2}(a_t - a_t^*) + p_t \tag{24a}$$

$$p^*_{F,t} = -\frac{\gamma}{2}\ln(1+\tau^*_t) + \frac{\gamma}{2}(a_t - a^*_t) + p^*_t \tag{24b}$$

As Eqs. (24a) and (24b) show, the price level of each type of goods, $p_{H,t}$ and $p^*_{F,t}$, will respond to both the current tariff directly, and to the anticipated future tariff changes indirectly, through their impact on the aggregate price index. To dampen the decrease in the sale of their goods, exporters reduce their price in response to increases in the current tariff as well as to expected future tariffs.

Finally, combining equilibrium consumption levels, (19), the price level, (A.3) in the Appendix, and the risk-sharing condition, (13), yields the nominal exchange rate (in logarithms), reported as (A.4) in the Appendix, from which we derive

$$\frac{d\varepsilon^{FP}_t}{\varepsilon^{FP}_t} = -\frac{\gamma}{2}\left(\frac{\omega}{1+\omega}\right)\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left\{\frac{dE_t\tau_s}{1+E_t\tau_s} - \frac{dE_t\tau^*_s}{1+E_t\tau^*_s}\right\} \tag{25}$$

The current exchange rate depends upon the discounted expected future tariff differentials between Home and Foreign, appreciating with the former, and depreciating with the latter. This adjustment is driven by interest rate disparity across the economies and eliminates the arbitrage opportunities in the international capital market. The effect of this is to remove the influence of the Foreign tariff on the Home price, thereby insulating Home consumption from the Foreign tariff; see (20).

3.1. Equilibrium under nominal rigidities

The assumption of perfectly flexible prices is a polar one and we therefore examine the extent to which the response in the exchange rate can be completely passed through onto import prices and the domestic economy when prices are sticky. In particular, we assume that the firms preset prices one period ahead, before the shocks are realized, subject to the demand that emerges at that price. Producers of nontradable goods or producers of tradable goods sold domestically set prices in their respective domestic currencies. In the case of exporters, we consider two alternatives. The first assumes that they set the price in their own currency, adopting producer-currency pricing (PCP). In this case the price for the goods sold in the foreign country will be converted into the foreign-currency price with the exchange rate movement, such that the law of one price holds for tradable goods in both countries. This is the conventional setting that Fender and Yip (2000) and the existing tariff literature assumes. Alternatively, producers may set the price in the currency of the purchaser, that is they adopt local-currency pricing (LCP). In this case there is no exchange rate pass-through onto the destination price of the exports. As a result, the law of one price may not hold.

In all cases prices are chosen to maximize the owners' expected utility and they can be re-set after one period. We begin by considering Home producer i, who is setting prices of traded goods sold domestically, $P_{H,t}(i)$, traded goods sold abroad, $P^*_{H,t}(i)$, and nontraded goods, $P_{N,t}(i)$. Because prices can be re-set after one period and in all other respects, the economic structure is static, the pricing decision can be made to maximize the one-period utility function

$$E_{t-1}\left(\frac{1}{1-\rho}C_t(i)^{1-\rho} - \kappa L_t(i)\right) \tag{26a}$$

subject to the budget constraint (11), the labor allocation constraint (1b), and the demand functions

$$\begin{aligned} C_{H,t}(i) &= \frac{\gamma}{2}\left[\frac{P_{H,t}(i)}{P_{H,t}}\right]^{-\theta}\left[\frac{P_{H,t}}{P_t}\right]^{-1}C_t,\ C_{N,t}(i) = (1-\gamma)\left[\frac{P_{N,t}(i)}{P_{N,t}}\right]^{-\theta}\left[\frac{P_{N,t}}{P_t}\right]^{-1}C_t, \\ C^*_{H,t}(i) &= \frac{\gamma}{2}\left[\frac{(1+\tau^*_t)P^*_{H,t}(i)}{P^*_{H,t}}\right]^{-\theta}\left[\frac{P^*_{H,t}}{P^*_t}\right]^{-1}C^*_t \end{aligned} \tag{26b}$$

where the output of each good and its associated employment of labor are determined by the corresponding demand. Under the assumption of monopolistic competition in setting prices, each producer takes the corresponding aggregate as given.

3.2. PCP

Consider a Home producer acting under PCP. The prices of both tradables and nontradables are set in Home currency at time $t-1$. In particular, he sets $P_{H,t}(i)$,$P_{N,t}(i)$ in accordance with the above maximization problem. In the case of tradables that are exported, at period t when the goods are sold abroad, the producers adjust the consumer prices to reflect the exchange rate movement, which in turn reflects the current shocks. Thus, the consumer price of the tradable goods sold abroad can be written as $P^*_{H,t} = P_{H,t}/\varepsilon_t$. As a result of the stochastic fluctuations in the exchange rate occurring in period t, the aggregate price indexes, P_t, P^*_t, are unknown at time $t-1$, when the pricing decisions are made.

Carrying out the optimization, with tradable and nontradable goods being produced subject to the identical production conditions, and focusing on a symmetric equilibrium in which all firms, facing the same conditions, set the same price, we find that the equilibrium price under PCP is

$$\varepsilon_t P^{*PCP}_{H,t} = P^{PCP}_{H,t} = P^{PCP}_{N,t} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}(P_tC_t/A_t)}{E_{t-1}\left(C_t^{1-\rho}\right)} \tag{27}$$

In Table 1 we report the analogous pricing relationships for the Foreign producer, and combining the two relationships we see that

$$\frac{P_{H,t}}{P_{F,t}} = \frac{P^*_{H,t}}{P^*_{F,t}} = \frac{1}{\varepsilon_t}\frac{E_{t-1}(P_tC_t/A_t)}{E_{t-1}\left(C_t^{1-\rho}\right)}\frac{E_{t-1}\left(C_t^{*1-\rho}\right)}{E_{t-1}(P^*_tC^*_t/A^*_t)} \tag{28a}$$

The two countries still face the same international relative prices but they now involve the correlation of consumption expenditures with the productivity shocks, as well as the fluctuations in the current nominal exchange rate. Combining (28) with (10) and the risk sharing condition (13), we find that for the PCP pricing the relative price can be expressed in the convenient form

$$\frac{P_{H,t}}{P_{F,t}} = \frac{P^*_{H,t}}{P^*_{F,t}} = \left(\frac{C^*_t}{C_t}\right)^{\frac{\rho}{1-\gamma}}\left(\frac{1+\tau^*_t}{1+\tau_t}\right)^{\frac{\gamma}{2(1-\gamma)}} \tag{28b}$$

3.3. LCP

In adopting LCP pricing, exporters set the price at time $t-1$ in the consumers' currency, namely $P^{*LCP}_{H,t}$ and $P^{LCP}_{F,t}$, for the Home and Foreign exports respectively. Thus there is no exchange rate pass-through. Performing the optimization for the Home producer, the equilibrium prices under LCP are[23]

$$P^{LCP}_{H,t} = P^{LCP}_{N,t} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}(P_t)E_{t-1}(C_t/A_t)}{E_{t-1}\left(C_t^{1-\rho}\right)} \tag{29a}$$

$$P^{*LCP}_{H,t} = \left(\frac{\kappa\theta}{\theta-1}\right)\frac{E_{t-1}(P^*_t)E_{t-1}(C^*_t/A_t)}{E_{t-1}\left(C_t^{*1-\rho}\right)} \tag{29b}$$

Analogous conditions characterize the optimal price for the Foreign producer under both PCP and LCP; see Table 1. As reported in that table, we see the parallels and the differences between the two pricing schemes with rigidities and that under flexible prices. We should note that the pricing is essentially as those in Devereux and Engel (2003) and Obstfeld (2008), except that the aggregate price

[23] Under LCP all prices are predetermined at time $t-1$. However, since P_t, P^*_t incorporate the tariffs that are unknown at that time, but are fixed independently and therefore uncorrelated with consumption or productivity shocks, we can express the LCP prices as in (29a), (29b).

Table 1
Optimal pricing.

	Home	Foreign
Flex Price	$P_{H,t} = P_{N,t} = \varepsilon_t P^*_{H,t} = \left(\frac{\theta}{\theta-1}\right)\frac{W_t}{A_t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{P_t}{A_t C_t^{-\rho}}$	$P^*_{F,t} = P^*_{N,t} = \frac{P^*_{F,t}}{\varepsilon_t} = \left(\frac{\theta}{\theta-1}\right)\frac{W^*_t}{A^*_t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{P^*_t}{A^*_t (C^*)_t^{-\rho}}$
PCP	$P^{PCP}_{H,t} = P^{PCP}_{N,t} = \varepsilon_t P^{*PCP}_{H,t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{E_{t-1}(P_t C_t/A_t)}{E_{t-1}(C_t^{1-\rho})}$	$P^{*PCP}_{F,t} = P^{*PCP}_{N,t} = \frac{P^{PCP}_{F,t}}{\varepsilon_t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{E_{t-1}(P^*_t)E_{t-1}(C^*_t/A^*_t)}{E_{t-1}(C^{*1-\rho}_t)}$
LCP	$P^{LCP}_{H,t} = P^{LCP}_{N,t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{E_{t-1}(P_t)E_{t-1}(C_t/A_t)}{E_{t-1}(C_t^{1-\rho})}$	$P^{*LCP}_{F,t} = P^{*LCP}_{F,t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{E_{t-1}(P^*_t C^*_t/A^*_t)}{E_{t-1}(C^{*1-\rho}_t)}$
	$P^{*LCP}_{H,t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{E_{t-1}(P^*_t)E_{t-1}(C^*_t/A_t)}{E_{t-1}(C^{*1-\rho}_t)}$	$P^{LCP}_{F,t} = \left(\frac{\theta}{\theta-1}\right)\kappa\frac{E_{t-1}(P_t)E_{t-1}(C_t/A^*_t)}{E_{t-1}(C_t^{1-\rho})}$

level here incorporates the tariff, and to the extent that the tariff is anticipated, P_t is replaced by $E_{t-1}(P_t)$. Thus in this case

$$\frac{P_{H,t}}{P_{F,t}} = \frac{E_{t-1}(C_t/A_t)}{E_{t-1}(C_t/A^*_t)} \neq \frac{E_{t-1}(C^*_t/A_t)}{E_{t-1}(C^*_t/A^*_t)} = \frac{P^*_{H,t}}{P^*_{F,t}} \tag{30}$$

implying that the relative international prices facing the two economies will deviate by an amount that reflects the correlations of their respective consumption levels with the productivity shocks.

3.4. Price and consumption effects

We now turn to the aggregate price and consumption effects generated by the tariffs. Because all variables are lognormally distributed, it is straightforward to obtain the analytical solutions for prices and consumption, although the derivations involve substantial detail and are set out in the online Appendix where the explicit solutions are also reported.

3.4.1. PCP

The solutions for the aggregate price, consumption in Home and Foreign and the nominal exchange rate in the case of PCP pricing are summarized in Equations (A.23), (A.21), and (A.22) in the Appendix, respectively. These imply the following responses to tariff changes:

$$\begin{aligned}\frac{dP_t^{PCP}}{P_t^{PCP}} = &\frac{\gamma}{2}\left\{\left(\frac{d\tau_t}{1+\tau_t} - \frac{dE_{t-1}\tau_t}{1+E_{t-1}\tau_t}\right) - \sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\left(\frac{dE_{t-1}\tau_{s+1}}{1+E_{t-1}\tau_{s+1}} - \frac{dE_{t-1}\tau_s}{1+E_{t-1}\tau_s}\right)\right\}\\ &-\frac{\gamma^2\omega}{4(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\left(\frac{dE_t\tau_s}{1+E_t\tau_s} - \frac{dE_t\tau^*_s}{1+E_t\tau^*_s}\right) - \left(\frac{dE_{t-1}\tau_s}{1+E_{t-1}\tau_s} - \frac{dE_{t-1}\tau^*_s}{1+E_{t-1}\tau^*_s}\right)\right]\end{aligned} \tag{31a}$$

$$\begin{aligned}\frac{d\varepsilon_t^{PCP}}{\varepsilon_t^{PCP}} = &-\frac{\gamma\omega}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\left(\frac{dE_{t-1}\tau_s}{1+E_{t-1}\tau_s} - \frac{dE_{t-1}\tau^*_s}{1+E_{t-1}\tau^*_s}\right)\\ &-\frac{\gamma\omega}{2(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\left(\frac{dE_t\tau_s}{1+E_t\tau_s} - \frac{dE_t\tau^*_s}{1+E_t\tau^*_s}\right) - \left(\frac{dE_{t-1}\tau_s}{1+E_{t-1}\tau_s} - \frac{dE_{t-1}\tau^*_s}{1+E_{t-1}\tau^*_s}\right)\right]\end{aligned} \tag{31b}$$

$$\begin{aligned}\frac{dC_t^{PCP}}{C_t^{PCP}} = &-\frac{\gamma}{2\rho}\frac{d\tau_t}{(1+\tau_t)} - \frac{\gamma\omega(2-\gamma+\gamma\omega)}{4\rho(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau_s}{(1+E_t\tau_s)} - \frac{dE_{t-1}\tau_s}{(1+E_{t-1}\tau_s)}\right]\\ &-\frac{\gamma^2\omega(1+\omega)}{4\rho(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau^*_s}{(1+E_t\tau^*_s)} - \frac{dE_{t-1}\tau^*_s}{(1+E_{t-1}\tau^*_s)}\right]\end{aligned} \tag{31c}$$

where we focus on Home and present the responses in a form to facilitate comparison with the flexible price case. In all cases, the responses depend upon the actual tariffs and the extent to which they are anticipated and expected to be permanent.

Equation (31a) indicates that the response of the aggregate price index can be decomposed into three components. First, to the extent that an increase in the current tariff (at time t) was unanticipated in the previous period, ($t-1$), it will lead to an increase in the current aggregate price index. Second, the current aggregate price will respond negatively to the discounted sum of all expected future tariff *changes*. This term is analogous to (23a), the only difference being that with prices being pre-set, expectations are now formed at time ($t-1$). The third is the discounted sum of revisions to expected future tariff differentials across the two economies. It represents an "updating of expectations" between periods ($t-1$) and t, as new information is revealed through the current exchange rate, and arises from the exchange rate pass-through, associated with the fact that producers are adopting PCP. Equation (31b) indicates that the nominal exchange rate itself appreciates in response to anticipated and unanticipated Home-Foreign tariff differentials. Finally, the response of consumption, (31c), also has three effects, the first of which is the "direct effect" identical to that obtained under flexible pricing. The remaining two terms measure updates to their expectations of future tariffs imposed by both Home and Foreign as between times ($t-1$) and t. An unanticipated increase in either domestic or foreign tariffs will lead to a decline in domestic consumption. Unsurprisingly, domestic consumption is more sensitive to expected future increases in Home tariffs rather than to Foreign.

More intuitively, firms seek to dampen the impact of tariffs on consumption, and thereby on their profit. Thus, in period $t-1$, they reduce prices in response to the anticipated imposition of tariffs in order to offset these possible adverse effects on their demand. With goods prices being preset, the current tariff is directly applied to the import prices without further adjustment of goods prices by firms. Thus the unanticipated imposition of current and future tariff changes, which have not been reflected in the pricing, will affect consumption. While Foreign firms also act to lower their prices in response to anticipated tariffs, unanticipated Home and Foreign tariff gaps, which have not been previously responded to, also drive the exchange rate movement which helps remove the arbitrage opportunity from the international capital market. The exchange rate movement thus passes the Home-Foreign tariff differences on to aggregate price and consumption.

While there is complete exchange rate pass-through under both flexible prices and PCP, the comparison between Equations (23), (25) and (30) under the former, and Equation (31) under the latter, demonstrates the difference between flexible prices and nominal rigidity. With the complete flexibility of goods prices, the relative home and foreign goods price will remain completely insulated from the tariffs as shown by Equation (18). The effects of tariffs on the aggregate price level and consumption in that case are due solely to the direct impact of the current tariff, and, as noted previously, are identical whether the tariffs are anticipated or unanticipated, permanent or temporary. However, under nominal rigidity, the price preset prior to the consumption decision making and thus the impact of the tariff on the consumption depends on whether or not the tariffs are anticipated. If so, firms will be able to respond, and the exchange rate movement will dampen the tariff difference embodied in the predetermined prices. But if the tariff is unanticipated, in addition to their direct effects, the imposition of current tariffs will lead to an exchange rate adjustment, and this will dampen the direct effect on consumption and the aggregate price index. Because producer prices fail to adjust, the impact of the tariff, if unanticipated, can be greater than that under flexible prices. As a result, the effects of tariffs will be identical under flexible prices and PCP if fully anticipated, but differ otherwise.

3.4.2. LCP

The solutions for aggregate prices, consumption and exchange rate under LCP pricing are reported in equations (A.28), (A.29), and (A.30) of the online Appendix. Taking differentials of these equations yields the corresponding responses:

$$\frac{\mathrm{d}P_t^{\mathrm{LCP}}}{P_t^{\mathrm{LCP}}} = \frac{\gamma}{2}\left\{\left(\frac{\mathrm{d}\tau_t}{1+\tau_t} - \frac{\mathrm{d}E_{t-1}\tau_t}{1+E_{t-1}\tau_t}\right) - \sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\left(\frac{\mathrm{d}E_{t-1}\tau_{s+1}}{1+E_{t-1}\tau_{s+1}} - \frac{\mathrm{d}E_{t-1}\tau_s}{1+E_{t-1}\tau_s}\right)\right\} \tag{32a}$$

$$\frac{d\mathcal{E}_t^{LCP}}{\mathcal{E}_t^{LCP}} = -\frac{\gamma\omega}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s+1-t}\left(\frac{dE_{t-1}\tau_s}{1+E_{t-1}\tau_s}-\frac{dE_{t-1}\tau_s^*}{1+E_{t-1}\tau_s^*}\right) - \frac{\gamma\omega}{2}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\left(\frac{dE_t\tau_s}{1+E_t\tau_s}-\frac{dE_t\tau_s^*}{1+E_t\tau_s^*}\right)-\left(\frac{dE_{t-1}\tau_s}{1+E_{t-1}\tau_s}-\frac{dE_{t-1}\tau_s^*}{1+E_{t-1}\tau_s^*}\right)\right] \tag{32b}$$

$$\frac{dC_t^{LCP}}{C_t^{LCP}} = -\frac{\gamma}{2\rho}\frac{d\tau_t}{(1+\tau_t)}-\frac{\gamma\omega}{2\rho}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau_s}{(1+E_t\tau_s)}-\frac{dE_{t-1}\tau_s}{(1+E_{t-1}\tau_s)}\right] \tag{32c}$$

In the absence of exchange rate pass-through, both Home aggregate price and consumption remain insulated from the impacts of the Foreign tariff. In both cases, only the first two effects identified above in connection with PCP are operative. As in that case, firms under LCP also attempt to lower prices to dampen the negative impact of the tariff on consumption. While the tariff is imposed at period t after the goods prices are predetermined, the unanticipated current tariff, which the firms do not anticipate, will lead to higher aggregate prices and reduce the consumption. With no exchange rate pass-through, the effect of an unanticipated permanent tariff on consumption under LCP can be greater than that under PCP.

Of these results, we view the consumption responses as most pertinent and summarize them in the following:

Proposition 1: Under both PCP and LCP a Home tariff has a contractionary effect on the Home aggregate consumption index, identical to that obtained under flexible prices. In addition, to the extent that anticipations of future tariffs are updated between periods $(t-1)$ and t, it has a further adverse effect. Under PCP a Foreign tariff has a similar negative updating effect, although the absence of exchange rate pass-through under LCP ensures that in that case Home aggregate consumption is insulated from this effect.

4. Impact on outputs under nominal rigidities

4.1. Output under PCP

The components of Home production under PCP are obtained by substituting (28b) into (16) to yield

$$\begin{aligned}\left(Y_{H,t}+Y_{N,t}\right)^{\mathrm{PCP}} &= \left(1-\frac{\gamma}{2}\right)\left(\frac{P_t}{P_{H,t}}\right)C_t^{\mathrm{PCP}} \\ &= \left(1-\frac{\gamma}{2}\right)(1+\tau_t)^{\frac{\gamma(2-\gamma)}{4(1-\gamma)}}\left(1+\tau_t^*\right)^{-\frac{\gamma^2}{4(1-\gamma)}}\left(C_t^{\mathrm{PCP}}\right)^{\frac{\gamma\rho}{2(1-\gamma)}+1}\left(C_t^{*\mathrm{PCP}}\right)^{-\frac{\gamma\rho}{2(1-\gamma)}}\end{aligned} \tag{33a}$$

$$\begin{aligned}Y_{H,t}^{*\mathrm{PCP}} &= \frac{\gamma}{2}\left(\frac{P_t^*}{(1+\tau_t^*)P_{H,t}^*}\right)C_t^{*PCP} \\ &= \frac{\gamma}{2}(1+\tau_t)^{\frac{\gamma(2-\gamma)}{4(1-\gamma)}}\left(1+\tau_t^*\right)^{-\frac{(2-\gamma)^2}{4(1-\gamma)}}\left(C_t^{\mathrm{PCP}}\right)^{\frac{\rho(2-\gamma)}{2(1-\gamma)}}\left(C_t^{*\mathrm{PCP}}\right)^{1-\frac{\rho(2-\gamma)}{2(1-\gamma)}}\end{aligned} \tag{33b}$$

Taking differentials of these two equations and substituting for (31c) and the analogous expression for Foreign, we can obtain the effects of the tariffs on Home output:

$$\begin{aligned}\frac{d\left(Y_{H,t}+Y_{N,t}\right)^{PCP}}{\left(Y_{H,t}+Y_{N,t}\right)^{PCP}} =& \frac{\gamma(\rho-1)}{2\rho}\frac{d\tau_t}{(1+\tau_t)} \\ &-\frac{\gamma\omega[2-\gamma+\gamma\omega+\rho\gamma]}{4\rho(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau_s}{(1+E_t\tau_s)}-\frac{dE_{t-1}\tau_s}{(1+E_{t-1}\tau_s)}\right] \\ &+\frac{\gamma^2\omega[\rho-(1+\omega)]}{4\rho(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau_s^*}{(1+E_t\tau_s^*)}-\frac{dE_{t-1}\tau_s^*}{(1+E_{t-1}\tau_s^*)}\right]\end{aligned} \tag{34a}$$

$$\frac{dY_{H,t}^{*PCP}}{Y_{H,t}^{*PCP}} = -\left(\frac{\rho(2-\gamma)+\gamma}{2\rho}\right)\frac{d\tau_t^*}{(1+\tau_t^*)}$$

$$-\frac{\gamma\omega[\rho(2-\gamma)+\gamma(1+\omega)]}{4\rho(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau_s}{(1+E_t\tau_s)}-\frac{dE_{t-1}\tau_s}{(1+E_{t-1}\tau_s)}\right] \tag{34b}$$

$$+\frac{\gamma\omega[\rho(2-\gamma)-(2-\gamma+\gamma\omega)]}{4\rho(1+\gamma\omega)}\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{dE_t\tau_s^*}{(1+E_t\tau_s^*)}-\frac{dE_{t-1}\tau_s^*}{(1+E_{t-1}\tau_s^*)}\right]$$

The first terms in Equations (34a) and (34b) are precisely the direct effects obtained under flexible prices, reported in (22a) and (22b), to which the previous comments regarding their expansionary and contractionary components apply. But in addition, (34a) and (34b) now include terms summarizing the updating of future tariff expectations between time $(t-1)$ and t. The updating term applying to the Home tariff has an unambiguously negative impact on both components of Home production. This is because the reduction in Home consumption, due to a previously unanticipated tariff is reinforced by an appreciation of the Home currency, thereby reducing Foreign demand for Home output. In contrast, in both (34a) and (34b), the updating term applicable to the Foreign tariff is ambiguous. In this case the contractionary impact on consumption is now offset by an expansionary effect due to the depreciation of the Home currency, arising from the exchange rate pass-through. The net effect involves a tradeoff between the taste parameters, ρ and γ, and the intensity of monetary policy in response to the price level, ω.

4.2. Output under LCP

Analogously, substituting (30) into (16), the two components of Home demand and Foreign demand for Home output under LCP can be expressed as follows:

$$\left(Y_{H,t}+Y_{N,t}\right)^{\mathrm{LCP}} = \left(1-\frac{\gamma}{2}\right)\left(\frac{P_{H,t}}{(1+\tau_t)P_{F,t}}\right)^{-\frac{\gamma}{2}}C_t^{\mathrm{LCP}} = \left(1-\frac{\gamma}{2}\right)(1+\tau_t)^{\frac{\gamma}{2}}\frac{E_{t-1}(C_t/A_t)}{E_{t-1}(C_t/A_t^*)}C_t^{\mathrm{LCP}} \tag{35a}$$

$$Y_{H,t}^{*\mathrm{LCP}} = \frac{\gamma}{2}\left(\frac{(1+\tau_t^*)P_{H,t}^*}{P_{F,t}^*}\right)^{\frac{\gamma}{2}-1}C_t^{*\mathrm{LCP}} = \frac{\gamma}{2}(1+\tau_t^*)^{\frac{\gamma}{2}-1}\frac{E_{t-1}(C_t^*/A_t)}{E_{t-1}(C_t^*/A_t^*)}C_t^{*\mathrm{LCP}} \tag{35b}$$

Noting the log-linearity C_t, C_t^*, A_t, A_t^* and taking expected values, the effects of tariffs on the Home output can be written as:

$$\begin{aligned}\frac{d\left(Y_{H,t}+Y_{N,t}\right)^{\mathrm{LCP}}}{\left(Y_{H,t}+Y_{N,t}\right)^{\mathrm{LCP}}} &= \frac{\gamma}{2}\frac{\mathrm{d}\tau_t}{(1+\tau_t)}+\frac{\mathrm{d}C_t^{\mathrm{LCP}}}{C_t^{\mathrm{LCP}}}\\ &= \frac{\gamma(\rho-1)}{2\rho}\frac{\mathrm{d}\tau_t}{1+\tau_t}-\frac{\gamma\omega}{2\rho}\left\{\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{\mathrm{d}E_t\tau_s}{1+E_t\tau_s}-\frac{\mathrm{d}E_{t-1}\tau_s}{1+E_{t-1}\tau_s}\right]\right\}\end{aligned} \tag{36a}$$

$$\begin{aligned}\frac{\mathrm{d}Y_H^{*\mathrm{LCP}}}{Y_{H,t}^{*\mathrm{LCP}}} &= \left(\frac{\gamma}{2}-1\right)\frac{\mathrm{d}\tau_t^*}{(1+\tau_t^*)}+\frac{dC_t^{*LCP}}{C_t^{*LCP}}\\ &= -\left[\frac{\rho(2-\gamma)+\gamma}{2\rho}\right]\frac{\mathrm{d}\tau_t^*}{1+\tau_t^*}-\frac{\gamma\omega}{2\rho}\left\{\sum_{s=t}^{\infty}\left(\frac{1}{1+\omega}\right)^{s-t}\left[\frac{\mathrm{d}E_t\tau_s^*}{1+E_t\tau_s^*}-\frac{\mathrm{d}E_{t-1}\tau_s^*}{1+E_{t-1}\tau_s^*}\right]\right\}\end{aligned} \tag{36b}$$

As in the PCP case, the first items in (36a) and (36b) are the direct effects obtained under flexible pricing, while the second is the "updating of expectations effect". But in contrast to PCP, the absence of

exchange rate pass-through leaves the domestic demand for the Home goods insulated from the impact of Foreign tariffs, and the Home exports independent of the Home tariff. Moreover, (36b) shows that the Foreign tariff, whether or not anticipated, will have an unambiguously negative effect on the Home exports. In this case the contractionary effect of the updating term arises from the absence of exchange rate pass-through under LCP. Under PCP, the exchange rate movement helps remove the price discrepancy in these two countries and makes the law of one price hold for the tradable goods sold in both countries.[24] This mechanism is absent under LCP. As a result, there is a direct negative effect of the Foreign tariff on Foreign demand due to higher import prices in Foreign which cannot be eliminated without exchange rate adjustment. We may summarize the output responses in:

Proposition 2: Under both PCP and LCP Home and Foreign tariffs have direct effects on the components of Home output, identical to those operating under flexible prices. In addition, to the extent that anticipations of future tariffs are updated between periods $(t-1)$ and t, under PCP both Home and Foreign tariffs impact both the domestically consumed and the exported components of Home output. In contrast, the absence of exchange rate pass-through under LCP ensures that in that case, domestic consumption of Home output is independent of Foreign tariff and Home exports are independent of the Home tariff.

5. Alternative tariff policies

In this section, we compare the effects of tariffs for two polar cases. Focusing on these extremes helps elucidate the contrasting effects of tariffs under flexible and sticky prices, and the role of exchange rate pass-through.

5.1. Anticipated permanent increase in tariff

We begin by considering a permanent constant increase in the tariff that is announced at time $(t-1)$ to take effect at time t, and is therefore anticipated at the time it takes effect. We specify this formally as follows:

$$E_{t-1}\mathrm{d}\tau_s = E_t\mathrm{d}\tau_s = \mathrm{d}\tau_s = \mathrm{d}\tau,$$

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

Substituting these specifications of the tariff policy into the solutions outlined in previous sections, we obtain the solutions under anticipated permanent tariffs. The effects of anticipated permanent tariffs for the three alternative pricing rules on the macroeconomic variables are reported in Table 2. In the polar case where a constant permanent increase in the tariff is fully anticipated, and there is therefore no updating of expectations, we find that its effects on the economy are identical under all three pricing schemes we have considered. In these circumstances a tariff has no effects on the aggregate price level, and has identical proportionate effects on consumption. That is, in all such cases, a tariff imposed by Home reduces Home consumption, but has no effect on Foreign consumption. The effects on output all reduce to the direct effects that we have identified.

But despite the fact that the effects of anticipated permanent tariffs on overall price level and consumption are identical under flexible price and PCP, the adjustment mechanisms differ. While there is complete exchange rate pass-through under PCP, the exchange rate moves to remove any pre-determined price discrepancy to make aggregate price level identical to that under flexible prices.

The adjustment mechanisms under PCP and LCP also differ. The contrast can be seen by comparing the movements in the terms of trade under the two pricing schemes. Under PCP, the current exchange rate movement drives a wedge between the ex ante and ex post terms of trade. From the risk-sharing condition, (13), the ex post Home terms of trade (TOT) (expressed in logarithms) can be shown to be:

[24] This is the case assumed in most of the existing theoretical literature.

Table 2
Macroeconomic variables under anticipated permanent tariffs.

	Flexible price[a], PCP, LCP
$\frac{dP_t/P_t}{d\tau_t/(1+\tau_t)}$	0
$\frac{dP_t/P_t}{d\tau_t^*/(1+\tau_t^*)}$	0
$\frac{d\mathcal{E}_t/\mathcal{E}_t}{d\tau_t/(1+\tau_t)}$	$-\frac{\gamma}{2}<0$
$\frac{d\mathcal{E}_t/\mathcal{E}_t}{d\tau_t^*/(1+\tau_t^*)}$	$\frac{\gamma}{2}>0$
$\frac{dC_t/C_t}{d\tau_t/(1+\tau_t)}$	$-\frac{\gamma}{2\rho}<0$
$\frac{dC_t/C_t}{d\tau_t^*/(1+\tau_t^*)}$	0
$\frac{dY_t/Y_t}{d\tau_t/(1+\tau_t)}$	$\varphi\frac{\gamma(\rho-1)}{2\rho}$
$\frac{dY_t/Y_t}{d\tau_t^*/(1+\tau_t^*)}$	$-(1-\varphi)\left[\left(1-\frac{\gamma}{2}\right)+\frac{\gamma}{2\rho}\right]<0$
$\frac{dU_t}{d\tau_t/(1+\tau_t)}$	$-\frac{\gamma}{2\rho}\left[C^{1-\rho}+\frac{\kappa Y}{A}\varphi(\rho-1)\right]$
$\frac{dU_t}{d\tau_t^*/(1+\tau_t^*)}$	$\frac{\kappa A}{Y}(1-\varphi)\left[\left(1-\frac{\gamma}{2}\right)+\frac{\gamma}{2\rho}\right]>0$

Note: $\varphi\equiv\frac{Y_H+Y_N}{Y};\ 1-\varphi\equiv\frac{Y_H^*}{Y}$.

[a] Responses under flexible prices also apply to unanticipated tariff changes.

$$\mathrm{TOT}^{\mathrm{PCP}} = \ln\mathcal{E}_t + p_{F,t}^* - p_{H,t} = \frac{\gamma}{2(1-\gamma)}\ln\left(\frac{1+\tau}{1+\tau^*}\right) + \frac{\rho}{1-\gamma}c_t - \frac{\rho}{1-\gamma}c_t^* \tag{37a}$$

However, because under LCP the exchange rate pass-through effect is absent, the ex ante and ex post Home terms of trade are identical and can be described directly by the optimal pricing in Table 1:

$$\mathrm{TOT}^{\mathrm{LCP}} = p_{F,t} - p_{H,t} = E_{t-1}(a_t - a_t^*) + \sigma_{ca} - \sigma_{ca^*} \tag{37b}$$

where $\sigma_{ca}, \sigma_{ca^*}$ denote covariances. Comparing (37a) and (37b), we see that the terms of trade under PCP reflects the current information that consumption embodies, while the terms of trade under LCP contains only the information that is known from the previous period.

In response to a permanent tariff, PCP firms act like firms under flexible prices where the exchange rate has complete pass-through. Home exporters reduce prices due to the Foreign tariff, and Foreign firms respond to the Home tariff. As discussed in the flexible price case, the ex ante price discrepancy caused by the tariffs has to be offset by the exchange rate movement. After substituting the solutions of consumption from (A.21) into (37a), we can see that the tariff does not affect the ex post terms of trade under PCP.

In contrast, under LCP where the exchange rate pass-through is absent, neither Home nor Foreign firms will reduce their prices because of the tariff. In the absence of the exchange rate adjustment, the ex ante price discrepancy caused by the tariff, which in turn causes the ex post price discrepancy creating the potential arbitrage opportunity, does not exist. The adjustment relies on the optimal pricing of firms, rather than exchange rate movements. Thus, the terms of trade remains insulated from the tariff.

While we have focused on how the anticipated tariffs impact key economic variables, a key issue is their overall welfare effects, as measured by the utility function (10). Given that prices are either perfectly flexible or can be re-set every period and there are no other sources of dynamics (such as capital accumulation), these can be assessed by substituting the consumption and equilibrium labor supply into the one-period utility measure, namely[25]

[25] Also relevant is the fact that the tariffs are permanent. Temporary tariffs would have differential effects at different points of time and their welfare effects would therefore need to be evaluated in terms of intertemporal utility.

$$U = \frac{1}{1-\rho}C^{1-\rho} - \frac{\kappa}{A}Y$$

and taking differentials to obtain

$$dU = C^{1-\rho}\frac{dC}{C} - \frac{\kappa Y}{A}\frac{dY}{Y} \tag{38}$$

The resulting effects, obtained by substituting the consumption and output responses are reported in the final panel of Table 2. There it is seen that the Home tariff will reduce Home welfare in the more plausible case where the intertemporal elasticity of substitution is less than one (i.e. $\rho > 1$), while its net impact on welfare is ambiguous if $\rho < 1$. In the former case, the expansionary effect of the Home tariff on output also raises the disutility of employment, reinforcing the welfare loss due to reduced consumption. In the latter case, the welfare improvement from reduced employment due to the contractionary effect on output will offset the lower consumption caused by tariff. Thus, which effect dominates relies on the relative magnitudes of preference parameters. In contrast, the Foreign tariff raises Home welfare under all three pricing schemes. The imposition of Foreign tariff benefits the Home economy from its contractionary effect on the Home output which reduces Home employment and the disutility this imposes.[26] We may summarize these in the following:

Proposition 3: The responses of the economy to an anticipated permanent tariff are the same under all three types of pricing schemes. In particular:

(i) The aggregate price index is insulated from both the Home and Foreign tariff.
(ii) Home consumption is reduced by the Home tariff but is independent of the Foreign tariff.
(iii) The Home tariff is expansionary (contractionary) for Home output when the elasticity of intertemporal substitution is less (greater) than unity; the Foreign tariff is contractionary for Home production.
(iv) The Home tariff is welfare-improving if the intertemporal elasticity of substitution is less than unity. Its effect on welfare will depend on preference parameters if the intertemporal elasticity of substitution is greater than unity. The Foreign tariff always improves Home economy welfare.

5.2. Unanticipated permanent tariff

The three pricing schemes lead to dramatically diverging effects for tariffs when they are unanticipated. Suppose that a permanent tariff increase is imposed at time t without prior announcement. Thus, the tariff structure can be stated as follows:

$$E_{t-1}\mathrm{d}\tau_s = E_{t-1}\mathrm{d}\tau_s^* = 0,\ \forall s < t,$$

$$E_t\mathrm{d}\tau_s = \mathrm{d}\tau_s = \mathrm{d}\tau,\ E_t\mathrm{d}\tau_s^* = \mathrm{d}\tau_s^* = \mathrm{d}\tau^*,\ \forall s \geq t$$

Because the flexible–price equilibrium can adjust instantaneously to the current tariff that is in effect, it does not matter when the policy is announced. The responses of macroeconomic variables are identical whether the permanent tariff is anticipated or unanticipated and remain as reported in Table 1. In contrast, the timing of the policy announcement is critical under nominal rigidity where prices are determined in advance. The results of the tariffs' effects under PCP and LCP are reported in Table 3.

By comparing the effects of tariffs on price, consumption, and exchange rate under flexible prices and PCP, we can see that the magnitude of (both Home and Foreign) tariffs' effects (whether positive or negative) on these three variables under PCP is greater than those under flexible prices. While prices

[26] The fact that an anticipated permanent Foreign tariff always benefits the Home economy may seem counterintuitive and merits further comment. It reflects the fact its impact on Home consumption is eliminated, either by the exchange rate movement or optimal pricing of firms. As a result, the Home country purely benefits from the reduced disutility of labor supply. However, if Foreign tariffs have a negative effect on the Home consumption, as in the unanticipated tariff in Section 6.2, whether or not the Foreign tariff benefits Home country depends on which effect dominates.

Table 3
Macroeconomic variables under unanticipated permanent tariffs.

	PCP	LCP
$\frac{dP_t/P_t}{d\tau_t/(1+\tau_t)}$	$\frac{\gamma(2-\gamma+\gamma\omega)}{4(1+\gamma\omega)}>0$	$\frac{\gamma}{2}>0$
$\frac{dP_t/P_t}{d\tau_t^*/(1+\tau_t^*)}$	$\frac{\gamma^2(1+\omega)}{4(1+\gamma\omega)}>0$	0
$\frac{d\mathcal{E}_t/\mathcal{E}_t}{d\tau_t/(1+\tau_t)}$	$-\frac{\gamma(1+\omega)}{2(1+\gamma\omega)}<0$	$-\frac{\gamma}{2}(1+\omega)<0$
$\frac{d\mathcal{E}_t/\mathcal{E}_t}{d\tau_t^*/(1+\tau_t^*)}$	$\frac{\gamma(1+\omega)}{2(1+\gamma\omega)}>0$	$\frac{\gamma}{2}(1+\omega)$
$\frac{dC_t/C_t}{d\tau_t/(1+\tau_t)}$	$-\left[\frac{\gamma}{2\rho}+\frac{\gamma(2-\gamma+\gamma\omega)(1+\omega)}{4\rho(1+\gamma\omega)}\right]<0$	$-\frac{\gamma}{2\rho}\left(2+\omega\right)<0$
$\frac{dC_t/C_t}{d\tau_t^*/(1+\tau_t^*)}$	$-\frac{\gamma^2(1+\omega)^2}{4\rho(1+\gamma\omega)}<0$	0
$\frac{dY_t/Y_t}{d\tau_t/(1+\tau_t)}$	$-\frac{\gamma(1+\omega)}{4\rho(1+\gamma\omega)}[(2-\gamma)\rho+\gamma(1+\omega)]$ $+\varphi\left(\rho-1\right)\frac{\gamma(\omega+2-\gamma)}{2\rho(1+\gamma\omega)}$	$\varphi\frac{\gamma}{2\rho}[\rho-2-\omega]$
$\frac{dY_t/Y_t}{d\tau_t^*/(1+\tau_t^*)}$	$-\frac{\gamma(1+\omega)}{4\rho(1+\gamma\omega)}[-\gamma\rho+\gamma(1-\omega)]$ $-(1-\varphi)\left\{\left(1-\frac{\gamma}{2}\right)+\frac{\gamma}{2}\left[1-\frac{\rho-1}{\rho}\frac{\gamma(\omega+2-\gamma)}{1+\gamma\omega}\right]\right\}$	$-\left(1-\varphi\right)\left[\left(1-\frac{\gamma}{2}\right)+\frac{\gamma}{2\rho}\left(2+\omega\right)\right]<0$
$\frac{dU_t}{d\tau_t/(1+\tau_t)}$	$-\frac{\gamma}{2\rho}\left\{C^{1-\rho}\left[1+\frac{(2-\gamma+\gamma\omega)(1+\omega)}{2(1+\gamma\omega)}\right]\right.$ $-\frac{\kappa Y}{A}\frac{1}{1+\gamma\omega}\left\{\frac{(1+\omega)}{2}[(2-\gamma)\rho\right.$ $\left.\left.+\gamma(1+\omega)]-\varphi\left(\rho-1\right)\left(\omega+2-\gamma\right)\right\}\right\}$	$-\frac{\gamma}{2\rho}\left[C^{1-\rho}(2+\omega)+\frac{\kappa Y}{A}\varphi(\rho-2-\omega)\right]$
$\frac{dU_t}{d\tau_t^*/(1+\tau_t^*)}$	$-\frac{\gamma}{2\rho}\left\{C^{1-\rho}\frac{\gamma(1+\omega)^2}{2(1+\gamma\omega)}+\frac{\kappa Y}{A}\left\{\frac{\gamma(1+\omega)}{2(1+\gamma\omega)}[\rho-1-\omega]\right.\right.$ $\left.\left.+(1-\varphi)\left[(\rho-1)\frac{\gamma(\omega+2-\gamma)}{2\rho(1+\gamma\omega)}-1\right]\right\}\right\}$	$\frac{\kappa Y}{A}\frac{(1-\varphi)}{2\rho}[(2-\gamma)\rho+\gamma(2+\omega)]\rangle 0$

Note: $\varphi\equiv\frac{Y_H+Y_N}{Y}$; $1-\varphi\equiv\frac{Y_H^*}{Y}$.

can adjust with the current policy shock under flexible prices to completely remove the distortions generated by the tariffs, exchange rate movements also help in this regard. Under PCP, however, an unanticipated tariff policy is not taken into account in the price, preset at time $t-1$. Thus, the imposition of a current tariff, which nonetheless is dampened by exchange rate movement driven by unanticipated tariff policy, will result in higher aggregate price level under PCP. This in turn reduces consumption more under the nominal rigidity of PCP than under flexible prices.

Furthermore, the effects of tariffs on price and consumption are greater under LCP than under PCP. This is because in the absence of pass-through of exchange rate appreciation under LCP, firms fail to reduce prices ahead of the imposition of tariffs, as they would under PCP. Consequently the tariff will directly raise the aggregate price level, and thereby reduce consumption.

The effects of tariffs on output and welfare under PCP rely crucially on the market structure of the economy, in particular the relative importance of exports in total production, as measured by $(1-\varphi)$ where $\varphi = (Y_H + Y_N)/Y$. Under PCP, the Home tariff has a direct positive (negative) protective effect on domestic output and offsetting indirect negative effects that operate through the responses in domestic and foreign consumption. If $\rho < 1$, the contractionary effects of both Home and Foreign tariffs dominate. If

$\rho > 1$, it is possible for the tariffs to be expansionary, depending upon tradeoffs between ω,γ and φ. Under LCP, the Home tariff is expansionary if $\rho > 2+\omega$, but contractionary if $\rho < 2+\omega$. We may also note that it is possible for the domestic tariff to be expansionary under LCP, but contractionary under PCP. This will occur if $\rho > 2+\omega$ and the share of domestic consumption in Home output, ϕ is sufficiently small.

The welfare effects involve the tradeoff between consumption and output (employment). These are summarized in the last panel of Table 3 and, given the conflicting adjustments of consumption and output in the face of unanticipated tariff changes, are themselves complex and may generate a diversity of responses, depending upon the relative magnitudes of the underlying taste and production parameters, as well as the intensity of monetary policy. But the fact that consumption is independent of the Foreign tariff implies that the decline in employment (output) resulting from a higher Foreign tariff is welfare-improving. We summarize the key results in the following:

Proposition 4: The effects of unanticipated tariffs on the economy are highly sensitive to the pricing of exports and can have dramatically diverse effects on all variables, including overall welfare. In particular, the effects of unanticipated Home tariff policies on Home price, consumption, and exchange rate are smaller under flexible prices than under PCP, and smaller under PCP than under LCP. Whether an unanticipated tariff has an expansionary or contractionary effect on output is sensitive to the tradeoffs involving taste, production, and monetary policy parameters. It is also possible for a Home tariff to be expansionary under LCP but contractionary under PCP, and conversely for the Foreign tariff.

6. Conclusion

Empirical evidence has suggested the widespread practice of both producer-currency pricing and local-currency pricing. In view of this, this paper has investigated the effects tariffs on an economy under LCP, comparing its effects to those implied by the more widely adopted assumption of PCP. We have employed a two-country DSGE model and assumed that both countries levy a permanent tariff which drives the long-term exchange rate movement.

Our main general conclusion is that the significance of export pricing for the effects of tariffs depends critically upon whether the tariffs are anticipated or unanticipated. In the former case both PCP and LCP yield the same outcome as do perfectly flexible prices, although the mechanisms whereby this is achieved are different. Under PCP it occurs through exchange rate adjustments, while under LCP it is the result of direct pricing decisions by exporters. In contrast, the effects of unanticipated permanent tariffs are highly sensitive to the pricing scheme adopted by exporters, leading to a wide range of conflicting outcomes, many involving tradeoffs among key parameters, and confirming that the form of pricing adopted by exporters is indeed potentially important in assessing the effects of tariffs.

Several interesting issues remain for future research. As Mundell (1961) originally suggested, the macroeconomic effects of tariffs depend upon the exchange rate regime in effect. Thus a first issue would be to examine the sensitivity of the effects of tariffs to the pricing schemes we have considered, under alternative exchange rate regimes. Second, the fact that different pricing schemes generate different degrees of spillovers of tariffs abroad suggests that comparing the potential for strategic tariff-setting under the alternative pricing schemes would be of interest. Finally, our model is based on the simplest production structure, and in particular excludes capital. Since much of the international macro literature emphasizes the role of capital accumulation, it would be interesting (and challenging) to develop a more general DSGE model with capital accumulation under alternative degrees of exchange rate pass-through, thereby re-examining the issues addressed in this paper from a more complete dynamic perspective.

Appendix A. Supplementary data

Supplementary data related to this article can be found athttp://dx.doi.org/10.1016/j.jimonfin.2012.10.004.

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國科會補助計畫衍生研發成果推廣資料表

日期:2013/10/31

國科會補助計畫	計畫名稱: 小型開放經濟體系下之政府公債與最適貨幣政策及財政政策
	計畫主持人: 黃俞寧
	計畫編號: 101-2410-H-004-016- 學門領域: 國際經濟學

無研發成果推廣資料

101 年度專題研究計畫研究成果彙整表

計畫主持人：黃俞寧	計畫編號：101-2410-H-004-016-
計畫名稱：小型開放經濟體系下之政府公債與最適貨幣政策及財政政策	

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	1	1	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	2	2	100%		
		博士後研究員	0	0	100%		
		專任助理	1	1	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
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		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

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請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

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本研究是在一小型開放的動態隨機一般均衡模型（DSGE）下探討政府公債政策的總體經濟效果。本文主要專注在探討在不同的經濟開放程度下，debt-GDP 比例的改變對於經濟體系面對外在衝擊的反應會有甚麼樣的影響。研究的結果發現，debt-GDP 比例的改變將使政府財政政策(稅與政府支出)產生相應變動。在一開放程度較低的國家，其對於國內經濟會有較大的影響，而導致較為劇烈的總體經濟變動。此一研究，於實務上，可以幫助我們瞭解在一開放經濟體系之下，政府的公債政策會造成甚麼樣的總體經濟變動，有助於幫助我們了解現今許多國家面對的高債務危機，以及台灣作為一個小型開放經濟體系，其公債政策應該如何施行。於學術面，此一模型可以更進一步幫助我們瞭解公債與財政政策的總體效果以進行更進一步的研究。