Finance and Economics Discussion Series
Divisions of Research & Statistics and Monetary Affairs
Federal Reserve Board, Washington, D.C.

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2004-45

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July, 2004

Abstract

This paper illustrates that the introduction of a money demand distortion into an otherwise standard New Keynesian Open Economy model generates multiple discretionary equilibria. These equilibria arise in the form of expectations traps whereby the monetary authority is trapped into validating expectations of the private sector because failing to do so is costly. One implication of the model is that provided initial inflation expectations are sufficiently anchored the global Friedman rule emerges as an equilibrium under discretion. It is therefore a time-consistent outcome and hence fully sustainable even in absence of a commitment device or reputational considerations.

- **JEL Classifications:** E58, E61, F41, F42
- **Keywords:** Discretionary Monetary Policy, Expectation Traps, Friedman Rule, Time Consistency Problem

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1 Introduction

Nominal rigidities and monopolistic competition are two key assumptions underlying the New Keynesian Open Economy Macroeconomics literature.[1] When a monetary authority has no means of credibly committing to future policy actions, these same two assumptions generate a Kydland-Prescott and Barro-Gordon time consistency problem.[2] The natural linkages between these two branches of the literature has resulted in a number of recent contributions that make significant progress towards understanding the nature of the inflationary (or deflationary) bias in an open economy.[3] Thus far, however, surprisingly little work has been done in the direction of providing a complete characterization of the equilibrium under discretion in an open economy.

This paper develops a two-country, monetary general equilibrium model to address this gap in the literature. Drawing on features of Corsetti and Pesenti (2001), the model extends Ireland (1997) to an open economy setting. A key difference separating it from existing literature is the inclusion of a non-trivial money demand distortion.[4] This feature turns out to be important not only for optimal monetary policy under commitment, as illustrated in Arseneau (2004), but also for discretionary monetary policy. Specifically, the main result of this paper is that the joint presence of international linkages and a monetary distortion result in multiple discretionary equilibria that occur in the form of expectation traps as described in Chari, Christiano, and Eichenbaum (1998).[5]

To understand why multiplicity arises, it is easiest to begin with the intuition behind the optimal policy choice under discretion in a standard New Keynesian Open Economy setup. The monetary authority faces a trade-off between the benefits of unanticipated inflation and the costs of realized inflation. Nominal rigidities and monopolistic competition generate an inflationary incentive through the standard aggregate demand channel whereby unanticipated inflation reduces the markup distortion. However, doing so depreciates the local currency thereby raising the domestic

[1] Obstfeld and Rogoff (1995, 1996) are the seminal contributions. See Lane (2001) and Sarno (2001) for broad surveys and Bowman and Doyle (2003) for a survey of contributions specifically related to monetary policy.

[2] For a survey of the KPBG literature see Persson and Tabellini (1994). Obstfeld and Rogoff (1996, Chapter 9) surveys open economy extensions. More recent contributions that derive the time consistency problem in a closed economy general equilibrium setup include Ireland (1997), Neiss (1999), Chari, Christiano, and Eichenbaum (1998), Albanesi, Chari, and Christiano (2003a, b), and King and Wolman (2003).

[3] For example, Obstfeld and Rogoff (2002), Corsetti and Pesenti (2001, 2002), Tille (2001), Benigno (2001), and Benigno and Benigno (2003), among others.

[4] The previous literature models money in the utility function. Typically when studying optimal stabilization policy this literature ignors the monetary component of utility under the assumption that changes in the real component of utility will dominate changes in total utility.

[5] See also Albanesi, Chari, and Christiano (2003b). Christiano and Gust (2001) provide a discussion of the expectations trap hypothesis and its relation to US monetary policy.

currency price of imports relative to exports. This adverse shift in the short-run terms of trade can be thought of as a relative price distortion that results in inefficient substitution between domestic and foreign produced goods. The optimal policy decision therefore requires the monetary authority to weigh the welfare gain from exploiting the aggregate demand channel against the loss in welfare that occurs through the terms of trade channel. If the former channel dominates, it is optimal to introduce an inflationary surprise, the size of which equates the marginal benefit of unanticipated inflation to marginal cost. On the other hand, if the terms of trade channel dominates, the monetary authority desires instead to produce a deflationary surprise in order to gain a strategic advantage over the short-run terms of trade.

This policy trade-off is well documented in the existing literature. In particular, Corsetti and Pesenti (2001a,b) and Tille (2001) examine the determinants of the relative strengths of the aggregate demand and terms of trade channels as well as implications for international spillovers. Generally speaking, the terms of trade channel tends to dominate for all but the largest of countries, implying a deflationary bias is pervasive in open economies. This result stands in marked contrast to the standard inflationary bias found in the original Kydland-Prescott and Barro-Gordon literature as well as in more recent closed economy general equilibrium representations.

This paper introduces a minor variation to the standard New Keynesian Open Economy framework by assuming a transactions demand for money and introducing it via a cash-in-advance constraint. In this setup, rising inflation expectations drive up the nominal interest rate causing agents to inefficiently economize on real balance holdings. Output, which is already suboptimally low due to the monopolistic distortion, is driven even lower and farther away from its perfectly efficient level. As a result, the potential welfare gain from exploiting the aggregate demand channel grows monotonically. The money demand distortion therefore implies that the deflationary bias found in the previous literature only exists provided inflation expectations are sufficiently anchored, so that the monetary distortion is small.

More precisely, this paper illustrates that for any parameterization of the model there exists a threshold level of expected future inflation such that the terms of trade channel exactly offsets the aggregate demand channel. At this point the monetary authority has no incentive to introduce a surprise and an interior, knife-edge discretionary equilibrium emerges. However, if expectations are above this threshold the aggregate demand channel dominates and an inflationary bias emerges. Rational firms understand the inflationary incentive and respond optimally by raising prices to preserve monopoly profits. This defensive reaction on the part of the private sector traps the monetary authority into validating a high expected inflation outcome because failure to do so would mean generating a large, costly deflationary surprise. On the other hand, if expectations are sufficiently anchored such that they are below the threshold the terms of trade channel dominates a deflationary bias emerges. In this case, it is the rational Foreign government that responds optimally by contracting the Foreign money supply to the point at which the zero lower bound on the nominal interest rate binds with equality – the Friedman rule. Doing so prevents a "beggar-thy-neighbor" shift in the terms of trade. In this case it is the defensive actions of the Foreign government, as opposed to the actions of the global private sector, that traps the Home government into validating the global Friedman rule as the low inflation discretionary equilibrium.

Uhlig (2000) notes that existing literature rarely discusses the optimality of the Friedman rule in the same context as the dangers of the liquidity trap. Uhlig's dual message of the "benign Friedman rule" versus the "dreaded liquidity trap" is particularly relevant in the context of this paper. On the one hand, drawing on previous work by Arseneau (2004), one interpretation of the main result presented here builds on the fact that the global Friedman rule coincides with the cooperative Ramsey policy under commitment. Therefore, its emergence as an expectations trap equilibrium is desirable not only because is it time consistent, thus fully sustainable even in absence of a commitment device or reputational considerations, but also because it is globally efficient. Interestingly, this has the counter-intuitive implication that there exists a discretionary outcome that Pareto dominates the non-cooperative outcome under commitment.

Alternatively, another view suggests that international linkages generate deflationary expectations when policy is set non-cooperatively. As a result, strategic interaction over the short-run terms of trade pushes the world economy into a self-enforcing global liquidity trap. While the deterministic nature of this model implies that it is not suitable to formally address the question of which of these two interpretations is more relevant for policy purposes, it nonetheless is useful in drawing attention to the close linkages between the deflationary bias that commonly arises in New Keynesian Open Economy models and the constraints imposed by the zero lower bound on the nominal interest rate.

The remainder of the paper is organized as follows. The next section discusses the relation of this paper to existing literature on discretionary monetary policy in closed economy New Keynesian models. Section 3 describes the model. Section 4 examines the optimal monetary surprise and discusses the existence of open economy expectations traps. Section 5 discusses implications of the global Friedman rule as an expectations trap equilibrium. Finally, Section 6 concludes.

2 Related Literature

This paper is closely related to a small branch of the literature studying discretionary monetary policy in a closed economy New Keynesian framework. In particular, two recent papers that also find multiple discretionary equilibria are Albanesi, Chari, and Christiano (2003b) and King and Wolman (2003). While more closely related to the former, the results of this paper are complimentary to both.

Intuitively, a similar underlying structure is at the heart of all three papers. Nominal rigidities and monopolistic competition generate an inflationary incentive through an aggregate demand channel. However, exploiting this channel necessarily generates realized inflation, which is costly. In a general equilibrium framework the resulting policy trade-off generates a nonlinearity in the optimal response function of the monetary authority, which in turn produces multiple equilibria.[6] The key point of differentiation concerning the way in which multiplicity arises in each of the three papers lies in the source of the welfare costs of inflation.

Albanesi, Chari, and Christiano (2003b) study a cash and credit good model where a fraction of firms to set prices before the monetary authority sets policy in a given period. The demand for money arises by assuming that households purchase the cash good subject to a cash-in-advance constraint. In this setup inflation generates a money demand distortion because a rising nominal interest rate drives a wedge in the relative price of cash and credit goods, causing inefficient substitution between the two.

King and Wolman (2003) model the demand for money as arising from the "shopping-time" approach of King and Wolman (1996) where money is interest bearing. As in King and Wolman (1999), the analysis is conducted in the limit where the return on money approaches the market rate so the real cost of holding money goes to zero. This approach, in contrast to Albanesi, Chari, and Christiano (2003b), allows the authors to completely ignore distortions associated with money demand. Instead, the welfare costs of inflation arise as a result of staggered price-setting behavior on the part of firms. When firms set prices in different periods unanticipated inflation distorts the relative price of goods produced by firms that adjust prices contemporaneously and those that do not.

Here, as in Albanesi, Chari, and Christiano (2003b), the cash-in-advance constraint generates a money demand distortion. However, in contrast with both of the papers discussed above, it is assumed here that all firms set prices one period in advance. In a closed economy these two assumptions are not sufficient to generate multiple equilibria.[7] However, opening the economy to international linkages introduces an additional transmission channel whereby unanticipated monetary policy generates a relative price distortion through the terms of trade. Allowing this terms of trade channel to co-exist with the monetary distortion is the feature that generates the multiplicity in this paper.

3 The Model

There is perfect information in a world economy consisting of a Home and a Foreign country. A representative agent in each country provides labor to a continuum domestic firms, each with monopoly power over the production of a single differentiated

[6] The multiplicity in King and Wolman (2003) is more complicated than the multiplicity that arises in either this paper or Albanesi, Chari, and Kehoe (2003b) due to the existence of complimentarity in the pricing behavior of forward-looking firms.

[7] See Ireland (1997).

product sold both domestically and abroad. Money enters the model via a cash-in-advance constraint and there are no barriers to trade so the law of one price holds. A benevolent government in each country controls the domestic money supply by making lump-sum transfers of domestic currency to domestic households. Neither government is assumed to have access to a commitment device.

Initial period money stocks in each country are normalized at $t = 0$, so that $M_0^s = M_0^{*s} = 1$, and initial period bond holdings in each country are normalized, so that $B_0 = B_0^* = 0$.

3.1 Monetary Policy

The conduct of monetary policy is the sole function of each government in the model. In the Home country the government makes a lump sum transfer, $(x_t - 1) M_t^s$, of the Home currency to the Home representative agent in the beginning of every period. This is done by choosing x_t, the gross growth rate of the domestic money supply, M_t^s, with the objective of maximizing the welfare domestic households. The Foreign government solves a similar problem by making a lump sum transfer, $(x_t^* - 1) M_t^{*s}$, of the Foreign currency to the Foreign representative agent. The money stock follows $M_{t+1}^s = x_t M_t^s$ in the Home country and $M_{t+1}^{*s} = x_t^* M_t^{*s}$ in the Foreign country.

3.2 Households

Preferences of the representative Home household are defined over consumption of an aggregate consumption basket and labor.

$$U_t = \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} c_t^{1-\sigma} - l_t \right), \text{ where } 0 < \beta < 1 \text{ and } 0 < \sigma < 1. \quad (1)$$

The Home aggregate consumption basket consists of differentiated products produced by firms residing in both the Home and Foreign country. Define an index of per capita consumption of the Home and Foreign commodity bundles as follows

$$c_t = c_{H,t}^{\gamma} c_{F,t}^{1-\gamma}, \text{ where } 0 < \gamma < 1. \quad (2)$$

The Home commodity bundle, $c_{H,t}$, aggregates consumption by the Home agent of all differentiated products produced by firms residing in the Home country. Similarly, the Foreign commodity bundle, $c_{F,t}$, aggregates consumption by the Home agent of all differentiated products produced by firms residing in the Foreign country. Consumption of the Home and Foreign commodity bundles are defined as follows

$$c_{H,t} = \left(\int_0^1 c_t(h)^{\frac{\theta-1}{\theta}} dh \right)^{\frac{\theta}{\theta-1}} \text{ and } c_{F,t} = \left(\int_0^1 c_t(f)^{\frac{\theta-1}{\theta}} df \right)^{\frac{\theta}{\theta-1}}, \ \theta > 1. \quad (3)$$

There exists a Foreign counterpart to equation 1 defining the utility of the Foreign representative agent, U_t^*. Also, similar expressions to equations 2 and 3 define an index of per capita consumption for the Foreign agent, c_t^*, and Foreign consumption of the Home and Foreign commodity bundles, denoted $c_{H,t}^*$ and $c_{F,t}^*$, respectively.

The functional form used for preferences implies the elasticity of intertemporal substitution is given by $\frac{1}{\sigma}$. The consumption aggregator used in equation 2 is Cobb-Douglas implying unit elasticity of substitution between Home and Foreign commodity bundles. Finally, the elasticity of substitution between goods produced within a given country is constant at $\theta > 1$.

The Home currency consumption-based price index aggregates over the subindexes for the price of the Home and Foreign goods in the Home country denominated in the Home currency.[8]

$$P_t = \frac{1}{\gamma^W} P_{H,t}^{\gamma} P_{F,t}^{1-\gamma}, \text{ where } \gamma^W = \gamma^{\gamma} (1-\gamma)^{1-\gamma} \tag{4}$$

$$P_{H,t} = \left(\int_0^1 P_t(h)^{1-\theta} dh \right)^{\frac{1}{1-\theta}} \text{ and } P_{F,t}^* = \left(\int_0^1 P_t^*(f)^{1-\theta} df \right)^{\frac{1}{1-\theta}} \tag{5}$$

There exists a Foreign counterpart to equation 4 defining the Foreign currency consumption-based price index, P_t^*. There are no barriers to trade in the model so the law of one price holds across individual goods, $P_t(h) = S_t P_t^*(h)$, $\forall h \in [0,1]$ and $P_t(f) = S_t P_t^*(f)$, $\forall f \in [0,1]$. Furthermore, Home and Foreign agents are assumed to have identical preferences, implying that consumption based purchasing power parity (PPP) holds across the price of Home and Foreign commodity bundles, $P_{H,t} = S_t P_{H,t}^*$ and $P_{F,t} = S_t P_{F,t}^*$. Finally, by equation 4, PPP holds across the aggregate price index in each country.

$$P_t = S_t P_t^* \tag{6}$$

At this point it is useful to define the terms of trade, $ToT_t = \frac{P_{H,t}}{S_t P_{F,t}^*}$, as the price of exports relative to the price of imports, denominated in the Home currency.

Agents hold two assets, domestic currency and a one-period international bond denominated in the Home currency. The Home representative agent enters each period with nominal balances, M_t, and bond holdings, B_t. The Foreign representative agent enters each period with nominal balances, M_t^*, and bond holdings, B_t^*. Assume that in the initial period there are zero bond holdings in both the Home and Foreign country, $B_0 = B_0^* = 0$.

At the beginning of the period the Home representative agent receives the nominal lump-sum transfer, $(x_t - 1) M_t^s$, from the Home government and then goes to the

[8] The consumption-based price index for the Home country is defined as the minimum expenditure required to purchase one unit of the Home aggregate consumption bundle, given the prices of the Home and Foreign goods.

asset market.[9] In the asset market, bonds carried over from the previous period, B_t, mature, bringing money holdings of the Home representative agent to $M_t + (x_t - 1) M_t^s + B_t$. New bonds, B_{t+1}, are purchased at a price of $\frac{B_{t+1}}{R_t}$ units of Home currency at time t and return B_{t+1} dollars at $t+1$, where R_t is the gross nominal interest rate between time t and $t+1$. Similarly, the Foreign currency price of the bond is $\frac{1}{S_t} \frac{B_{t+1}^*}{R_t}$ units of foreign currency at time t, where S_t is the nominal exchange rate (Home price of a unit of Foreign currency). Upon conclusion of trade in asset markets the Home representative agent is left with $M_t + (x_t - 1) M_t^s + B_t - \frac{B_{t+1}}{R_t}$ in Home currency cash balances.

The representative household in each country then splits into a worker and a shopper. The shopper takes the remaining cash balances to the goods market. Assuming the existence of a frictionless foreign exchange market so that the representative shopper in either country can purchase both domestic and foreign goods, the Home shopper purchases a consumption basket, c_t , the price of which is given by P_t. The Home shopper faces the following cash-in-advance constraint

$$P_t c_t \leq M_t + (x_t - 1) M_t^s + B_t - \frac{B_{t+1}}{R_t}. \tag{7}$$

Meanwhile, the worker in the Home country supplies $l_t(h)$, $\forall h \in [0,1]$ units of labor to individual firms residing in the Home country. Firms use labor for production of a differentiated product also indexed by h. Foreign workers supply $l_t^*(f)$, $\forall f \in [0,1]$ units of labor to firms residing in the Foreign country. Define the following aggregators for Home and Foreign labor, respectively: $l_t = \int_0^1 l_t(h)\, dh$ and $l_t^* = \int_0^1 l_t^*(f)\, df$.

At this point production takes place, exchange occurs, and the goods and labor markets both clear. Workers receive a nominal wage denominated in the domestic currency, denoted W_t and W_t^* for Home and Foreign workers, respectively. Each firm pays out monopoly profits to domestic households in the form of a dividend. The dividend is denominated in the domestic currency, denoted $D_t(h)$ and $D_t^*(f)$ for the representative firm in the Home and Foreign country, respectively. Households in each country use unspent cash, wages, and dividends to accumulate domestic money to take into the next period, M_{t+1} and M_{t+1}^*.

The budget constraint for the Home representative household is

$$P_t c_t + \frac{B_{t+1}}{R_t} + M_{t+1} \leq M_t + (x_t - 1) M_t^s + B_t + \int_0^1 D_t(h)\, dh + W_t l_t. \tag{8}$$

[9] Note that the lump sum transfer, $(x_t - 1) M_t^s$, depends on the money holdings of the typical agent through money supply, M_t^s. Therefore, all Home agents receive an identical lump sum transfer regardless of the quantity of money they choose to bring into the period, M_t.

3.2.1 Household Optimization

Nominal variables in the cash-in-advance constraint and the budget constraint are scaled by the domestic money supply. Let lower case letters denote normalized variables, so for generic Home nominal variable, Z_t, its normalization is defined as $z_t = \frac{Z_t}{M_t^s}$ and its Foreign counterpart as $z_t^* = \frac{Z_t^*}{M_t^{*s}}$.

This allows the Home representative household's normalized cash-in-advance constraint to be expressed as[10]

$$p_t c_t \leq m_t + (x_t - 1) + b_t - \frac{b_{t+1} x_t}{R_t}. \tag{9}$$

The normalized budget constraint is as follows

$$p_t c_t + \frac{b_{t+1} x_t}{R_t} + m_{t+1} x_t \leq m_t + (x_t - 1) + b_t + \int_0^1 d_t (h) \, dh + w_t l_t. \tag{10}$$

Using this notation, the representative household in the Home country maximizes 1 subject to 2, 3, 9, and 10. The representative household in the Foreign country solves a similar problem.

3.3 Firms

Profit maximizing firms in both the Home and Foreign country enter each period with preset prices and produce output according to a linear production technology that requires one unit of labor to produce one unit of output. Let $Y_t (h) = l_t (h), \forall h \in [0, 1]$ denote the output of a typical firm residing in the Home country. Similarly, let $Y_t^* (f) = l_t^* (f), \forall f \in [0, 1]$ denote the output of a typical firm residing in the Foreign country. Aggregating output over all domestic firms yields total output produced in the Home and Foreign country, denoted Y_t and Y_t^* respectively.

$$Y_t = \int_0^1 Y_t (h) \, dh, \text{ and } Y_t^* = \int_0^1 Y_t^* (f) \, df$$

After production and exchange, each firm makes its wage payment to the worker and pays out profits to the representative household in the form of a dividend, denoted $d_t (h), \forall h \in [0, 1]$ and $d_t^* (f), \forall f \in [0, 1]$ for firms residing in the Home and Foreign country, respectively. Finally, at the end of the period each firm sets prices to maximize the period $t+1$ anticipated dividend. Given the linear production technology, the representative firm's profits equals price minus wage times quantity sold, where shoppers in the global goods market determine world demand for the good,

[10] In equations 9 and 10 we make use of the fact that $\frac{B_{t+1}}{M_t^s} \frac{1}{R_t} = b_{t+1} x_t \frac{1}{R_t}$, where $x_t = \frac{M_{t+1}^s}{M_t^s}$.

$c^W_{t+1}(h)$. The normalized profit function for a typical producer in the Home country is as follows.[11]

$$\underset{p_{H,t+1}(h)}{Max}\; E_t\left(p_{H,t+1}(h) - w_{t+1}\right) c^W_{t+1}(h)$$

The first order condition for a profit maximizing firm setting prices one period in advance is:

$$p_{H,t+1}(h) = E_t\left[\frac{\theta}{\theta - 1} w_{t+1}\right] \tag{11}$$

This equation says that at the end of period t each firm sets its price as a markup over the marginal cost that is anticipated to prevail in period $t+1$. Foreign firms solve a similar problem.

3.4 The Competitive Equilibrium

Conditional on Home and Foreign monetary policy, a competitive equilibrium obtains when all agents behave optimally and all markets clear. By manipulating the first order conditions of both households and firms, the competitive equilibrium can be expressed as a set of restrictions on prices and quantities that must hold in any competitive equilibrium for any given period. These restrictions are as follows.

$$c_t = \gamma \frac{x_t^{\gamma} x_t^{*1-\gamma}}{p_{H,t}^{\gamma} p_{F,t}^{*1-\gamma}},\; c_t^* = (1-\gamma)\frac{x_t^{\gamma} x_t^{*1-\gamma}}{p_{H,t}^{\gamma} p_{F,t}^{*1-\gamma}} \tag{12}$$

$$l_t = \frac{x_t}{p_{H,t}},\; l_t^* = \frac{x_t^*}{p_{F,t}^*}, \tag{13}$$

From equation 11, the optimal pricing setting behavior on the part of firms that $p_{H,t}$ and $p^*_{F,t}$ are set in the previous period as a markup over anticipated marginal cost. Anticipated marginal cost, in turn, is forecasted from the expected future paths of money growth and consumption.

$$E_{t-1}[w_t] = E_{t-1}\left[\left(\frac{1}{\beta}\right) x_t x_{t+1}\left(\frac{1}{c_{t+1}}\right)^{1-\sigma}\right],\text{ and} \tag{14}$$

$$E_{t-1}[w_t^*] = E_{t-1}\left[\left(\frac{1}{\beta}\right) x_t^* x_{t+1}^*\left(\frac{1}{c_{t+1}^*}\right)^{1-\sigma}\right]$$

As discussed in the next section, each government solves a non-cooperative Ramsey problem. Domestic monetary policy is chosen to maximize period utility of the domestic household, taking as given the actions of the other government and the optimal response of the global private sector, summarized by equations 12-14.

[11] The use of the expectations operator in a deterministic economy may seem odd. I use it for information accounting purposes. It serves as a useful reminder of the set of information available to each agent when solving the relevent optimization problem.

4 Discretionary Monetary Policy

Throughout the remainder of the paper we assume the global private sector is endowed in the intial period with an set of expectations regarding future steady state money growth in both Home and Foreign country. Let $x^e = E_0(x_t,)$, $\forall t = 1, 2, \ldots$ denote expected steady state money growth in the Home country and $x^{*e} = E_0(x_t^*,)$, $\forall t = 1, 2, \ldots$ denote expected steady state money growth in the Foreign country. Given initial expectations, each government, operating under discretion, has an incentive to generate a monetary surprise to influence the domestic real economy in the initial period of the model. Furthermore, these monetary surprises have international welfare spillovers. In this section we first analyze the optimal monetary surprise and then turn to the implications for the discretionary equilibrium.[12]

4.1 The Optimal Monetary Surprise

Denote the optimal monetary surprise in the Home country as $(\widetilde{x}_t - x^e)$ where $\widetilde{x}_t$ is the gross rate of period t money growth that maximizes the instantaneous utility of the representative agent subject to the restrictions implied by the competitive equilibrium, taking as given Foreign monetary policy. Specifically, $\widetilde{x}_t$ solves the following static optimization problem.

$$\max_{(\widetilde{x}_t)} \frac{1}{1-\sigma} c_t^{1-\sigma} - l_t$$

$$\text{subject to: } c_t = \gamma \frac{\widetilde{x}_t^{\gamma} x^{*e1-\gamma}}{p_{H,t}^{\gamma} p_{F,t}^{*1-\gamma}},\ l_t = \frac{\widetilde{x}_t}{p_{H,t}},\ \widetilde{x}_t \in [\beta, \overline{x}].$$

The solution is as follows:[13]

$$\widetilde{x}_t = \left(\gamma \Phi \frac{1}{\beta} x^{e\ 2-\gamma(1-\sigma)}\right)^{\frac{1}{1-\gamma(1-\sigma)}} \quad \text{and}$$

Let $\Omega = [\gamma, \Phi, \beta, \sigma]$ be a vector containing the structural parameters of the model. Substitute $\widetilde{x}_t$ back into the expression for the optimal monetary surprise and define the following:

$$g(\Omega, x^e) = \left[\left(\gamma \Phi \frac{1}{\beta} x^e\right)^{\frac{1}{1-\gamma(1-\sigma)}} - 1\right] x^e.$$

The function $g(\Omega, x^e)$ can be either positive or negative in sign implying that the optimal monetary surprise can be either expansionary or contractionary. Previous literature has concentrated only on the influence of the structural parameters, Ω, on

[12] We study the Markov-perfect equilibrium, which coinsides with the discretionary equilibrium in absense of reputation. The two terms are used interchangeable throughout the rest of the paper.

[13] Details are provided in a technical appendix available from the author upon request.

the optimal surprise. The novel feature of this paper is that, due to the inclusion of the monetary distortion, it is now also a function of expected domestic inflation.

4.2 The Policy Trade-off

The intuition behind why the optimal surprise can be either inflationary or deflationary comes from the fact that unanticipated inflation influences the real economy through two separate and opposing transmission channels. The first channel is standard in any new Keynesian framework and operates through aggregate demand. Nominal rigidities and monopolistic competition create an inflationary incentive whereby unanticipated inflation reduces the markup distortion. This channel can be seen directly by looking at equation 12. Recalling that $p_{H,t}$ and $p^*_{F,t}$ are set one period in advance, an unanticipated increase in the money supply, $\widetilde{x}_t > x^e_t$, increases the real balance holdings of the representative agent causing consumption demand to rise. Profit-maximizing firms respond by increasing production in order to satisfy demand. Increased production pushes output closer to its efficient level thereby reducing the distortionary effect of the markup.

In addition, there exists a second transmission channel – unique to the open economy dimension of the model – by which unanticipated domestic inflation shifts the burden of labor input away from foreign workers and onto domestic workers. This channel implies costs associated with exploiting the aggregate demand channel. If these costs are large enough a deflationary incentive emerges. To see this more clearly consider that an unanticipated monetary expansion causes an instantaneous depreciation of the nominal exchange rate, which, due to nominal rigidities, deteriorates the terms of trade. Home agents respond by substituting away from relatively more expensive imports and into relatively cheaper domestically produced goods, so $c_{F,t}$ falls and $c_{H,t}$ rises. Foreign agents benefit from a favorable shift in the terms of trade and similarly shift expenditures away from the Foreign produced good and into imports from the Home country, so $c^*_{F,t}$ falls and $c^*_{H,t}$ rises. The increase in Home export revenues causes Home import demand to rise, exactly offsetting the initial downward shift in import demand resulting from the deterioration of the terms of trade. The net effect leaves both $c_{F,t}$ and the current account balance unchanged.[14]

Overall, aggregate consumption rises equally in both countries leaving the ratio of Home to Foreign aggregate consumption unchanged. This can be seen using the Home and Foreign counterparts to equation 12.

$$\frac{c_t}{c^*_t} = \frac{\gamma}{1-\gamma}$$

[14]This offsetting effect is due to the functional form assumed for the consumption aggregator in conjunction with the zero initial bond holdings assumption. Together these two assumptions imply that the economy is in financial autarky with all international adjustment occuring through the terms of trade. See Cole and Obstfeld (1991) for details.

Expenditure switching resulting from a movement in the terms of trade, however, implies that the increased level of consumption in each country stems entirely from higher demand for the Home produced good. Equilibrium in the labor market, in turn, requires Home labor input to rise along with the increase in global demand for the Home produced good while Foreign labor input remains unchanged. This drives up the ratio of Home to Foreign labor input.

$$\frac{l_t}{l_t^*} = \frac{\widetilde{x}_t}{x^{*e}} \frac{p_{F,t}^*}{p_{H,t}}$$

For convenience, Table 1 provides a summary of the response of Home and Foreign real quantities to unanticipated inflation generated in the Home country holding constant Foreign monetary policy.

These opposing channels generate a policy trade-off which dictates the direction of the optimal surprise. When the welfare gain that resulting from the aggregate demand channel outweighs the loss in welfare that occurs through the terms of trade channel a unanticipated monetary expansion is "prosper-thyself" and creates a "prosper-thy-neighbor" spillover to the Foreign agent. If the opposite is true then an unanticipated domestic monetary expansion is "beggar-thyself". It is instead optimal to introduce a deflationary surprise to gain an advantage over the short-run terms of trade. Doing so causes a "beggar-thy-neighbor" welfare spillover.

4.2.1 A Fiscal Interpretation

The intuition becomes even more clear when one takes a fiscal interpretation of unanticipated inflation. An inflationary surprise can be thought of as a welfare-enhancing consumption subsidy designed to push output closer to its efficient level through Keynesian demand driven adjustment. Equivalently, if adjustment is viewed as occurring through the labor market, it can also be thought of as a welfare-reducing tax on leisure. According to this view, unanticipated inflation drives the real wage closer to the marginal product of labor enticing workers to optimally supply more labor to firms for production.

These two equivalent interpretations imply that the decision to introduce an inflationary surprise involves a trade-off. On the one hand, the surprise produces a welfare enhancing consumption subsidy. On the other hand, doing so requires levying tax on leisure that reduces welfare. This trade-off is relatively uninteresting in a closed economy absent additional distortions because under reasonable parameterizations of the utilty function the welfare gain of the consumption subsidy outweighs the loss in welfare due to the leisure tax. As a result, the optimal surprise is always expansionary as illustrated in Ireland (1997).

However, in the presence of international linkages the story changes. International trade allows the welfare gains from the consumption subsidy to be shared equally across countries via international trade. However, leisure is a nontraded good so the welfare cost of the leisure tax cannot be shared. Domestic workers must therefore work harder relative to their foreign counterparts to meet increased global demand for the Home produced good while still consuming in equal proportion. Thus, from a fiscal perspective a domestic inflationary surprise in an open economy can be interpreted as a global subsidy for consumption of the domestically produced good. At the same time, it acts as a strictly domestic leisure tax. An implication of this – previously noted in Benigno (2003) – is that a single government operating independently can never completely remove the global monopolistic distortion because it can only influence the domestic markup.

4.3 Comparative Statics

Three underlying distortions in the model determine the relative strength of these two transmission channels and hence whether the optimal monetary surprise is expansionary or contractionary. The role of the first two, the monopolistic distortion and the strategic terms of trade distortion, have been discussed in previous literature. The third, however, has not and it turns out to have important implications for the equilibrium under discretion.

4.3.1 Monopolistic Distortion

The monopolistic distortion arises because firms use the markup to restrict output, thereby maximizing monopoly profits. This generates an incentive for government to try to eliminate this distortion by exploiting the aggregate demand channel.

This incentive can be isolated in the special case of the closed economy, $\gamma = 1$, with steady state inflation expectations consistent with the Friedman rule, $x^e = \beta$. In this case, $g(\Omega, x^e) = \left(\Phi^{\frac{1}{\sigma}} - 1\right) > 0$, for $\theta < \infty$. The optimal monetary surprise is always expansionary illustrating that the monopolistic distortion generates an inflationary bias.

The strength of this bias is monotonically increasing with both the size of the markup and the elasticity of intertemporal substitution. In the case of the former, the intuition comes from the fact that as the markup grows output is pushed farther from its efficient level, strengthening the incentive to eliminate this distortion. In the case of the later, as the elasticity of intertemporal substitution rises the substitutability between consumption and leisure falls. This strengthens the inflationary incentive in the sense that it now takes a larger leisure tax to generate a shift in the real wage sufficient to eliminate the monopolistic distortion.

4.3.2 Strategic Terms of Trade Distortion

The strategic terms of trade distortion arises because each government is a monopoly supplier of domestic currency and therefore has a degree of monopoly power over the price of domestic goods on world markets. This generates an incentive to further restrict the output of domestic firms through a deflationary surprise.

This deflationary incentive can be isolated in the special case of perfect competition, $\theta \to \infty$, with steady state expectations consistent with the Freidman rule, $x^e = \beta$. In this case, $g(\Omega, x^e) = \left(\gamma^{\frac{1}{1-\gamma(1-\sigma)}} - 1\right) < 0$ in an open economy where $0 < \gamma < 1$. The optimal monetary surprise is always contractionary illustrating that the strategic terms of trade distortion generates an deflationary bias.

The strength of this bias is monotonically decreasing with country size. The intuition lies in the fact that as γ gets smaller domestic goods constitute a smaller share of the aggregate consumption basket. Therefore, any tax on the consumption of domestically produced good produces a large decline in labor input while only having a small impact on aggregate consumption.

Similar to its influence on the aggregate demand channel, as the elasticity of intertemporal substitution rises the strategic terms of trade channel grows stronger in the sense that it takes a larger deflationary surprise to achieve the desired shift in the terms of trade. This result, in conjunction with the comparative statics on the influence of the elasticity of intertemporal substitution on the strength of the aggregate demand channel, suggests that the absolute value of the magnitude of the optimal monetary surprise is a decreasing function of $\frac{1}{\sigma}$. In other words, as the elasticity of intertemporal substitution rises, the strength of both channels increases.

4.3.3 Monetary Distortion

Lastly, the final distortion operating in the model arises because rising inflation expectations push the nominal interest rate above zero implying that money is dominated in rate of return. Households inefficiently economize on real balances, substituting out of consumption and into leisure. Similar to the monopolistic distortion this generates an incentive for government to exploit the aggregate demand channel because output is driven further from its efficient level.

We can isolate this inflationary incentive in the special case of a closed economy under perfect competition, $\gamma = 1$ and $\theta \to \infty$. In this case, $g(\Omega, x^e) = \left(\left(\frac{1}{\beta}x^e\right)^{\frac{1}{\sigma}} - 1\right) < 0$ for any $x^e > \beta$. The optimal monetary surprise is always expansionary illustrating that the monetary distortion, like the monopolistic distortion, generates an inflationary bias.

The strength of this bias is monotonically increasing in expectations of future inflation. A higher the nominal interest rate generates a larger a distortion in the consumption/leisure decision, requiring a larger consumption subsidy to move output back to its efficient level.

4.4 Open Economy Expectation Traps

What happens when all three distortions interact simultaneously? For any parameterization of the model there exists a threshold level of initial steady state inflation expectations, $\overline{x}^e$, such that $g(\Omega, \overline{x}^e) = 0$. This threshold is given by the following in the Home and Foreign country, respectively:

$$\overline{x}^e = \frac{\beta}{\gamma\Phi} \text{ and } \overline{x}^{*e} = \frac{\beta}{(1-\gamma)\Phi}.$$

When $x^e = \overline{x}^e$ the welfare gains from exploiting the aggregate demand channel exactly offset the loss in welfare that occurs through the terms of trade channel implying that there are no gains from introducing a monetary surprise. The private sector understands this and an interior Markov perfect equilibrium emerges. This is, however, a knife-edge equilibrium. If inflation expectations are slightly above or below the threshold the monetary authority has an incentive to try to surprise the private sector.

First, consider the case where $x^e > \overline{x}^e$. The monetary distortion causes the aggregate demand channel to dominate. The optimal monetary surprise is expansionary and it creates a "prosper-thy-neighbor" welfare spillover to the Foreign agent. In a rational expectations equilbrium the global private sector understands this inflationary incentive and domestic firms respond by raising prices to restrict output such that it exactly offsets the expansionary impact of the inflationary surprise. Doing so preserves monopoly profits. In turn, the government understands the optimal response of firms and therefore desires to create an even larger monetary surprise. This serves only to drive inflation expectations higher. Recalling that the strength of the aggregate demand channel is monotonically increasing in the size of the monetary distortion, this iterative process continues until firms, anticipating the largest possible monetary surprise, set prices consistent with money growth being at its upper bound.[15] At this point, government has no alternative but to validate these expectations because failing to do so would generate a large deflationary surprise resulting in substantially large welfare costs. Hyperinflation emerges as a Markov perfect equilibrium.

Now consider the case in which initial inflation expectations are sufficiently anchored such that $x^e < \overline{x}^e$. The aggregate demand channel is weak relative to the terms of trade channel so that an unanticipated monetary expansion is "beggar-thyself". A deflationary surprise is optimal generating a "beggar-thy-neighbor" welfare spillover

[15] In absense of the upper bound a monetary equilibrium would not exist. Ireland (1997) and Chari, Christiano, and Eichenbaum (1998) also find corner solutions under discretion in closed economy models. As noted in Wolman (1999) the reason for this is that all firms set prices one period in advance so there is no cost to the monetary authority of introducing a monetary surprise regardless of whether it is inflationary or deflationary. Introducing some form of relative price distortion, such as through a cash-credit good setup or through staggered price setting, would produce interior multiple equilibria.

to the Foreign agent. Understanding that a deflationary surprise in the Home country generates an adverse shift in the terms of trade for Foreign agents, the Foreign government responses optimally by deflating. This defensive reaction on the part of the Foreign government generates an incentive for the Home government to create an even larger deflationary surprise with the iterative process ending when global private sector and Home and Foreign government expectations all coincide at the global Friedman rule. At this point the zero lower bound on the nominal interest rate binds, preventing further deflationary surprises.

Figures 1a and 1b provide graphic representations of the existence of multiple equilibria. Figure 1a considers the case of a small open economy, $\gamma = 0.1$, allowing the size of the monopolistic distortion to very. Figure 1b considers the case of the symmetric open economy. Comparing the two figures, or alternativly by looking directly at the expression for $\overline{x^e}$, illustrates that multiple equilibria arise in a larger part of the parameter space for smaller countries.

Finally, to facilitate comparison with the existing literature, table 2 shows threshold country size, $\overline{\gamma}$, for various levels of the markup and inflation expectations holding the discount rate constant, $\beta = 0.9$. A useful benchmark occurs under the parameterization $\theta = 6$, $x^e = \beta = 0.9$ where $\overline{\gamma} = 0.83$. This value reproduces Tille's (2001) result for the case of unit elasticity of substitution between the domestic and foreign produced commodity bundles[16]. The thing to note here is that Tille's result only holds in this model when $x^e = \beta$. This should not be surprising because there is no monetary distortion in Tille's (2001) paper and this is only true in this paper at the Friedman rule.

5 The Case For (and Against) the Global Friedman Rule

Uhlig (2000) notes that existing literature rarely discusses the optimality of the Friedman rule in the same context as the dangers of the liquidity trap. This point is particularly relevant in the context of this paper given the emergence of the global Friedman rule as an expectations trap equilibrium. In this section we present an informal discussion of two alternative interpretations of this result. The purpose is simply to draw attention to the close linkages between the deflationary bias that commonly arises in New Keynesian Open Economy models and the constraints imposed by the zero lower bound.

5.1 The glass is half full...

The deflationary bias has important implications for sustainability over long horizons because the zero lower bound implies that the global Friedman rule is a self-enforcing

[16] Specifically, it corresponds to the case of $\rho = 1$ in Table 4 of Tille (2001).

outcome in the presence of international linkages. It is therefore a time consistent outcome and fully sustainable even in absence of a commitment device or reputational considerations. In contrast, in a closed economy ($\gamma = 1$) the Friedman rule minimizes the severity of the time consistency problem, it does not eliminate it.

5.1.1 Rules vs. discretion revisited

In addition to sustainability the emergence of the global Friedman rule as a discretionary equilibrium has a counter-intuitive implication for the classic debate on rules versus discretion. Although a wide body of literature demonstrates that commitment is Pareto preferred to discretion, the opposite is true here over a large subset of the parameter space.

To see this we first need a description of the optimal non-cooperative monetary policy under commitment.[17] This problem takes a slightly different form than the one examined in the previous section. Rather than the static maximization problem of the previous section, when each government has access to a commitment device it must solve a non-cooperative Ramsey problem in the initial period subject to the restrictions on real quantities that must hold in a long-run competitive equilibrium. Specifically, the following restrictions must hold for the path of consumption and labor input in the Home country.

$$c = \left(\alpha\beta \frac{\theta - 1}{\theta} \frac{1}{x^{\gamma} x^{*1-\gamma}} \right)^{\frac{1}{\sigma}}, \tag{15}$$

$$l = \frac{1}{\gamma^W} \left(\left(\frac{1-\gamma}{\gamma} \right)^{\sigma} \frac{x^*}{x} \right)^{1-\gamma} c, \tag{16}$$

Where $\alpha = \gamma \left((1-\gamma)/\gamma \right)^{(1-\sigma)(1-\gamma)}$. The Home government's problem therefore is to set the sequence of domestic money growth rates to maximize discounted lifetime utility subject to 15, 16, and $x \in [\beta, \overline{x}]$, taking as given Foreign monetary policy, x^*. The Foreign government solves a similar problem.

The solution is presented in Table 2. The main thing to take away is that the Friedman rule is sub-optimal across much of the parameter space. Intuitively, anticipated inflation has the exact opposite real effects as does unanticipated inflation, so there is an incentive to inflate away from the Friedman rule to gain a strategic advantage over the long run terms of trade. Strategic use of the inflation tax, however, results in coordination failure by pushing the private optimum away from the constrained social optimum. Both governments would be better off if they could engage in international policy coordination by internalizing the strategic terms of trade externality, thereby restoring the optimality of the Friedman rule and returning the world economy to the Pareto frontier.

[17] This section draws heavily on previous work by Arseneau (2004). Readers interested in details are referred to that paper.

Alternatively, the results from the previous section indicate that if the commitment assumption is relaxed and inflation expectations are sufficiently anchored, strategic interaction over the short run terms of trade pushes the economy back to the constrained social optimum. In other words, over the majority of the parameter space of the model there exists a discretionary outcome that Pareto dominates the optimal non-cooperative Ramsey outcome under commitment. This result illustrates that an otherwise robust conclusion in the closed economy literature does not necessarily carry over into an open economy setting and illustrates the importance of strategic interaction when studying optimal policy in open economies.

5.2 ...or, is it half empty?

Stabilization policy plays no role in this paper because, trivially, there is nothing to stabilize. In the deterministic setting assumed here, the fact that the government is trapped into a situation in which the zero lower bound binds with equality is not troublesome. On the contrary, as discussed above, it is desirable.

However, in a more realistic stochastic setting it is worth drawing attention to the possibility that such an outcome could potentially lead to a much different conclusion. In a global liquidity trap non-cooperation self-enforces the constraints imposed by a zero lower bound that binds with equality in both countries. There are two implications of this. First, monetary policy cannot be used to respond optimally to shocks because money and bonds are perfect substitutes. In addition, escaping a global liquidity trap could potentially be considerably more difficult than escaping a liquidity trap in a closed economy. The reason for this is that it is not enough for domestic expectations to coordinate to the high inflation outcome to escape the trap, it must be the case that both the domestic and foreign private sector cooperate in coordinating expectations to escape the global trap.

6 Conclusion

This paper derived a two-country, monetary general equilibrium model to analyze the discretionary equilibrium when monetary policy is set non-cooperatively in an open economy. The main result of the paper is that introducing a money demand distortion into an otherwise standard New Keynesian Open Economy framework generates multiple equilibria that take the form of expectation traps. An important implication is that, provided initial inflation expectations are sufficiently anchored, the global Friedman rule emerges as an expectations trap equilibrium.

Looking forward, in future research it would be useful to understand how alternative assumptions regarding the price setting behavior of firms influence the results in this paper. For example, it would be interesting to introduce staggered price setting or pricing-to-market behavior on the part of firms. Second, Albanesi, Chari, and Kehoe (2003a) show that in a closed economy the functional form of money demand has an important influence on the severity of the time consistency problem. In light of this, another interesting direction is to examine the robustness of the multiplicity found here to alternative functional forms for money demand.

Finally, this paper presented an informal discussion of two alternative views of the emergence of the global Friedman rule as an expectations trap equilibrium. In order to formalize this discussion progress is needed on two fronts. First, although some work has been done in the closed economy literature, for example Wolman (2004), very little has been done on the real implications of the zero lower bound in an open economy setting. Second, recent proposals by McCallum (2000) and Svensson (2003) involve using exchange rate targets to escape liquidity traps. It would be interesting to see if these proposals generalize to a two country setting when policy is set non-cooperatively.

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Table 1. Threshold country size, γ, given markup and inflation expectations, $\beta = 0.9$.

	$x^e = 0.9$	$x^e = 1.0$	$x^e = 1.025$	$x^e = 1.05$	$x^e = 1.1$	$x^e = 1.5$	$x^e = 2$
$\theta = 2$	0.50	0.45	0.44	0.43	0.41	0.30	0.23
$\theta = 6$	0.83[1]	0.75	0.73	0.71	0.68	0.50	0.38
$\theta = 8$	0.88	0.79	0.77	0.75	0.72	0.53	0.39
$\theta = 12$	0.92	0.83	0.80	0.79	0.75	0.55	0.41

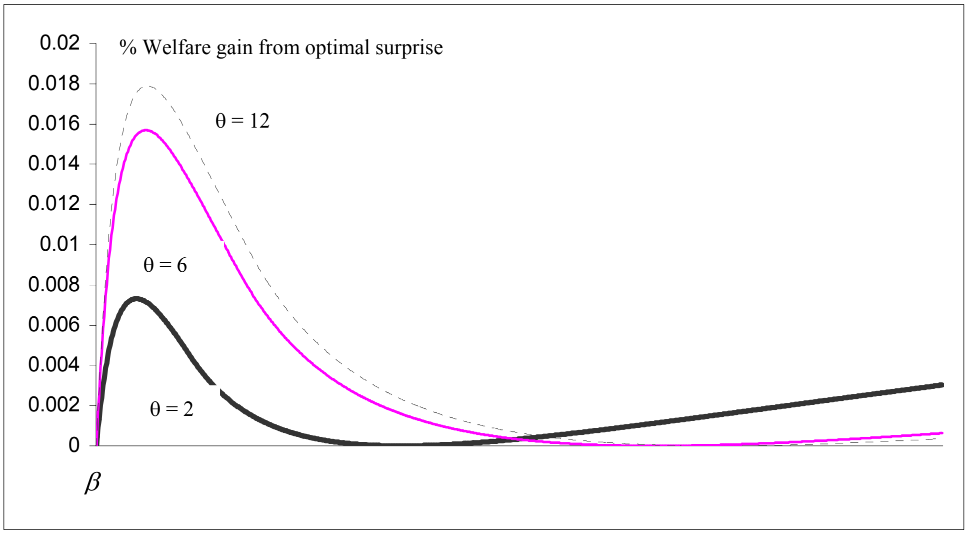
Notes: For a given parameterization, values of γ below the table entry imply the optimal monetary surprise is deflationary. Values of γ above the table entry imply the optimal monetary surprise is inflationary. [1] Represents threshold country size under the paramterization used in Tille (2001),, table x, for $\rho = 1$.

Table 1. Nash-Ramsey world monetary policy

	$\Phi > D^*$	$\Phi > D^*$
$\Phi > D$	$x = x^* = \beta$ $R = R^* = 1$	$x = \beta;\ x^* = \beta \frac{1}{\Phi} D^*$ $R = 1;\ R^* = \frac{1}{\Phi} D^*$
$\Phi \le D$	$x = \beta \frac{1}{\Phi} D;\ x^* = \beta$ $R = \frac{1}{\Phi} D;\ R^* = 1$	$x = \beta \frac{1}{\Phi} D;\ x^* = \beta \frac{1}{\Phi} D^*$ $R = \frac{1}{\Phi} D;\ R^* = \frac{1}{\Phi} D^*$

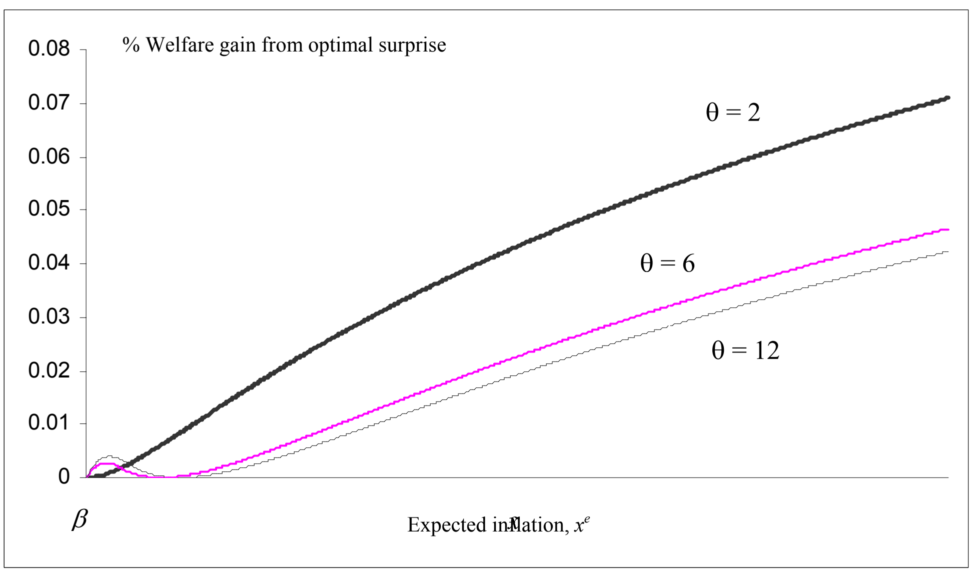
Notes: $\Phi = \frac{\theta}{\theta - 1}$; $D = 1 + \frac{1-\gamma}{\gamma}\sigma$; $D^* = 1 + \frac{\gamma}{1-\gamma}\sigma$.

Figure 1a. Welfare gain from the optimal monetary surprise,
$\beta = 0.9$, $\sigma = 0.9$, $\gamma = 0.1$.



Note: Under all three parameterizations there are three Markov perfect equilibria: the Friedman rule, an interior equilibrium, and the worst possible hyperinflation.

Figure 1b. Welfare gain from the optimal monetary surprise,
$\beta = 0.9$, $\sigma = 0.9$, $\gamma = 0.5$.



Note: When $\theta = 2$ there are two Markov perfect equilibria: the Friedman rule, and the worst possible hyperinflation. When $\theta = 6$, 12 there are three: the Friedman rule, an interior equilibrium, and the worst possible hyperinflation.