Is Openness Inflationary? Imperfect Competition and Monetary Market Power *

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Abstract

This paper highlights a channel through which increased openness to international trade results in increased inflation. I use a two-country model in which a degree of inelasticity in consumer demand for both domestic and foreign goods allows a monetary authority to export some of the inflation tax from money creation. I also find that the level of imperfect competition among producers within a country is a perfect substitute for the international market power of the monetary authority in extracting the monopoly rents available in this international structure.

keywords: Optimal Monetary Policy; Imperfect Competition; International Monetary Policy

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1 Introduction

This paper highlights a channel through which increased openness to international trade results in increased inflation. I find that a monetary authority has an increased incentive to create money when the country is more open to international trade because the inflation tax can be exported to foreign holders of the domestic currency. I also find that the level of imperfect competition among producers within a country is a perfect substitute for the international market power of the monetary authority in extracting monopoly rents available in this international structure. Put another way, whatever rents are not captured by the firms within each country are captured by the actions of the country's monetary authority.

The economic environment is a two-country general equilibrium model in which monetary authorities choose their respective money growth rates in order to maximize the lifetime utility of the representative household. The key assumptions that drive the results in this paper are that consumers have preferences for both domestic and foreign goods, producers have some degree of market power, and monetary authorities have a degree of international market power because transactions must occur in the currency of the producer.

The positive effect of openness on inflation described in this paper runs counter to much of the previous work on this question. This new result is not surprising given that the approach taken in this paper has three key augmentations to the standard theoretical work on openness and inflation. The model in this paper characterizes the objective of the monetary authority as maximizing the utility of domestic households instead of a quadratic loss function in output and prices. Also, the aggregate supply relationship here is the sum of all the production in the economy rather than an assumed Phillips curve relationship. Lastly, the characterization of imperfect competition is the Dixit-Stiglitz (1977) differentiated goods model of monopolistic competition, which is more highly specified than most of the previous openness and inflation literature.

The relationship between openness and inflation has been the subject of a large body of research beginning as early as Triffin and Grubel (1962). Using data from six European countries during the 1950s, they provide evidence that inflationary pressures are more correlated, and thus less independent, across countries that are more integrated.

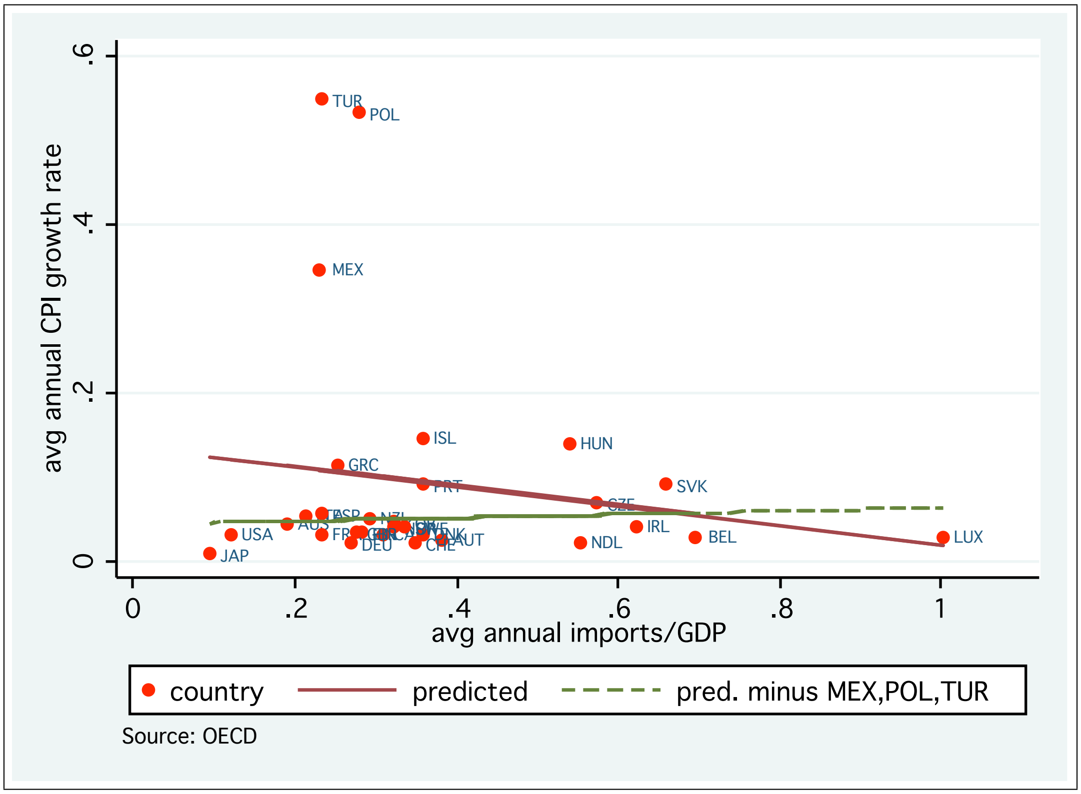
The first structural model directly addressing the question of openness and inflation is Rogoff (1985), and it is still the most cited theoretical foundation for questions about openness and inflation. His approach is to extend the Barro and Gordon (1983) framework to a two-country Mundell-Fleming model. As in Barro and Gordon, a labor market friction causes the optimal time-consistent policy of the monetary authority to be increased inflation in order to raise the level of employment. However, in Rogoff's international version, the increased inflation has an extra cost in that optimal employment is a function of the real exchange rate and that the real exchange rate depreciates with higher inflation. Thus the optimal time-consistent inflation rate chosen by a monetary authority is lower as the deteriorating effect on the exchange rate increases. More openness leads to a lower equilibrium inflation rate in this time-consistent environment.

The empirical literature testing the effect of openness on inflation primarily cites the model and conclusions of Rogoff (1985). The most important empirical paper that addresses this question is Romer (1993). He cites the Rogoff prediction that, in his time-consistent environment, more openness should lead to lower inflation. In his regressions, Romer controls for endogeneity, includes political controls, development level controls, regional controls, and uses many different samples of countries over the post-Bretton Woods period from 1973 to the early 1990s. Romer's empirical findings lend support to the theoretical results of Rogoff (1985) in that he finds robust evidence of a negative relationship between openness and inflation and that the negative relationship becomes weaker in countries with less independent central banks and more political instability.[1]

Figure 1 shows a scatterplot of the average annual import share and average

[1]A number of empirical papers follow up on Romer (1993), and most either confirm his finding of a negative relationship or find that the relationship is not statistically significant. Wynne and Kersting (2007) is a good survey of the empirical literature and includes some original analysis.

Figure 1: Import share vs. CPI for 30 OECD countries: annual avg. for 1982 to 2005



annual CPI growth rate for the 30 OECD countries over the period from 1982 to 2005. This picture is similar to figures in Romer (1993) and Wynne and Kersting (2007) and is common to this empirical literature. However, the conclusions to take from Figure 1 are not obvious. A slight negative correlation exists between import share and inflation over the sample period (solid line), but that negative relationship becomes positive when I drop the three high-inflation outliers of Mexico, Poland, and Turkey (dotted line). Restricting the sample to the G7 countries produces a positive correlation nearly identical to that of the whole sample minus Mexico, Poland, and Turkey. When the sample period is shortened to more recent periods, the negative relationship with all the countries and the positive relationship without the high-inflation countries both diminish to the point where the two predicted value lines for the year 2005 are nearly indistinguishable and are both slightly positive. However, none of the slopes in any specification is significantly different from zero.

The "natural rate" approach of the model used in Rogoff (1985) has been criticized on a number of dimensions. Azariadis (1981) questions the Phillips curve assumption of dropping all but the first two terms of a Taylor series expansion of the aggregate supply equation around the expected logarithm of price. Also, the natural rate models on which so much of New Keynesian monetary policy today is based, assume that the welfare of a representative agent is a quadratic loss function in the deviation of output from its natural rate and in the deviation of inflation from expected inflation. This type of disutility function is a step removed from maximization of individual's utility functions that is standard in most micro-founded macroeconomics.

Another key characteristic implicit in the Rogoff model is that the labor market friction that causes the optimal employment level to be higher than the level desired by the suppliers of labor could be interpreted as some form of monopoly power on the part of these suppliers such as a labor union. Thus, the monetary authority uses the inflationary money injection to induce higher demand which causes the owners of labor to supply more. Intuitively, the more open an economy is, the less market power the monopolistic labor suppliers enjoy and the less incentive a monetary authority has to inflate.

An alternative to the natural rate international models mentioned above for addressing the relationship between openness and inflation are some more recent works related to the New Open Economic Macroeconomics (NOEM) models. A number of optimal monetary policy papers have come out recently in this vein of the literature that address optimal inflation levels generated by a monetary authority in general equilibrium multi-country environments in which firms and consumers are acting optimally and the monetary authority is maximizing the utility of its citizens.

Cooley and Quadrini (2003) and Cooper and Kempf (2003) both use models in which the production market is perfectly competitive to answer the questions of whether and when countries gain from cooperating in currency unions. Cooley and Quadrini (2003) employ a model in which domestic final goods producers use inputs from both domestic and foreign intermediate goods producers, and then consumers in each country only consume the final goods produced in their own country. Monetary policy in Cooley and Quadrini is set by a country's monetary authority choosing a nominal interest rate on a bond that final goods producers in both countries purchase to finance the intermediate inputs from both countries.

Cooper and Kempf (2003) use a technique that is conceptually different but structurally similar in which consumers only care about final goods consumption and that the final goods consumption is an aggregation of a Home produced good and a Foreign produced good in an overlapping generations setting. Monetary policy in Cooper and Kempf is set by a country's monetary authority choosing a currency growth rate. They impose two cash-in-advance constraints such that a Home consumer must pay for Home produced goods in his own currency and he must pay for Foreign produced goods in the Foreign currency.

In both papers, the standard consumption tax of inflation results. But, in the two-country setting with international trade, both papers find that the a degree of monetary market power—derived in Cooley and Quadrini (2003) from some degree of inelasticity in the demand for both domestic and foreign intermediate goods and derived in Cooper and Kempf (2003) from a degree of inelasticity in the demand for domestic and foreign final goods—generates an added benefit to inflation of being able to appreciate the terms of trade in favor of the inflating country. Cooley and Quadrini find that this inflationary bias in open economies is actually larger if the monetary authority cannot commit to a policy.

In a more traditional NOEM paper, Arseneau (2007) uses a model very similar to Corsetti and Pesenti (2001) that adds imperfectly competitive firms in each country. In an environment in which the monetary authority can commit to policy, Arseneau shows that the degree of imperfect competition can dampen the inflationary bias faced by a monetary authority, and can even fully offset it such that the equilibrium inflation rate is zero or negative. However, none of these four papers attempts to answer the question of how the degree of openness in a country affects its equilibrium inflation level when monetary policy is set optimally.

The goal of this paper is to use the micro-founded two-country model with optimal monetary policy in this paper that borrows heavily from the NOEM literature—

instead of following the Mundell-Fleming "natural rate" approach—to highlight a channel through which more openness to international trade can lead to increased inflation. The rest of the paper is organized as follows. Section 2 presents the model, and section 3 presents some results of the model. Section 4 concludes.

2 Model

Following Cooper and Kempf (2003), I use a two-country overlapping generations (OLG) general equilibrium framework with an independent monetary authority in each country whose objective is to maximize the welfare of its own citizens. In addition, this model includes imperfectly competitive producers in each country similar to Arseneau (2007). The model includes no stochastic shocks and agents enjoy perfect foresight.

I will call the two countries Home and Foreign, which are not relative terms but are the names of the actual countries. Most of the exposition in this section will focus on the problem of Home agents and the Home monetary authority, but the Foreign problem is symmetric in almost every dimension. However, I will allow Home and Foreign countries to differ in their respective levels of openness to international trade in a way that I will specify. Within a country, I assume the equilibrium is symmetric, so I will drop any subscripting of individuals. Home variables will be denoted by either no superscript or an "h" superscript, and Foreign variables will be denoted by either an "$*$" superscript or a "f" superscript or both.

This stylized economy is made up of two countries, each of which has a monetary authority, producers, and consumers. The overlapping generations of agents live for two periods. In the first period of their lives, they produce differentiated goods in a monopolistically competitive environment and sell the goods to both Home and Foreign consumers in exchange for the producer's Home-currency. The producers then choose how much of their Home currency to hold and how much of the Foreign currency to hold given that they will use a portfolio of each respective currency to consume Home and Foreign goods in the second period of their lives.

The role of each country's monetary authority is to maximize the lifetime welfare of the representative agent in the Home country by giving a non-proportional transfer of Home currency to the consumers of its own country in each period. Money is held in this economy because it is the only store of value and because of the two cash-in-advance constraints. Changes in the money supply are not neutral due to the transfers being non-proportional.[2] The two cash-in-advance constraints and consumer preferences generate demand for both currencies by a given consumer.

2.1 Money

The objective of the monetary authority in each country is to choose a fixed gross money growth rate $x_t = x$ or $x_t^* = x^*$ at the beginning of time in such a way as to maximize the welfare of its own citizens. I assume here that the monetary authority commits to its money growth rate at the beginning of time and cannot deviate once it has chosen its money growth path.[3]

Let M_t and M_t^* be the aggregate supply of Home currency and Foreign currency, respectively, in period t. I normalize the initial supply of Home and Foreign currency to 1 and divide it equally among the period-1 consumers at the beginning of the period.

$$M_0 = M_0^* = 1 \quad \text{and} \quad m_0^h = m_0^f = m_0^{h*} = m_0^{f*} = \frac{1}{2}$$

where m_0^h and m_0^{f*} are the individual holdings of Home currency by Home consumers and Foreign currency by Foreign consumers, respectively, at the beginning of period 1. Each country's monetary authority makes non-proportional transfers of $(x-1)M_{t-1}$ to each Home consumer in and $(x^*-1)M_{t-1}^*$ to each Foreign consumer period t. So aggregate supply of currency in each country obeys the following laws of motion.

$$M_{t+1} = xM_t \qquad \text{and} \qquad M_{t+1}^* = x^* M_t^* \tag{1}$$

[2]See Azariadis (1981) for a proof that non-proportional monetary transfers are not neutral, even in a perfect foresight economy.

[3]The reason to avoid discretionary monetary policy in this paper is due to the resulting characteristic of multiple equilibria. See King and Wolman (2004) and Ireland (1997).

This implies that the following relationships for τ_{t+1} and τ^*_{t+1} represent the non-proportional transfer to each Home consumer and to each Foreign consumer by their respective monetary authorities.

$$\tau_{t+1} = (x-1)\,M_t \qquad \text{and} \qquad \tau^*_{t+1} = (x^*-1)\,M^*_t \tag{2}$$

At the end of the first period of their lives, producers make a portfolio decision of how much of each type of currency to hold. They have just received $p_t(z)n_t(z)$ in Home currency from the sale of their differentiated goods, where z is an index value of the type of differentiated goods producer. Before the end of the first period of life, producers in each country exchange some of their domestic currency balances from sales revenues for foreign currency balances at the nominal exchange rate e_t as shown in the budget constraint equation (11). Let m^h_t and m^f_t represent each Home producer's portfolio choice between Home and Foreign currency, respectively, in period t. Because the monetary authority of each country only transfers currency to its own consumers, the laws of motion for individual currency balances in each country are the following:

$$\begin{aligned} m^h_{t+1} &= m^h_t + \tau_{t+1} \\ m^f_{t+1} &= m^f_t \\ m^{f*}_{t+1} &= m^{f*}_t + \tau^*_{t+1} \\ m^{h*}_{t+1} &= m^{h*}_t \end{aligned} \tag{3}$$

Because the equilibrium currency holdings within each country are symmetric, then $m^h_t, m^f_t, m^{f*}_t, m^{h*}_t$ represent the aggregate amounts of each currency $(M^h_t, M^f_t, M^{h*}_t, M^{f*}_t)$ held in each country in each period.

2.2 Individuals

A unit measure of agents are born in each period in both the Home country (indexed by z) and the Foreign country (indexed by z^*) and live for two periods. In the first period of their lives, individuals can either enjoy leisure l_t or provide labor $n_t(z)$ subject to their endowment of one unit of time.

$$l_t + n_t(z) = 1 \quad \forall t, z$$

Each individual also has access to a linear production technology through which he can convert labor hours into a differentiated good indexed by the individual z for each Home producer and z^* for each Foreign producer.

$$y_t(z) = f\big(n_t(z)\big) \quad \forall t, z \quad \text{where} \quad f\big(n_t(z)\big) = n_t(z)$$

Supplying labor to the production process costs producers $g\big(n_t(z)\big)$ in terms of utility.

Producers in the Home country then sell their differentiated good $y_t(z)$ to both Home and Foreign consumers for Home currency money balances at their profit maximizing prices $p_t(z)n_t(z)$. At the end of the period, producers take their revenue in terms of Home currency and exchange some of it for Foreign currency. In the next period of life, producers become consumers. Their balances of home currency are augmented by the lump-sum transfer from the central bank as shown in (3). They then spend their currency balances on Home and Foreign goods.

Lifetime utility U is separable in individual aggregate consumption C_{t+1} and labor $n_t(z)$ and is given by the following function.

$$\begin{aligned} U(C_{t+1}, n_t) &= u\left(C_{t+1}\right) - g\big(n_t(z)\big) \\ \text{where} \quad u\left(C_{t+1}\right) &= \frac{\left(C_{t+1}\right)^{1-\sigma} - 1}{1-\sigma} \quad \text{for} \quad \sigma > 0 \\ \text{and} \quad g\big(n_t(z)\big) &= \chi\big(n_t(z)\big)^{\xi} \quad \text{for} \quad \chi > 0 \quad \text{and} \quad \xi \geq 1 \end{aligned} \tag{4}$$

Individual aggregate consumption C_{t+1} is a CES aggregator of individual aggregate consumption of Home goods C^h_{t+1} and individual aggregate consumption of Foreign goods C^f_{t+1}.

$$C_{t+1} \equiv \left(C^h_{t+1}\right)^{1-\theta_h}\left(C^f_{t+1}\right)^{\theta_h} \quad \text{for} \quad \theta_h \in \left[0, \frac{1}{2}\right]$$

(5)

$$C^*_{t+1} \equiv \left(C^{f*}_{t+1}\right)^{1-\theta_f}\left(C^{h*}_{t+1}\right)^{\theta_f} \quad \text{for} \quad \theta_f \in \left[0, \frac{1}{2}\right]$$

In this Cobb-Douglas form, the elasticity of substitution between individual aggregate consumption of Home goods C^h_{t+1} and individual aggregate consumption of Foreign goods C^f_{t+1} equals one. The parameters θ_h and θ_f represent the exogenous degree of openness to international trade for the Home country and Foreign country, respectively. That is, higher values of θ_h represent increased preferences for Foreign goods by Home consumers.

I follow an international variation of the Dixit and Stiglitz (1977) model of monopolistic competition in characterizing the individual aggregate consumption of Home goods C^h_{t+1} and the individual aggregate consumption of Foreign goods C^f_{t+1} as CES aggregators of the individual differentiated goods from each country,

$$\text{(6)} \quad C^h_{t+1} \equiv \left(\int_0^1 c_{t+1}(z)^{\frac{\varepsilon-1}{\varepsilon}}\, dz\right)^{\frac{\varepsilon}{\varepsilon-1}} \quad \text{and} \quad C^f_{t+1} \equiv \left(\int_0^1 c_{t+1}(z^*)^{\frac{\varepsilon-1}{\varepsilon}}\, dz^*\right)^{\frac{\varepsilon}{\varepsilon-1}} \quad \forall\, t$$

where $\varepsilon \geq 1$ represents the elasticity of substitution among all the differentiated goods of a given country.[4] The individual aggregate consumption levels for Foreign consumers are defined in the same way. The Dixit-Stiglitz differentiated goods aggregation assumptions in (5) and (6) deliver the following expressions for consumer demand and aggregate prices.[5]

$$\text{(7)} \quad c_{t+1}(z) = \left(\frac{p_{t+1}(z)}{P^h_{t+1}}\right)^{-\varepsilon} C^h_{t+1} \quad \text{and} \quad c_{t+1}(z^*) = \left(\frac{p_{t+1}(z^*)}{P^f_{t+1}}\right)^{-\varepsilon} C^f_{t+1} \quad \forall\, t, z, z^*$$

[4]Note that $\varepsilon \geq 1$ has the intuitive implication that the elasticity of substitution among goods produced within a given country is at least as large as the elasticity of substitution between Home goods and Foreign goods.

[5]A derivation for these demand and price equations is in the Technical Appendix and is available upon request.

$$(8) \qquad C^h_{t+1} = (1-\theta_h)\left(\frac{P^h_{t+1}}{P_{t+1}}\right)^{-1} C_{t+1} \quad \text{and} \quad C^f_{t+1} = \theta_h \left(\frac{e_t P^f_{t+1}}{P_{t+1}}\right)^{-1} C_{t+1} \quad \forall t$$

$$(9) \qquad P^h_{t+1} = \left(\int_0^1 p_{t+1}(z)^{1-\varepsilon}\, dz\right)^{\frac{1}{1-\varepsilon}} \quad \text{and} \quad P^f_{t+1} = \left(\int_0^1 p_{t+1}(z^*)^{1-\varepsilon}\, dz^*\right)^{\frac{1}{1-\varepsilon}} \quad \forall\, t$$

$$(10) \qquad P_{t+1} = \frac{1}{(1-\theta_h)^{1-\theta_h}\theta_h^{\theta_h}} \left(P^h_{t+1}\right)^{1-\theta_h} \left(e_t P^f_{t+1}\right)^{\theta_h} \quad \forall t$$

where $p_{t+1}(z)$, P^h_{t+1}, and P_{t+1} are prices of individual consumption, aggregate country-specific consumption, and aggregate total consumption, respectively.

Individuals seek to maximize lifetime utility derived from disutility of work in the first period of life in order to sell a differentiated production good for own-country currency balances that are carried over to the second period of life in which the individual can spend those balances on consumption of both Home and Foreign goods. Because the monopolistically competitive producers can set the quantity demanded by choosing price in order to clear their goods, the consumer's problem is characterized by choosing how much to charge for her differentiated good $p_t(z)$ and then the portfolio decision of how much of her sales to keep in the form of Home currency m^h_t and how much to exchange for Foreign currency m^f_t.[6]

$$(4) \qquad \max_{c_t(z), c_t(z^*), m^h_t, m^f_t, p_t(z)} \; u\left(C_{t+1}\right) - g\left(n_t(z)\right)$$

$$(11) \qquad \text{s.t.} \quad p_t(z) n_t(z) = m^h_t + e_t m^f_t$$

$$(12) \qquad P^h_{t+1} C^h_{t+1} = m^h_t + \tau_{t+1}$$

$$(13) \qquad P^f_{t+1} C^f_{t+1} = m^f_t$$

where (11) is the budget constraint reflecting the portfolio decision and (12) and (13)

[6] An implicit assumption in this setup is that the producer will meet demand, whatever it is. Thus the producer sets price $p_t(z)$ and then produces $n_t(z)$ to meet the resulting demand. Some other interesting cases arise in a model with shocks when producers are not required to meet demand.

are cash-in-advance constraints.[7]

Using the individual demand equations represented by (7), I define the total demand $d_t(z)$ for differentiated Home good z as the sum of the individual Home and Foreign demands:[8]

$$d_t(z) \equiv c_t(z) + c_t^*(z) = \left(\frac{p_t(z)}{P_t^h}\right)^{-\varepsilon} \frac{xM_{t-1}}{P_t^h} \tag{14}$$

I assume that producers always choose price to maximize utility given their knowledge of total demand $d_t(z)$ and then meet the demand.

$$n_t(z) = d_t(z) = \left(\frac{p_t(z)}{P_t^h}\right)^{-\varepsilon} \frac{xM_{t-1}}{P_t^h} \tag{15}$$

Using the cash-in-advance constraints (12) and (13), the money laws of motion (3), and the expressions for the non-proportional transfer in terms of the Home money growth rate (2), country-specific aggregate consumptions can be expressed in the following way:

$$C_{t+1}^h = \frac{m_t^h + (x-1)xM_{t-1}}{P_{t+1}^h} \tag{16}$$

$$C_{t+1}^f = \frac{m_t^f}{P_{t+1}^f} \tag{17}$$

The expression for Home aggregate total consumption is then:

$$C_{t+1} = \left(\frac{m_t^h + (x-1)xM_{t-1}}{P_{t+1}^h}\right)^{1-\theta_h} \left(\frac{m_t^f}{P_{t+1}^f}\right)^{\theta_h}$$

Using the portfolio constraint in (11) to substitute out either $m_{i,t}^h$ or $m_{i,t}^f$ and substituting in the expression for labor supply from (15), the maximization problem then

[7]The two cash-in-advance constraints are a simplification of a richer environment in which governments or monetary authorities strategically choose what currencies to accept for exchange that takes place within their borders. See Appendix A-2 for a detailed discussion of this two CIA constraint setup, as well as references to richer theoretical environments.

[8]The derivation is given in Derivation 1 in Technical Appendix T-2 and is available upon request.

becomes

$$\max_{m_t^f, p_t(z)} \frac{\left[\left(\left[\frac{p_t(z)}{P_t^h}\right]^{1-\varepsilon} \frac{xM_{t-1}}{P_{t+1}^h} - \frac{e_t m_t^f - (x-1)xM_{t-1}}{P_{t+1}^h}\right)^{1-\theta_h} \left(\frac{m_t^f}{P_{t+1}^f}\right)^{\theta_h}\right]^{1-\sigma} - 1}{1-\sigma} \ldots$$
$$-\chi \left[\left(\frac{p_t(z)}{P_t^h}\right)^{-\varepsilon} \frac{xM_{t-1}}{P_t^h}\right]^{\xi} \tag{18}$$

The first order conditions with respect to m_t^f and $p_t(z)$, respectively, are:

$$\frac{P_{t+1}^h C_{t+1}^h}{e_t P_{t+1}^f C_{t+1}^f} = \frac{1-\theta_h}{\theta_h} \tag{19}$$

$$(1-\theta_h)\left(\frac{\varepsilon-1}{\varepsilon}\right) \frac{p_t(z)}{P_{t+1}^h} \left(C_{t+1}^h\right)^{(1-\theta_h)(1-\sigma)-1} \left(C_{t+1}^f\right)^{\theta_h(1-\sigma)} = \chi\xi \left(n_t(z)\right)^{\xi-1} \tag{20}$$

where equation (19) equates the marginal cost of giving up a Home-currency unit of Home consumption for the marginal benefit of a Home-currency unit of Foreign consumption. Equation (20) equates the marginal benefit of raising price to its marginal cost in terms of reduced demand, increased utility of leisure, and the change in income in the next period of life. Because each agent within a country is identical, other than for a differentiated production good, the resulting individual equilibrium price $p_t(z)$ and the amount of total revenues held in Foreign currency m_t^f will be symmetric across individuals in a given country.

The first order condition for m_t^f in (19) is a direct result of the unit elasticity Cobb-Douglas form of the CES aggregator for individual aggregate consumption in (5). It implies that constant shares of income are spent on consumption of Home goods and on consumption of Foreign goods. Using the demand for individual aggregate consumption of Foreign goods from (8), the import share is exactly equal to the openness parameter θ_h.

$$\frac{e_t P_{t+1}^f C_{t+1}^f}{P_{t+1} C_{t+1}} = \theta_h \quad \forall t \tag{21}$$

2.3 Market clearing conditions

This economy has three markets that must clear—the goods market, the money market, and the currency exchange market. The following paragraphs describe each market and the respective market clearing condition.

Goods Market. Both Home and Foreign consumers demand goods from both countries. Producers meet that demand by construction in this model. Due to the linear production technology, $n_t(z)$ represents the amount of production by each Home producer of differentiated good z. Goods market clearing requires that production equal the sum of all the Home demands $c_t(z)$ and Foreign demands $c_t^*(z)$ for differentiated good z.

$$n_t(z) = d_t(z) = c_t(z) + c_t^*(z) \quad \forall\, t, z \tag{22}$$

$$n_t(z^*) = d_t(z^*) = c_t(z^*) + c_t^*(z^*) \quad \forall\, t, z^* \tag{23}$$

where the the right-hand side of each equation is characterized by (14) and its Foreign country analogue. This market clearing condition is assumed in the individual maximization stage as shown in (15).

Money Market. Money market clearing simply requires that money supply equal money demand at the time that goods are purchased.

$$M_t = m_t^h + m_t^{h*} \quad \forall\, t \tag{24}$$

$$M_t^* = m_t^f + m_t^{f*} \quad \forall\, t \tag{25}$$

where M_t and M_t^* are the Home and Foreign aggregate money supplies, respectively, at time t.

Currency Exchange Market. After trade has taken place in the goods market, period-t producers go to the currency market and make a portfolio decision of how much of each currency to hold. The nominal exchange rate e_t is the price that equates the amount of Foreign currency purchased with Home currency by Home producers with the amount of Home currency purchased by Foreign producers with Foreign currency.

$$e_t m_t^f = m_t^{h*} \quad \forall t \tag{26}$$

It is important to note that the exchange rate here is not pinned down by the assumption of the law of one price as in models with a single cash-in-advance constraint, such as Corsetti and Pesenti (2001) and Arseneau (2007). I follow Cooper and Kempf (2003) in that the exchange rate is a price that clears the currency exchange market in period-t. Because of the two cash-in-advance constraints, the law of one price holds by definition. Using the cash-in-advance constraint (13) and its Foreign country analogue, it can be shown that currency exchange market clearing implies that the nominal value of imports equals the nominal value of exports.

$$e_t P_{t+1}^f C_{t+1}^f = P_{t+1}^h C_{t+1}^{h*} \quad \forall t \tag{27}$$

2.4 Equilibrium

In this section, I define two equilibria. The first is the steady-state equilibrium given international monetary policies x and x^*. The second is the international monetary Nash equilibrium in which both monetary authorities implement their best responses given the steady-state equilibrium outcomes for those best responses.

I define the steady-state international equilibrium given both Home and Foreign monetary policy (x, x^*) as follows, and Table 1 shows the conditions that must hold for the steady state-equilibrium in Definition 1.

Definition 1 (Steady-state International Equilibrium given x and x^*). A steady-state international equilibrium, given Home and Foreign monetary policy (x, x^*) is the set of Home consumption of both Home and Foreign aggregate goods C^h and C^f, Home production n, Home portfolio holdings of both Home and Foreign currency

m^h and m^f (or rather, as a percentage of initial Home holdings, ϕ and $1-\phi$), the Foreign counterparts $(C^{h*}, C^{f*}, n^*, m^{h*}, m^{f*})$, individual Home and Foreign prices $p_t(z)$ and $p_t(z^*)$, and exchange rate e_t such that:

- **Individual optimization**: Home and Foreign agents choose the price level of their differentiated good as well as their currency portfolio holdings in order to maximize lifetime utility in (4) and its Foreign counterpart subject to a budget constraint (11) and two cash-in-advance constraints (12) and (13). Therefore, the two first order conditions (19) and (20) hold.

- **Market Clearing** The goods markets (22) and (23), money markets (24) and (25), and currency exchange market (26) all clear.

Table 1: Equilibrium conditions given x and x^*

	Home country	Foreign country
(19)	$\frac{P^h_{t+1}C^h_{t+1}}{e_t P^f_{t+1}C^f_{t+1}} = \frac{1-\theta_h}{\theta_h}$	$\frac{e_t P^f_{t+1}C^{f*}_{t+1}}{P^h_{t+1}C^{h*}_{t+1}} = \frac{1-\theta_f}{\theta_f}$
(20)	$(1-\theta_h)\left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{p_t(z)}{P^h_{t+1}}\frac{\left(C^h_{t+1}\right)^{(1-\theta_h)(1-\sigma)-1}}{\left(C^f_{t+1}\right)^{-\theta_h(1-\sigma)}} = ...$ $...\chi\xi\left(n_t(z)\right)^{\xi-1}$	$(1-\theta_f)\left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{p_t(z^*)}{P^f_{t+1}}\frac{\left(C^{f*}_{t+1}\right)^{(1-\theta_f)(1-\sigma)-1}}{\left(C^{h*}_{t+1}\right)^{-\theta_f(1-\sigma)}} = ...$ $...\chi\xi\left(n_t(z^*)\right)^{\xi-1}$
(15)	$n_t(z) = \left(\frac{p_t(z)}{P^h_t}\right)^{-\varepsilon}\frac{xM_{t-1}}{P^h_t}$	$n_t(z^*) = \left(\frac{p_t(z^*)}{P^f_t}\right)^{-\varepsilon}\frac{x^*M^*_{t-1}}{P^f_t}$
(11)	$p_t(z)n_t(z) = m^h_t + e_t m^f_t$	$p_t(z^*)n_t(z^*) = m^{f*}_t + \frac{m^{h*}_t}{e_t}$
(16)	$C^h_{t+1} = \frac{m^h_t+(x-1)xM_{t-1}}{P^h_{t+1}}$	$C^{f*}_{t+1} = \frac{m^{f*}_t+(x^*-1)x^*M^*_{t-1}}{P^f_{t+1}}$
(17)	$C^f_{t+1} = \frac{m^f_t}{P^f_{t+1}}$	$C^{h*}_{t+1} = \frac{m^{h*}_t}{P^h_{t+1}}$
(5)	$C_{t+1} = \left(C^h_{t+1}\right)^{1-\theta_h}\left(C^f_{t+1}\right)^{\theta_h}$	$C^*_{t+1} = \left(C^{f*}_{t+1}\right)^{1-\theta_f}\left(C^{h*}_{t+1}\right)^{\theta_f}$
	Market clearing conditions	
(22)	$n_t(z) = c_t(z) + c^*_t(z)$	
(23)	$n_t(z^*) = c_t(z^*) + c^*_t(z^*)$	
(24)	$M_t = m^h_t + m^{h*}_t$	
(25)	$M^*_t = m^f_t + m^{f*}_t$	
(26)	$e_t m^f_t = m^{h*}_t$	

Following Cooper and Kempf (2003), let ϕ_t represent the share of revenues $p_t(z)n_t(z)$ kept in the form of Home currency in period t, and let $1-\phi_t$ be the share of revenues exchanged for Foreign currency as characterized in the portfolio budget constraint

(11). Then the following expressions hold.

$$p_t(z)n_t(z) - m_t^h = e_t m_t^f = (1-\phi_t)\, M_t \tag{28}$$

$$p_t(z^*)n_t(z^*) - m_t^{f*} = \frac{m_t^{h*}}{e_t} = (1-\phi_t^*)\, M_t^* \tag{29}$$

$$m_t^h + \tau_{t+1} = (\phi_t + x - 1)\, M_t \tag{30}$$

$$m_t^{f*} + \tau_{t+1}^* = (\phi_t^* + x^* - 1)\, M_t^* \tag{31}$$

Plugging (28), (29), (30), and (31) into the first order condition (19) and its Foreign country analogue, the unique nonautarkic steady-state equilibrium share of currency from sales held for own-country consumption is given by:

$$\phi = 1 - \theta_h x \quad \forall\, x \in \left(0, \frac{1}{\theta_h}\right) \tag{32}$$

$$1 - \phi = \theta_h x \quad \forall\, x \in \left(0, \frac{1}{\theta_h}\right) \tag{33}$$

$$\phi^* = 1 - \theta_f x^* \quad \forall\, x^* \in \left(0, \frac{1}{\theta_f}\right) \tag{34}$$

$$1 - \phi^* = \theta_f x^* \quad \forall\, x^* \in \left(0, \frac{1}{\theta_f}\right) \tag{35}$$

From the aggregate money laws of motion in (1) and from the money market clearing conditions in (24) and (25), it is clear that the non-autarkic steady-state equilibrium country-specific consumption inflation rates are:

$$\frac{P_{t+1}^h}{P_t^h} = x \qquad \text{and} \qquad \frac{P_{t+1}^f}{P_t^f} = x^* \tag{36}$$

Furthermore, using the definition of the Home country CPI level P_{t+1} from (10) and its Foreign country analogue, the expressions for the share Home country revenues traded for Foreign currency balances (33) and the share of Foreign country revenues traded for Home currency balances (35), and the currency exchange market clearing condition (26), the Home country CPI growth rate and the Foreign country CPI growth rates can be shown to be equal to their respective countries' money growth rates as well.[9]

$$\frac{P_{t+1}}{P_t} = x \qquad \text{and} \qquad \frac{P^*_{t+1}}{P^*_t} = x^* \tag{37}$$

Using (32), (33), (34), and (35), as well as the equilibrium inflation rates from (36), steady-state equilibrium consumption can be derived in terms of steady-state employment from the cash-in-advance constraints as:

$$C^h = (1-\theta_h)n \tag{38}$$

$$C^f = \theta_f n^* \tag{39}$$

$$C^{f*} = (1-\theta_f)n^* \tag{40}$$

$$C^{h*} = \theta_h n \tag{41}$$

where the steady-state employment levels n and n^* are characterized below in equations (44) and (45).

The expressions for the steady-state international equilibrium employment is then found by solving the two equilibrium forms of the Home first order condition (20) and its Foreign analogue.

$$(1-\theta_h)\left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{1}{x}\left[(1-\theta_h)n\right]^{(1-\theta_h)(1-\sigma)-1}\left[\theta_f n^*\right]^{\theta_h(1-\sigma)} = \chi\xi(n)^{\xi-1} \tag{42}$$

$$(1-\theta_f)\left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{1}{x^*}\left[(1-\theta_f)n^*\right]^{(1-\theta_f)(1-\sigma)-1}\left[\theta_h n\right]^{\theta_f(1-\sigma)} = \chi\xi(n^*)^{\xi-1} \tag{43}$$

Solving (43) for n^* and plugging it into (42), and doing the symmetric operation for the Foreign country gives the expressions for Home and Foreign steady-state equilib-

[9]The derivation is given in the Technical Appendix, and is available upon request.

rium labor supply:

$$n\left(x,x^{*}\right)=\Omega_{H}\left(x\right)^{\frac{\Delta_{f}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}}\left(x^{*}\right)^{\frac{-\Sigma_{h}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}} \tag{44}$$

$$n^{*}\left(x^{*},x\right)=\Omega_{F}\left(x^{*}\right)^{\frac{\Delta_{h}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}}\left(x\right)^{\frac{-\Sigma_{f}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}} \tag{45}$$

where the symbols in (44) and (45) summarize the parameters of the model in the following way:

$$\begin{aligned}
\Delta_{h} &= (1-\theta_{h})(1-\sigma)-\xi\\
\Delta_{f} &= (1-\theta_{f})(1-\sigma)-\xi\\
\Sigma_{h} &= \theta_{h}(1-\sigma)\\
\Sigma_{f} &= \theta_{f}(1-\sigma)\\
\Omega_{h} &= \left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{\chi\xi}{(1-\theta_{h})^{(1-\theta_{h})(1-\sigma)}(\theta_{f})^{\theta_{h}(1-\sigma)}}\\
\Omega_{f} &= \left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{\chi\xi}{(1-\theta_{f})^{(1-\theta_{f})(1-\sigma)}(\theta_{h})^{\theta_{f}(1-\sigma)}}\\
\Omega_{H} &= (\Omega_{h})^{\frac{\Delta_{f}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}}\,(\Omega_{f})^{\frac{-\Sigma_{h}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}}\\
\Omega_{F} &= (\Omega_{f})^{\frac{\Delta_{h}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}}\,(\Omega_{h})^{\frac{-\Sigma_{f}}{\Delta_{h}\Delta_{f}-\Sigma_{h}\Sigma_{f}}}
\end{aligned}$$

The signs of these expressions and their derivatives with respect to the openness parameters θ_h and θ_f are given in Table 2. From the signs of the representative parameters, it is clear that steady state equilibrium Home employment n decreases in x always and increases in x^* when $\sigma > 1$.

Looking at the equation for Home labor supply in (44), the sign of Σ_h determines how Foreign monetary policy affects the real economy in the Home country.

$$\Sigma_{h}=\begin{cases}>0 & \text{if}\quad \theta_{h}\in(0,0.5]\quad\text{and}\quad\sigma\in(0,1)\\ =0 & \text{if}\quad \theta_{h}=0\quad\text{or}\quad\sigma=1\\ <0 & \text{if}\quad \theta\in(0,0.5]\quad\text{and}\quad\sigma>1\end{cases} \tag{46}$$

Table 2: **Properties of representative parameters**

Symbol	Sign	$\frac{\partial(\cdot)}{\partial\theta_h}$	$\frac{\partial(\cdot)}{\partial\theta_f}$
Δ_h	$(-)$ always	$(+)$ when $\sigma > 1$	
Δ_f	$(-)$ always		$(+)$ when $\sigma > 1$
Σ_h	$(-)$ when $\sigma > 1$, $\theta_h > 0$	$(-)$ when $\sigma > 1$	
Σ_f	$(-)$ when $\sigma > 1$, $\theta_f > 0$		$(-)$ when $\sigma > 1$
Ω_h	$(+)$ when $\theta_f > 0$	$(-)$ when $\sigma > 1$, $\theta_f > 0$	$(+)$ when $\sigma > 1$, $\theta_h > 0$
Ω_f	$(+)$ when $\theta_h > 0$	$(+)$ when $\sigma > 1$, $\theta_f > 0$	$(-)$ when $\sigma > 1$, $\theta_h > 0$
$\Delta_h\Delta_f - \Sigma_h\Sigma_f$	$(+)$ always	$(-)$ when $\sigma > 1$	$(-)$ when $\sigma > 1$

Note: The results from this table are derived in the Technical Appendix and are available upon request.

The third case is the most common in which $\Sigma_h < 0$, implying that Foreign inflation causes an increase in the equilibrium level of Home production and, therefore, an increase in equilibrium consumption of the Home good by both Home and Foreign consumers.

If one were to make the strong assumption that the coefficient of relative risk aversion σ were less than one, the first case in (46) occurs in which Foreign inflation causes a decrease in the equilibrium level of Home production. Lastly, it is interesting to notice the cases in which Foreign monetary policy has no real effect on the Home country ($\Sigma = 0$). Obviously, when the economies do not trade with each other, $\theta_h = 0$, Foreign monetary policy will be neutral. But it is interesting to note that the case of log utility ($\sigma = 1$) also induces the neutrality of Foreign monetary policy.

The monetary authority in each country seeks to maximize the lifetime utility of a representative agent in this economy by choosing Home monetary policy x given Foreign monetary policy x^*. Define $V(x, x^*)$ as the lifetime utility of a representative agent. The objective of the Home monetary authority is then:

(47)

$$\max_x V(x, x^*) = \max_x \frac{\left([(1-\theta_h)n(x, x^*)]^{1-\theta_h}[\theta_f n^*(x^*, x)]^{\theta_h}\right)^{1-\sigma} - 1}{1-\sigma} - \chi n(x, x^*)^{\xi}$$

Definition 2 (**Steady-state International Monetary Nash Equilibrium**). A steady-state international monetary Nash equilibrium is the intersection of a monetary policy function for the Home monetary authority as a function of Foreign monetary policy $\hat{x}(x^*)$ and a monetary policy function for the Foreign monetary authority as a function of Home monetary policy $\hat{x}^*(x)$ such that:

- the individual steady state equilibrium conditions from Definition 1 hold for each country,
- each monetary policy function $\hat{x}(x^*)$ and $\hat{x}^*(x)$ is a best response function to the other country's monetary policy derived from the maximization problem (47).

Taking the derivative of (47), the resulting solution for the Home monetary best response function $\hat{x}(x^*)$ is:[10]

$$\begin{aligned} \hat{x} &= \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\Delta_f}{(1-\theta_h)\Delta_f - \theta_h \Sigma_f} \\ &= \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{(1-\theta_f)(1-\sigma) - \xi}{(1-\theta_h-\theta_f)(1-\sigma) - (1-\theta_h)\xi} \end{aligned} \tag{48}$$

The analogous solution for the Foreign monetary authority $\hat{x}^*(x)$ is:

$$\begin{aligned} \hat{x}^* &= \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\Delta_h}{(1-\theta_f)\Delta_h - \theta_f \Sigma_h} \\ &= \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{(1-\theta_h)(1-\sigma) - \xi}{(1-\theta_h-\theta_f)(1-\sigma) - (1-\theta_f)\xi} \end{aligned} \tag{49}$$

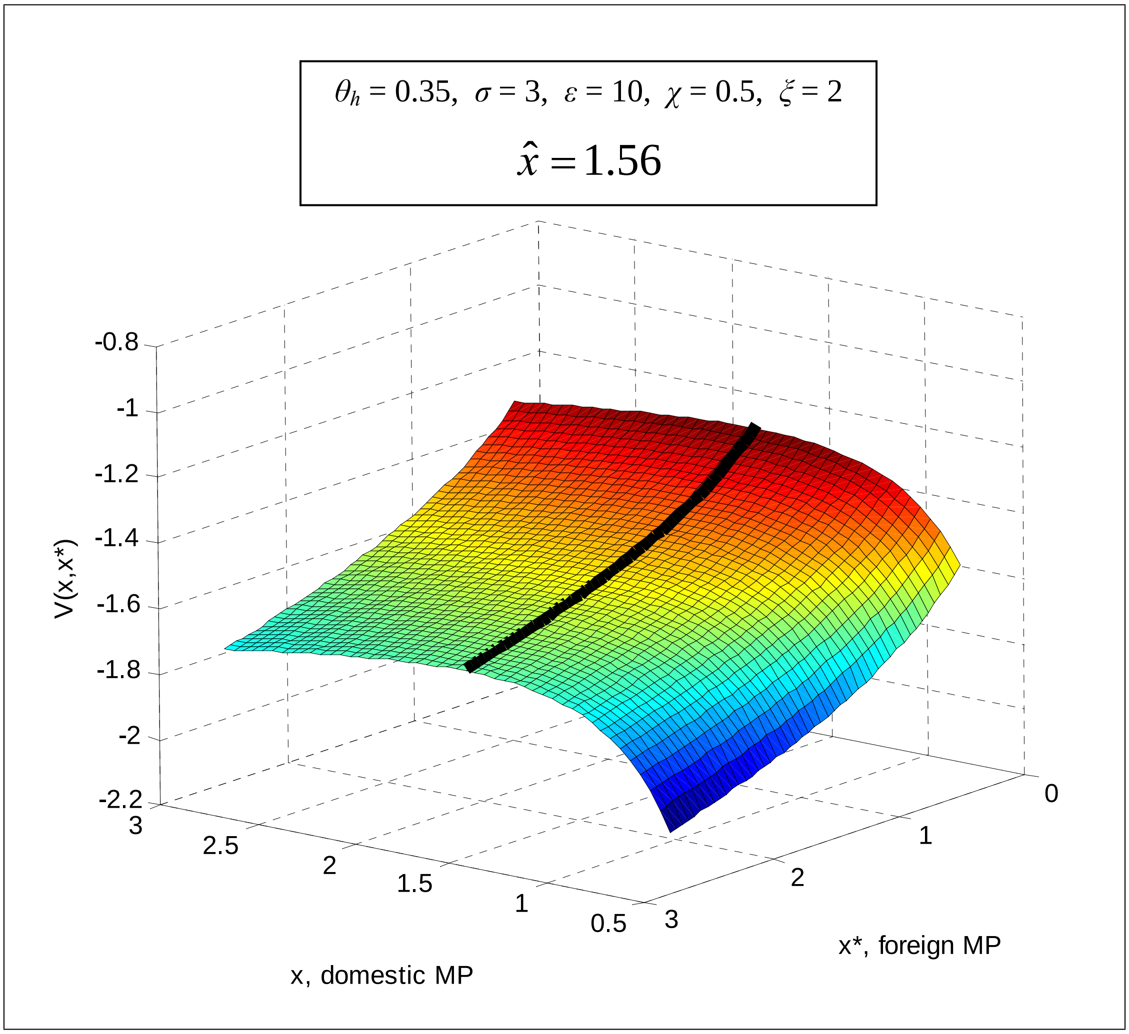
The first characteristic to note about the optimal Home monetary policy function in (48) is that it is independent of Foreign monetary policy x^*. That is, the optimal level of the Home money growth rate does not change with changes in the Foreign money growth rate and is a dominant strategy equilibrium.[11]

This dominant strategy equilibrium is shown in Figure 2, which plots the lifetime utility of a representative Home agent from (47) as a function of Home inflation x and Foreign inflation x^*. The parameters $(\theta, \sigma, \varepsilon, \chi, \xi)$ are calibrated to reflect values estimated in the empirical literature in order to make a simple example. The dark line running across the top of Figure 2 represents the Home monetary policy best response function from (48). The optimal Home inflation level at the selected parameter values is a constant $\hat{x} = 1.56$, which is not overly high given that the duration of a period is

[10] The derivation for this result is in the Technical Appendix which is available upon request.

[11] The Technical Appendix details why $\hat{x}$ is independent of x^* and is available upon request.

Figure 2: Home lifetime utility V as a function of x and x^*



a generation. Because each country's best response function for monetary policy is a dominant strategy equilibrium, the world Nash monetary equilibrium is the same as the country partial monetary equilibrium.

3 Results

The goal of this paper is to study how openness to international trade affects inflation. The policy functions in (48) and (49) highlight the effect of both openness and imperfect competition on a country's inflation rate. The following propositions detail the new result of a channel through which increased openness can increase inflation and decreased competition can actually lower inflation. These results depend on the international structure of the model in which a competitive game emerges between monetary authorities.

Proposition 1 (**Monetary response to changes in openness**)**.** The equilibrium Home money growth rate $\hat{x}$ in (48) increases with more Home openness in the form of a higher level of θ_h and in response to more Foreign openness in the form of a higher level of θ_f. The argument for the Foreign country is symmetric. However, when θ_h increases, the increase in $\hat{x}$ is greater than the increase in $\hat{x}^*$. Conversely, when θ_f increases, the increase in $\hat{x}^*$ is greater than the increase in $\hat{x}$.

Proof. See Appendix A-1. □

Because the Home country CPI growth rate (P_{t+1}/P_t) is equal to the Home money growth rate x, an increase in θ_h increases Home country inflation as well as Foreign country inflation. From the perspective of the Home monetary authority, if the Home marginal utility of Home consumption decreases relative to the Home marginal utility of Foreign consumption, as is the case when θ_h increases while θ_f remains constant, Home country agents bear a smaller proportion of the inflation tax. In effect, higher θ_h increases the welfare benefits from higher money growth rates to the Home country and lowers the costs. Consequently, the optimal response by the Home monetary authority is to raise the Home money growth rate or the CPI inflation rate in response to a higher degree of openness. This is a *beggar thy neighbor* effect.

The next two propositions further explain how the level of imperfect competition among producers in a country, as parameterized by the elasticity of substitution among a country's differentiated goods ε, influences the optimal money growth rate x and the real outcomes of the economy in equilibrium.

Proposition 2 (**Deflationary bias of imperfect competition**)**.** Both the optimal Home money growth rate $\hat{x}$ and the optimal Foreign money growth rate $\hat{x}^*$ decrease as the level of imperfect competition increases (as ε decreases). Furthermore, there exist two critical within-country elasticities of substitution for the Home country and Foreign country $(\bar{\varepsilon}, \bar{\varepsilon}^*)$ such that $\hat{x} = 1$ when $\varepsilon = \bar{\varepsilon}$ and $\hat{x}^* = 1$ when $\varepsilon = \bar{\varepsilon}^*$. That is, these two critical levels of the imperfect competition parameter implement the

Friedman Rule in the Home and Foreign country, respectively.

$$\bar{\varepsilon} = \frac{(1-\theta_f)(1-\sigma)-\xi}{\theta_h(1-\sigma-\xi)} \tag{50}$$

$$\bar{\varepsilon}^* = \frac{(1-\theta_h)(1-\sigma)-\xi}{\theta_f(1-\sigma-\xi)} \tag{51}$$

Proof. See Appendix A-1. □

This result that the level imperfect competition induces a deflationary bias in monetary policy has been shown recently by Arseneau (2007).

Lastly, Proposition 3 highlights the relationship between the level of market power held by producers within a country and the monopoly power held by the each monetary authority in international markets.

Proposition 3 (Market power neutrality). In the case of symmetric countries $\theta_h = \theta_f$, the steady state equilibrium levels of employment n and n^* are not affected by the level of imperfect competition ε within both countries.

Proof. See Appendix A-1. □

Proposition 3 says that the real outcomes in each country $(n, n^*, C^h, C^f, C^{h*}, C^{f*})$ are the same regardless of whether the countries are characterized by perfect competition $\varepsilon = \infty$ or whether any degree of monopoly power is enjoyed by producers $\varepsilon < \infty$. However, this result only applies to the special case in which the two countries have symmetric levels of openness $\theta_h = \theta_f$. The implication of this result is that if any monopoly rents available to Home or Foreign agents are not collected through producer price setting, the remainder will be collected by the monetary authority raising prices. As stated in Proposition 2, a level of imperfect competition exists at which all the monopoly rents are collected through producer price setting along. That is, inflation generated by the monetary authority increasing the money growth rate is not needed.

These results provide an interesting interpretation of the empirical findings summarized in Figure 1. If one is looking at the negative relationship between openness and inflation from the entire sample predicted values, Propositions 1 through 3 suggest that the inflationary bias of openness is dominated by the deflationary bias of imperfect competition. That is, the level of imperfect competition is greater than the critical value at which optimal monetary policy causes zero inflation ($\varepsilon < \bar{\varepsilon}, \bar{\varepsilon}^*$). On the other hand, if one is looking at the positive relationship between openness and inflation that results when looking at low-inflation countries, the conclusion is that the inflationary bias of openness slightly dominates the deflationary bias of imperfect competition.

4 Conclusion

Questions about the costs and benefits of openness to international trade draw interest during times of both expansion and contraction due to the increased international linkages among countries today. This paper contributes insight how one factor, inflation, is affected by openness. The main result of this work is to describe a new channel through which increased openness to international trade can increase inflation.

In a closed economy, the leisure subsidy of inflation is strictly dominated by the consumption tax, so the only role for the optimal money growth rate is to offset the inefficiencies of imperfect competition. However, as a country becomes more open, more of the burden of the consumption tax of inflation is borne by Foreign consumers, and the terms of trade and the real wage appreciate with increased inflation. These extra benefits from higher money growth rates cause an inflationary effect of openness in equilibrium.

However, another important finding of this paper is that, not only does the level of imperfect competition among producers in a given country dampen the incentive for a monetary authority to increase the money growth rate, but it is a perfect substitute. That is, any monopoly rents that are available to the agents of a country that are not collected through price setting behavior of producers derived from the level of imperfect competition within the country are extracted by the monetary authority.

The result that openness is inflationary runs contrary to much previous work that has documented a negative correlation between various measures of the level of globalization or openness and inflation. However, much less work exists that explores this relationship through structural international models based on microeconomic foundations. This work is a first pass at studying, specifically, the imperfect competition and monetary market power channel.

An obvious extension of this work is to empirically test the effects of openness on inflation while controlling for imperfect competition. However, more data on international measures of imperfect competition are needed.[12] Further work includes relaxing the strong assumption that the elasticity of substitution between aggregate Home-produced consumption and aggregate Foreign-produced consumption is unity $\rho = 1$, which results in the Cobb-Douglas form of the final consumption aggregator. Relaxing this assumption would break the constant expenditure share result and allow consumers to substitute away from expenditures on a country's production when the monetary authority raises the money growth rate. This may also break the dominant strategy equilibrium result in which the optimal monetary policy of each country is independent of the policy of the other country. Other extensions that may break the dominant strategy equilibrium result are to add pricing or exchange rate frictions such as time- or state-dependent pricing or pricing-to-market.

Also, this paper assumes that the two countries are asymmetric with respect to the level of openness θ. However, another dimension of asymmetry that might be interesting is the elasticity of substitution ε that parameterizes the level of imperfect competition within both countries. Furthermore, a vein of the literature exists that studies environments with endogenous markups in which the elasticity of substitution changes as firms enter and exit.[13]

And lastly, if the degree of openness has such important effects on the ability of the monetary authority to extract monopoly rents for its citizens, then how would an entity like a congressional body set openness policy optimally if it could? That is,

[12]Høj, Jimenez, Maher, Nicoletti, and Wise (2007) estimate markups over marginal cost for 16 countries for the year 2004. But data on either more countries, more years, or both are needed in order to run legitimate empirical tests of the theory in this paper. Another strategy is to use a proxy for imperfect competition. Evans (2008) uses union coverage rates (in addition to country markup estimates), which are more broadly available across countries but are a more noisy proxy for imperfect competition.

[13]See Ferreira and Lloyd-Braga (2005), Ferreira and Dufourt (2006), and D'Aspremont, Ferreira, and Gérard-Varet (1996).

what would be the equilibrium outcomes with endogenous openness θ?

APPENDIX

A-1 Proofs

Proof of Proposition 1: Monetary response to changes in openness. Taking the derivative of the expression for $\hat{x}$ in (48) with respect to θ_h and θ_f gives the following results:

$$\hat{x} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\Delta_f}{(1-\theta_h)\Delta_f - \theta_h \Sigma_f} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{(1-\theta_f)(1-\sigma) - \xi}{(1-\theta_h-\theta_f)(1-\sigma) - (1-\theta_h)\xi}$$

$$\frac{\partial \hat{x}}{\partial \theta_h} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\Delta_f (1-\sigma-\xi)}{\left[(1-\theta_h)\Delta_f - \theta_h \Sigma_f\right]^2} > 0$$
$$\frac{\partial \hat{x}}{\partial \theta_f} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\theta_h (1-\sigma)(1-\sigma-\xi)}{\left[(1-\theta_h)\Delta_f - \theta_h \Sigma_f\right]^2} > 0$$

Taking the derivative of the expression for $\hat{x}^*$ in (49) with respect to θ_f and θ_h gives the following results:

$$\hat{x}^* = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\Delta_h}{(1-\theta_f)\Delta_h - \theta_f \Sigma_h} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{(1-\theta_h)(1-\sigma) - \xi}{(1-\theta_h-\theta_f)(1-\sigma) - (1-\theta_f)\xi}$$

$$\frac{\partial \hat{x}^*}{\partial \theta_f} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\Delta_h (1-\sigma-\xi)}{\left[(1-\theta_f)\Delta_h - \theta_f \Sigma_h\right]^2} > 0$$
$$\frac{\partial \hat{x}^*}{\partial \theta_h} = \left(\frac{\varepsilon - 1}{\varepsilon}\right) \frac{\theta_f (1-\sigma)(1-\sigma-\xi)}{\left[(1-\theta_f)\Delta_h - \theta_f \Sigma_h\right]^2} > 0$$

The proposition that when θ_h increases, the increase in $\hat{x}$ is greater than the increase in $\hat{x}^*$, simply means that $\frac{\partial\left(\frac{\hat{x}}{\hat{x}^*}\right)}{\partial\theta_h} > 0$.

$$\begin{aligned}
\frac{\partial\left(\frac{\hat{x}}{\hat{x}^*}\right)}{\partial\theta_h} &= \frac{\partial\hat{x}}{\partial\theta_h}\left[\frac{1}{\hat{x}^*}\right] - \frac{\partial\hat{x}^*}{\partial\theta_h}\left[\frac{\hat{x}}{(\hat{x}^*)^2}\right] \\
&= \left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{\Delta_f(1-\sigma-\xi)}{\left[(1-\theta_h)\Delta_f-\theta_h\Sigma_f\right]^2}\left(\frac{\varepsilon}{\varepsilon-1}\right)\frac{(1-\theta_f)\Delta_h-\theta_f\Sigma_h}{\Delta_h}\ldots \\
&\quad -\left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{\Sigma_f(1-\sigma-\xi)}{\left[(1-\theta_f)\Delta_h-\theta_f\Sigma_h\right]^2}\left(\frac{\varepsilon}{\varepsilon-1}\right)\left(\frac{\Delta_f\left[(1-\theta_f)\Delta_h-\theta_f\Sigma_h\right]^2}{\Delta_h^2\left[(1-\theta_h)\Delta_f-\theta_h\Sigma_f\right]}\right) \\
&= \frac{\Delta_f(1-\sigma-\xi)[(1-\theta_f)\Delta_h-\theta_f\Sigma_h]}{\Delta_h[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]^2} - \frac{\Delta_f\Sigma_f(1-\sigma-\xi)}{\Delta_h^2[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]} \\
&= \frac{\Delta_h\Delta_f(1-\sigma-\xi)[(1-\theta_f)\Delta_h-\theta_f\Sigma_h] - \Delta_f\Sigma_f(1-\sigma-\xi)[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]}{\Delta_h^2[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]^2} \\
&= \Delta_f(1-\sigma-\xi)\left(\frac{\Delta_h[(1-\theta_f)\Delta_h-\theta_f\Sigma_h] - \Sigma_f[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]}{\Delta_h^2[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]^2}\right) \\
&= \Delta_f(1-\sigma-\xi)\left(\frac{\Delta_h[(1-\theta_h-\theta_f)(1-\sigma)-(1-\theta_f)\xi] - \Sigma_f[(1-\theta_h-\theta_f)(1-\sigma)-(1-\theta_h)\xi]}{\Delta_h^2[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]^2}\right) \\
\frac{\partial\left(\frac{\hat{x}}{\hat{x}^*}\right)}{\partial\theta_h} &= \Delta_f(1-\sigma-\xi)\left(\frac{(\Delta_h-\Sigma_f)(1-\theta_h-\theta_f)(1-\sigma)+\xi\left[\Sigma_f(1-\theta_h)-\Delta_h(1-\theta_f)\right]}{\Delta_h^2[(1-\theta_h)\Delta_f-\theta_h\Sigma_f]^2}\right) > 0
\end{aligned}$$

The last line is true because $\Delta_h - \Sigma_f < 0$ and $\Sigma_f(1-\theta_h) - \Delta_h(1-\theta_f) > 0$. □

Proof of Proposition 2: Deflationary bias of imperfect competition. From (48) and (49):

$$\begin{aligned}
\frac{\partial\hat{x}}{\partial\varepsilon} &= \left(\frac{1}{\varepsilon^2}\right)\frac{\Delta_f}{(1-\theta_h)\Delta_f-\theta_h\Sigma_f} > 0 \\
\frac{\partial\hat{x}^*}{\partial\varepsilon} &= \left(\frac{1}{\varepsilon^2}\right)\frac{\Delta_h}{(1-\theta_f)\Delta_h-\theta_f\Sigma_h} > 0
\end{aligned}$$

Then, to find the respective levels of ε that induce the Home and Foreign monetary authorities, respectively, to set their money growth rates equal to 1 is found by solving (48) and (49) for ε when $\hat{x} = 1$ and when $\hat{x}^* = 1$.

$$\begin{aligned}
\bar{\varepsilon}: \quad 1 &= \left(\frac{\bar{\varepsilon}-1}{\bar{\varepsilon}}\right)\frac{(1-\theta_f)(1-\sigma)-\xi}{(1-\theta_h-\theta_f)(1-\sigma)-(1-\theta_h)\xi} \\
\bar{\varepsilon}^*: \quad 1 &= \left(\frac{\bar{\varepsilon}^*-1}{\bar{\varepsilon}^*}\right)\frac{(1-\theta_h)(1-\sigma)-\xi}{(1-\theta_h-\theta_f)(1-\sigma)-(1-\theta_f)\xi}
\end{aligned}$$

Solving these two equations for $\bar{\varepsilon}$ and $\bar{\varepsilon}^*$, respectively, gives the results in (50) and

(51).

$$\bar{\varepsilon} = \frac{\Delta_f}{\Sigma_h - \theta_h \xi} = \frac{(1-\theta_f)(1-\sigma) - \xi}{\theta_h(1-\sigma-\xi)}$$
$$\bar{\varepsilon}^* = \frac{\Delta_h}{\Sigma_f - \theta_f \xi} = \frac{(1-\theta_h)(1-\sigma) - \xi}{\theta_f(1-\sigma-\xi)}$$

□

Proof of Proposition 3: Market power neutrality. When the Home and Foreign Country are symmetric $\theta_h = \theta_f = \theta$, the equilibrium employment level is given by:

$$n = \left[\frac{\chi\xi}{(1-\theta)^{(1-\theta)(1-\sigma)}\theta^{\theta(1-\sigma)}}\left(\frac{\varepsilon}{\varepsilon-1}\right)\right]^{\frac{\Delta-\Sigma}{\Delta^2-\Sigma^2}} (\hat{x})^{\frac{\Delta}{\Delta^2-\Sigma^2}} (\hat{x}^*)^{\frac{-\Sigma}{\Delta^2-\Sigma^2}}$$

where $\Delta = (1-\theta)(1-\sigma) - \xi$ and $\Sigma = \theta(1-\sigma)$. The expressions for the optimal money growth rates in this symmetric case are given by:

$$\hat{x} = \hat{x}^* = \left(\frac{\varepsilon-1}{\varepsilon}\right)\frac{\Delta}{(1-\theta)\Delta - \theta\Sigma}$$

Now the equilibrium employment level can be written as:

$$n = n^* = \left[\frac{\chi\xi}{(1-\theta)^{(1-\theta)(1-\sigma)}\theta^{\theta(1-\sigma)}}\right]^{\frac{1}{1-\sigma-\xi}} \left(\frac{\varepsilon}{\varepsilon-1}\right)^{\frac{1}{1-\sigma-\xi}} \left(\frac{\varepsilon-1}{\varepsilon}\right)^{\frac{1}{1-\sigma-\xi}} \left[\frac{\Delta}{(1-\theta)\Delta-\theta\Sigma}\right]^{\frac{1}{1-\sigma-\xi}}$$
$$= \left[\left(\frac{\chi\xi}{(1-\theta)^{(1-\theta)(1-\sigma)}\theta^{\theta(1-\sigma)}}\right)\left(\frac{\Delta}{(1-\theta)\Delta-\theta\Sigma}\right)\right]^{\frac{1}{1-\sigma-\xi}}$$

It is clear that neither n nor n^* is a function of the level of imperfect competition ε. And because the equilibrium consumption levels are simply constant fractions of the output level, consumption is also not affected by changes in the level of imperfect competition. □

A-2 Two Cash-in-advance Constraint Setup

The two cash-in-advance constraints can be thought of as a simplification of one equilibrium outcome of a richer environment in which governments or monetary authorities strategically choose what currencies to accept for exchange that takes place within their borders. Matsuyama, Kiyotaki, and Matsui (1993) present a random matching search model of money after the flavor of Kiyotaki and Wright (1989) in which blocks of agents (countries) choose which currencies to accept for local and international transactions based on the likelihood of that currency being accepted in future transactions. In one equilibrium, corresponding to the two cash-in-advance constraint environment of this paper, each block of agents (country) only accepts local currency for all local and international transactions.

Another equilibrium in the Matsuyama, Kiyotaki, and Matsui (1993) is the case in which vendors in both countries accept currency of both countries. This is analogous to the more standard approach in the NOEM literature as exemplified by Corsetti and Pesenti (2001). Their environment is one characterized by a single cash-in-advance constraint in which producers sell their goods in both countries and charge a price in terms of Home currency and a price in terms of Foreign currency. The exchange rate is then pinned down by an assumption of the law of one price.

The reason for choosing the two cash-in-advance constraints approach as shown in equations (12) and (13) instead of the more standard Corsetti and Pesenti (2001) method of one cash-in-advance constraint and the law of one price is that the method employed here gives rise to a portfolio decision. The law of one price is implicit in the two cash-in-advance constraint assumption because, by definition, vendors only accept one currency and therefore only charge one price. As will be in Section 2.3, the exchange rate here serves as a price that clears the currency exchange market rather than a mechanism for enforcing the law of one price. Furthermore, the currency portfolio decision is an interesting one that has not received much attention. Engel and Matsumoto (2006) and Evans and Lyons (2005) are good international portfolio papers. However, both the single CIA constraint with the law of one price method and the dual CIA constraints with currency exchange market clearing method deliver the same results for optimal monetary policy.

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