This is page 0 and is to be ignored

Comment on Ben McCallum,
'Theoretical Analysis Regarding a Zero Lower Bound on Nominal Interest Rates'
by
Lawrence J. Christiano

1. Introduction

The sharp decline in interest rates in the past two decades has shifted attention to a new policy question. Do low interest rates interfere with the ability of a central bank to do its job? Some say the answer is *yes.* According to them, with rates low the central bank has lost the option to cut them further in the event of a bad economic shock.[1] According to McCallum, the right answer is *no.* He asserts that the central bank has a second tool for stabilizing the economy: the exchange rate. He maintains that the central bank can stabilize the economy by exploiting its control over the exchange rate, even if it cannot cut the interest rate because it is stuck on its zero lower bound.

According to McCallum's model, exchange rate policy can even lift the economy out of the worst case scenario. This occurs when the nominal rate of interest is zero and the expected future price level and exchange rate are fixed because the public firmly believes the central bank is committed to a price level target. In this scenario, a standard prescription for stimulating the economy - reduce the real interest rate by committing to loose money in the future - is ineffective. According to McCallum's model, this worst case scenario is not as big a problem as it might seem. The central bank can still stimulate the economy by depreciating the currency through purchases of foreign exchange.

In my comment I make two points:

(1) McCallum's prescription for avoiding problems associated with the zero bound constraint rests on the dubious notion that sterilized currency intervention is effective.

(2) A full evaluation of the potential dangers of low interest rates requires also assessing the role of the central bank in managing shocks to the general level of economic 'confidence'. These are excluded from McCallum's framework. I take a 'baby' step in the direction of the type of analysis I think is needed.

In short, McCallum does not provide a compelling theoretical (or, other) basis for allaying the fears of a central banker who is worried about the supposed dangers of low interest rates.

Before going into details, I now provide a brief summary of the discussion. Consider (1) first. In a conventional open market operation, a central bank exchanges domestic assets for domestic currency. This is thought to have no effect on the economy when the interest rate is zero, since in this case domestic assets and currency are perfect substitutes. In a sterilized foreign currency purchase, the central bank buys foreign exchange with domestic

[1] Interest rates cannot be pushed below zero because money is assumed to have a sure rate of return of zero (I ignore storage costs). To see that this rules out a negative market rate of interest, suppose to the contrary that the money market-clearing rate of interest rate *is* negative. Then, anyone holding money maximizes their return by holding on to it. Moreover, the arbitrage opportunity would make the demand for money infinite. Markets obviously cannot clear with infinite demand and no supply.

currency, and then neutralizes ('sterilizes') the impact of this on the domestic currency by selling domestic assets. The increased demand for foreign exchange represented by the central bank action is thought to trigger additional demands from private portfolio managers, when domestic and foreign assets are imperfect substitutes. The reason for this is that sterilized intervention increases the share of domestic versus foreign assets in private portfolios. Risk averse portfolio managers try to reduce their exposure to domestic assets by selling them, and buying foreign assets. The foreign exchange that they demand in the process adds to the demand already coming from the central bank. The notion is that this general increase in demand produces a depreciation in the value of the currency. Now, McCallum's recommendation to central bankers in a zero interest rate environment is that they undertake *un*sterilized foreign exchange purchases. So, strictly speaking, it is wrong to analyze his proposal as though he were recommending *sterilized* foreign exchange intervention. Still, it is only a very slight misuse of terminology to do so, since in a zero interest rate environment, whether or not the sterilization step is taken is irrelevant, because domestic currency and assets are perfect substitutes in this case.

The connection between foreign currency purchases in a zero interest rate environment and sterilized foreign exchange operations is very useful for present purposes. This is because there exists an extensive literature which attempts to assess the effectiveness of the latter. The general conclusion of this literature is that sterilized foreign exchange operations are *not* effective in producing a change in the exchange rate.[2] In the end, it may be that the only real effect of the imperfect asset substitutability channel is a pernicious one. Central bankers who believe in it may be encouraged to think that when interest rates are positive, they have *two* tools for conducting monetary policy: conventional open market operations and sterilized foreign currency purchases. Under these circumstances, it is natural for them to be lulled into thinking that domestic priorities and foreign exchange objectives can be pursued independently. Such central bankers could easily find themselves taking actions which spark a socially costly foreign exchange rate crisis.[3] Indeed, the mere suspicion by

[2] There are various possible reasons for this. For example, the sheer size of foreign and domestic assets may be too large for central bank open market operations to appreciably affect their relative magnitude. Another argument is presented in Backus and Kehoe (1989). They argue that sterilized interventions that are large enough to significantly alter the risk characteristics of household portfolios also alter the risks in the consolidated government budget constraint. How people expect governments to adjust their state-contingent tax, spending and monetary policies to accommodate this change in risk may play an important role in determining the economic consequences of sterilized interventions. If these expectations vary across different intervention episodes, then we would expect to find no systematic pattern of response, according to Backus and Kehoe. For a summary of the empirical literature, see Krugman and Obstfeld (1997), chapter 17.

[3] Consider the following example of an economy in which the rate of interest is positive, the central bank has a fixed exchange rate policy, and the central banker believes in the effectiveness of sterilized foreign exchange interventions. Suppose the country with which it fixes its exchange rate raises its interest rate sharply, perhaps because it fears inflation. Normally, the fixed exchange rate regime requires raising the domestic interest rate. However, suppose that doing so would inflict considerable pain on the domestic economy because output and employment are low, the banking system is in a weak and fragile state, and there is a presidential election on the horizon. According to conventional economic reasoning, the foreign and domestic priorities of the central bank are in sharp conflict. But, the central banker who believes that sterilized foreign exchange operations are effective is likely to think that he has the tools preserve the fixed exchange rate regime, while not raising the domestic rate of interest. He will try to keep the domestic money supply unchanged while at the same

foreign exchange speculators that a central banker believes in the effectiveness of sterilized foreign exchange operations could spark a currency attack.[4]

So, there is little empirical support for McCallum's idea that exchange rate policy offers a way around the zero bound constraint on the interest rate. Moreover, the two-tool view about central banking on which his advice is based is uncomfortably hospitable to some ideas that have led many central bankers to an unhappy end.[5] But, is there some compelling *theoretical* argument in McCallum's paper that overwhelms these concerns? The answer here is no. A shortcoming of McCallum's paper is its loose theoretical foundations. The heart of the analysis - the mechanism by which the central bank affects the exchange rate when the interest rate is zero - is left substantially unspecified. This would be fine if there existed a body of literature that did flesh out the logical foundations of McCallum's argument. In this case, we could feel comfortable that his analysis somehow hangs together. But, this is not the case. The economics of the zero bound constraint is unfamiliar territory, and one wonders to what extent the conclusions and concerns rest on solid logical foundations.

For this reason, I present a formal analysis of a completely worked, open economy model. The example elaborates on the discussion of Krugman (1998) using a model in Obstfeld and Rogoff (1996). It shows that, when the interest rate is zero, conventional open market operations have *no* effect on the exchange rate (or, anything else). The example supports Krugman's idea that the exchange rate does not provide a way around the constraints imposed on policy by the zero bound restriction on the interest rate. The example does not incorporate the kind of risk considerations discussed above. But, I am not aware of any fully worked out model that does. McCallum's does not.

Does McCallum's framework capture all the reasons why policy makers are concerned about low interest rates? In part (2) of my comment I argue that the answer is no. Policy makers seem to feel that the option to cut interest rates is an important tool to preserve the 'general level of confidence'. The idea is that, at times, financial markets become fragile and

---

time conducting sterilized sales of foreign assets. He will expect that the resulting increase in sales of foreign exchange (both by the central bank itself, and portfolio managers unhappy with the resulting fall in the share of domestic assets in their portfolios) will serve to protect the exchange rate from falling.

But now suppose that sterilized foreign exchange operations are in fact ineffective, as the empirical literature suggests. In this case, the central bank will simply experience a loss in its foreign exchange reserves. In the end, when the reserves are gone, we can expect that the devaluation will occur anyway.

[4] To see this, consider the example in the previous footnote. Any speculator who can see through that scenario to its end point, would be motivated to go to the central bank and turn in domestic currency in exchange for foreign exchange. With a lot of speculators thinking this way, we have a Krugman (1979) - style speculative attack. The example is designed to resemble Mexico (domestic economy) versus the United States (foreign economy) in 1994.

[5] There is one important practical distinction between the policies advocated by McCallum and those that have brought ruin to some central bankers. In particular, McCallum's policy of depreciating the currency would *increase* the central bank's holdings of foreign reserves. The policy that has brought disaster down on some central bankers - defending the exchange rate against a depreciation - produces a *decrease* in those reserves. The latter raises the specter of speculative attack, while McCallum's policy does not. And, I do not wish to suggest that it does. What I am saying is that the 'two tool' view of central banking, to which McCallum implicitly subscribes, *can* lead to such attacks. It is a very small step to slip from McCallum's idea that you can *depreciate* your currency without changing your interest rate to the idea that you can *appreciate* your currency without changing your interest rate.

are vulnerable to a collapse in confidence that can - through balance sheet or other effects - lead to a fall in economic activity. There is a view that the central bank has a constructive role to play in preventing these crises altogether, or at least mitigating their impact once they do occur. The Fed's commitment to reduce interest rates in the event of a major stock market crash is an example. This policy may, by supporting market confidence, prevent the stock market from crashing in the first place, or at least mitigate the consequences if it does fall. Now, obviously if the rate of interest is set at zero, then the policy is not feasible. How important is this? If the Fed had not been able to cut rates sharply in October 1987, or August 1998, would this have made a difference? To answer these questions, we need to construct models which incorporate all the ingredients of the concerns about 'confidence'. This will enable us to understand whether, first, the concerns are well founded and, second, whether interest rate policy is the only way to address these concerns. If the answer to both questions is 'yes', then of course this provides another reason to keep the interest rate well above its zero lower bound. The discussion below presents a model that can be used to articulate these issues.

In the following section, I provide a very simple statement of McCallum's basic point. The two sections after that elaborate on (1) and (2) above. Concluding remarks appear in the last section.

2. McCallum's Argument

In a nutshell, McCallum's argument goes like this. He uses a sticky-price IS-LM model in which some of the equations have been previously derived from an optimizing framework. McCallum begins with a conventional analysis of this model, in which the central bank influences the level of economic activity through its control over the nominal rate of interest. For example, if the economy is in a recession, then by conducting a conventional open market purchase of domestic assets, the central bank drives down the nominal rate of interest. This stimulates nominal spending which, because prices are assumed to be sticky, translates into an increase in real output (Blanchard and Kiyotaki (1987)). When the nominal rate of interest is on its zero-bound constraint, this mechanism is short-circuited. Demand cannot be stimulated in this way because it is not possible to drive the rate of interest down lower.

At this point, there are various possibilities. They are best described by considering a stylized version of McCallum's IS curve:

$$y^d = f(r),\ 1 + r = (1 + i)\,\frac{P}{P^e},$$

where y^d is aggregate demand, r is the real interest rate, P is the current price level, and P^e is the expected future price level. When $i = 0$, then the possibility of stimulating y^d by reducing i further is foreclosed. A second possibility, emphasized recently by Krugman (1998), is that the monetary authority can stimulate y^d by committing to increasing the money supply in the *future*, raising P^e. Since it is actually the *real* interest rate that is thought to drive investment and durable goods spending, raising P^e is another way the central bank can stimulate demand. The central message of McCallum's paper is that, in an open economy setting, there may be a third channel by which the central bank can influence aggregate demand. This is of interest because there may be several reasons why it is not possible for the central bank to influence P^e. One scenario is that the public is so convinced of the central bank's commitment to price stability that an announced policy of increasing the money supply in the future may simply be non-credible. Another, emphasized in Fuhrer and Madigan (1997) and Orphanides and Wieland (1998), is that price stickiness may be extend over a sufficiently long horizon that P^e is sticky too. So, McCallum's argument that there is another way to stimulate aggregate demand when $i = 0$ is substantial potential interest.

To explain McCallum's argument, consider the aggregate demand curve, modified to reflect the open economy framework:

$$y^d = f(r, nx(q)), \; q = \frac{sP^*}{P},$$

where nx denotes net exports, q denotes the real exchange rate, s denotes the nominal exchange rate and P^* denotes the foreign price level. Again, P is treated as temporarily fixed due to sticky-price considerations. And, P^* is beyond the control of the domestic monetary authorities. McCallum argues that the ability of the central bank to influence q via its control over s offers another channel by which it can influence demand. The central bank can stimulate the economy by bringing about a depreciation of the currency, i.e., increasing s.

According to McCallum, this is still possible, even when $i = 0$. He posits a kind of Taylor rule for s :

$$s = s_{-1} + \mu_0 - \mu_1(\Delta p - \pi) - \mu_2 E_{-1}\tilde{y} + e,$$

where π is the target inflation rate, $\Delta p = \log(P/P_{-1})$, and $\tilde{y}$ is the percent deviation of output from its trend, the value it would take on if there were no sticky prices. Also, e is a monetary policy shock. Of course, if you add an equation like this to the open economy IS-LM model, you have to take another one out. The equation McCallum removes is the uncovered interest parity (UIP) relation:

$$1 + i = (1 + i^*)\frac{s^e}{s},$$

where s^e is the expected future exchange rate. McCallum shows that, even when i is fixed at zero, s shows up in the reduced form expression for output. So, monetary policy remains effective in McCallum's model, despite the fact that $i = 0$. He has pulled an end run around the zero bound constraint. Or has he?

In one sense, it should be surprising that exchange rate policy is still possible. In standard textbooks, the UIP condition lies at the heart of the mechanism whereby the monetary authority influences s.[6] The mechanism is a recursive one: first, the central bank affects the domestic interest rates by open market operations, and then, via the UIP, there is a change in s. Now, at the level of algebra, it is not surprising that movements in s influence equilibrium output in the model. With P sticky and P^* exogenous, a shift in s induces a

[6] See, for example, Krugman and Obstfeld (1997), chapter 14, or Blanchard (1997), chapter 13.3.

shift in q, which moves nx and, hence, y^d. The problem is not the algebra, it's the economics. The economics of how the central bank influences s is left unclear in McCallum's paper.

The discussion in the introduction suggests one interpretation, based on imperfect asset substitutability.[7] Under this interpretation, $\rho(B^d/B^f)$ is added to the right hand side of the UIP relation, where B^x is quantity of domestic ($x = d$) and foreign ($x = f$) holdings of bonds in private portfolios and ρ is an increasing function. Under this modification, the central bank can influence s even if s^e and i are both fixed, simply by conducting sterilized foreign exchange interventions.[8] What this does for the logical coherence of McCallum's model is left unclear, however. The UIP relation is an Euler equation in the optimization model that underlies McCallum's IS-LM specification. Whether some credible modification can be found that rationalizes adding $\rho(B^d/B^f)$ to the right hand side of this equation is not established.

What is clear is that dropping, or modifying, the UIP relation is fundamental to McCallum's thesis that the central bank can influence the exchange rate even when the domestic interest rate is fixed. This is particularly clear when McCallum's analysis is compared with Krugman (1998), which also considers the possibility that the central bank can influence the exchange rate when the interest rate is at its lower bound. The latter paper concludes that exchange rate policy does *not* provide a way around the zero bound constraint.

3. The Zero Bound Constraint in the Open Economy

Why do Krugman (1998) and McCallum arrive at opposite conclusions? In this section, I argue that it has to do with their treatment of the UIP relationship. When that relationship is in place, then exchange rate policy does *not* provide a way around the zero bound constraint. In the first section below, I elaborate on this point informally. I then do so formally using a standard, dynamic open economy model.

A. Intuitive Argument

When the domestic nominal rate of interest rate is zero, then the UIP reduces to:

$$1 = (1 + i^*)\frac{s^e}{s}.$$

Now, the novelty of McCallum's argument is that it purports to find a way around the zero bound constraint which does not require convincing people that monetary policy will be expansionary in the future. Otherwise, the existing prescriptions described above, which involve driving down the real rate of interest, are available. For this reason, I will keep s^e fixed in the remainder of this subsection. I will ask whether it is possible to depreciate the currency, i.e., drive up s, through monetary policy. The discussion basically involves elaborating on the economics of the UIP relation. Since Japan is currently the paradigm example of a country caught in the zero bound, I will for concreteness think of the 'domestic economy' as Japan and the central bank as the Bank of Japan (BOJ).

[7] This was suggested to me verbally by McCallum at the conference.

[8] For an analysis of the IS-LM model with this modification to the UIP relation, see Krugman and Obstfeld (1997, chapter 17). As noted in the introduction, the modification effectively gives the central bank a second tool with which to conduct monetary policy.

When $i = 0$, why would people hold assets denominated in Yen if $i^* > 0$ is available abroad? The answer, according to UIP, is that they anticipate that the Yen will appreciate. For example, US interest rates have been higher than Japanese rates for about two decades. Why did this not spark massive capital outflows from Japan? The best answer we have is based on UIP. With only a few exceptions (the period from 1995 to 1998 was a long one) the Yen has steadily appreciated relative to the dollar since the early 1970s. Presumably, when people caught on to this, they began to anticipate that the trend would continue. In this way, foreigners holding assets in Japan expected to be compensated for their low nominal return through currency appreciation. Similarly, Japanese residents holding low-yielding Japanese assets chose not to hold the higher-yielding foreign assets instead because they anticipated that those returns would be reduced by foreign currency depreciation.

In conventional textbook treatments, the way the monetary authority raises s is by reducing i through open market purchases of domestic financial assets. The idea is that the cut in i sparks a capital outflow, as people seek higher returns abroad. In their attempts to sell domestic currency for foreign currency, traders then cause it to depreciate until UIP is restored. At this point, the pressure for capital to flow abroad ceases. When $i = 0$, this mechanism is inoperative. People view Yen currency and Yen interest bearing assets as equivalent, since they both generate the same expected return, zero. As a result, open market purchases of financial assets by the BOJ have no impact on prices or rates of return. By extension, they therefore do not affect the exchange rate.

But, what if instead the BOJ purchases *foreign currency* in exchange for Yen? Could this direct intervention in the exchange market produce a depreciation in the Yen? Do purchases of foreign currency represent a tool that is effective at controlling the real economy, even when conventional open market operations cease to be effective because of the zero lower bound? According to UIP, the answer is no. The logic is in part an implication of the same reasoning underlying the notion that domestic open market operations can't work when the rate of interest is zero. And, in part it is an implication of the fact that UIP focuses only on the mean return to assets, not other moments.

Suppose the BOJ buys US dollars and converts them into US government securities.[9] What has happened to households' balance sheets? One 'interest-bearing' asset (i.e., Yen currency) has replaced another (US government securities), which have the same expected return. According to UIP, which assumes traders focus only on expected returns, this should have no impact on any asset price or return. In effect, an open market purchase of foreign exchange is equivalent to a sterilized intervention, when the nominal rate of interest is zero.

Of course, the change in the asset composition of households' balance sheets may alter its risk characteristics. If households were happy with the composition of Yen and US dollar assets before the BOJ intervention, then perhaps they would not be afterward at

[9] If they don't convert its dollars into securities, then the BOJ operation is tantamount to a contractionary US open market operation. This would ordinarily lead to a rise in the US interest rate, i^*, which would then lead to a depreciation of the Yen. But, to highlight the novelty of McCallum's argument, I want to hold i^* fixed. For example, if the BOJ did not convert its increased dollar holdings into US securities, and the Fed were following an interest rate target, then it would automatically undo the effect of the BOJ operation on the US money supply by purchasing US government debt in exchange for dollars.

unchanged exchange rates and asset prices. Inducing households to shift the composition of their portfolios towards Yen and away from dollar assets may require a rise in the relative price of the latter. And, in principle this could be achieved by a depreciation of the Yen. But, as noted in the introduction, the data suggest that, at best, this effect is small.[10]

B. A Formal Example

Following is a formal model which illustrates the effects on monetary policy when UIP holds. Here, I basically elaborate on the argument in Krugman (1998), using the plain vanilla, off-the-shelf cash advance version of the deterministic, sticky-price, traded good/nontraded good, small open economy model in Obstfeld and Rogoff (1996, chapter 10.2).

The basic result is that when there is a temporary, unexpected increase in the money supply, real output increases, the exchange rate depreciates and the interest rate falls, as long as the interest rate is positive. As soon as the interest rate reaches its zero lower bound, then all effects of further increases in the money supply cease: output, the interest rate, the exchange rate do not change.

In the previous example, the assumption that the increase in the money supply is temporary is crucial. I show that if the money supply increase is instead viewed as permanent, then the interest rate does not fall with an increase in the money supply. In this case, the lower bound on the interest rate does not constrain the central bank's ability to stimulate the economy. This result underlines Krugman's argument that, to stimulate an economy that is on the zero bound constraint, it is necessary to convince people that future money will be increased.

The example is constructed to be as simple and standard as possible, subject to getting my point across. The open economy complication is obviously needed if we are to talk about exchange rates at all. In addition, I introduce price setting (and, I need monopolistic competition for that) so that monetary policy does have real effects when the interest rate is above its lower bound.

Statement of the Model

Each time period is divided into three parts. In the first, producers in the nontraded good sector set their prices, and commit to supply whatever demand materializes later in the goods market. In the second part of the period, an asset market meets. Financial claims stemming from the previous period are settled in this market, and the monetary authority executes a monetary transfer at this time. Finally, in the third part of the period, goods markets meet and clear and other prices and rates of return are determined. I now describe the households, the firms, the monetary authority, and then the implications for exchange rate policy when the domestic nominal rate of interest is on its zero bound.

The $j \in (0, 1)$ household has the following preferences over traded good consumption,

[10] Of course, if the BOJ did open market operations on a very large scale, then perhaps there would be a noticeable effect. However, the arguments in Backus and Kehoe (1989) summarized in a previous footnote suggest that that effect is hard to predict using economic theory.

c_t^T, nontraded good consumption, c_t^N, and effort, $y_t(j)$:

$$\sum_{t=0}^{\infty}\beta^t\left\{\gamma\log\left(c_t^N\right)+(1-\gamma)\log(c_t^T)-\frac{\psi_0}{1+\psi}y_t^N(j)^{1+\psi}\right\}.$$

The household holds A_t financial assets at the end of the t^{th} period asset market. It splits these between bonds, B_t, and money, $\tilde{M}_t$, as follows:

$$(1)\qquad A_t=B_t+\tilde{M}_t.$$

These are all denominated in domestic currency units. The bond earns a gross nominal rate of return, $1+i_t$, for delivery in the period $t+1$ asset market. The reason households hold currency, $\tilde{M}_t$, is that they need it to satisfy a cash constraint:

$$(2)\qquad \tilde{M}_t\geq P_t^Nc_t^N+P_t^Tc_t^T,$$

where P_t^N and P_t^T represent the domestic currency price of nontraded and traded goods, respectively. The household's financial assets at the end of the period t asset market are composed of any unused cash from the previous goods market, the period t money transfer, X_t, and other receipts accumulated in period $t-1$:

$$(3)\qquad A_t=(1+i_{t-1})B_{t-1}+\tilde{M}_{t-1}-\left[P_{t-1}^Nc_{t-1}^N+P_{t-1}^Nc_{t-1}^N\right]+X_t+P_{t-1}^T\bar{y}^T+P_{t-1}^N(j)y_{t-1}^N(j).$$

Here, the last two terms represent receipts arising from the sale of the household's endowment of the traded good, $\bar{y}^T$, and receipts arising from its expenditure of effort, $y_{t-1}^N(j)$. We also imagine that additional restrictions are placed on the household to guarantee boundedness of its intertemporal consumption opportunities. Among these is the zero bound restriction on the nominal rate of interest and a lower bound constraint on B_t.

In each date, t, the household maximizes discounted utility subject to a given level of initial wealth, A_t. It also takes the $\left\{i_j,P_j^N,P_j^T\right\}_{j=t}^{\infty}$ and (1)-(3) as given. Finally, the household is a monopoly supplier of $y_t^N(j)$, and so it chooses $P_t^N(j)$ and $y_t^N(j)$ subject to a demand curve to be specified below.

The real rate of return, $r>0$, denominated in terms of the traded good, is assumed to be fixed and determined on world markets. Under the assumption of free international capital mobility, this implies:

$$(4)\qquad (1+i_t)\frac{P_t^T}{P_{t+1}^T}=1+r.$$

For simplicity, I assume $\beta(1+r)=1$. Free mobility of the traded good implies the law of one price:

$$(5)\qquad P_t^T=s_tP_t^*,$$

where P_t^* is the foreign price of the traded good. The foreign nominal interest rate, i_t^*, is:

$$1+i_t^*=(1+r)\frac{P_{t+1}^*}{P_t^*}.$$

Combining the previous three equations, we obtain the UIP relation for this economy:

$$1 + i_t = (1 + i_t^*) \frac{s_{t+1}}{s_t}.$$

Since there is no uncertainty, the *actual* next period exchange rate appears here. Otherwise, this is the same as the UIP relationship discussed above.

Now consider the production of the nontraded good. I imagine there is a perfectly competitive final good firm which uses a linear homogeneous technology to convert the effort of each household, $j \in (0, 1)$, into the nontraded good:

$$c_t^N = \left[\int_0^1 y_t^N(j)^{\frac{1}{\mu}} dj \right]^{\mu}, \ \mu \geq 1.$$

Profit maximization by the final good producer implies the following demand curve for the j^{th} input:

$$(6) \qquad y_t^N(j) = y_t^N \left[\frac{P_t^N}{P_t^N(j)} \right]^{\frac{\mu}{\mu-1}},$$

where y_t^N denotes aggregate production of the traded good. The j^{th} household treats this as the demand curve for its service, $y_t^N(j)$.

Production of the traded good is trivial. As noted above, the household receives an endowment of the good, $\bar{y}^T$, in each period. The household cannot consume its own endowment. To consume the traded good, it must sell its endowment and spend cash to get it. The economy can consume more than its aggregate endowment in any particular period, by running up foreign debt.

The monetary authority simply transfers cash to the household, as indicated above. A monetary policy is a sequence of cash injections, X_0, X_1,... . The aggregate stock of currency evolves according to:

$$M_t = M_{t-1} + X_t.$$

In addition to a transversality condition, the following conditions are necessary and sufficient for household optimization of c_t^T, c_t^N, $y_t^N(j)$, $\tilde{M}_t$:

$$(7) \qquad \begin{aligned} c_t^T &= c_{t+1}^T, \\ \frac{\gamma}{1-\gamma} \frac{c_t^T}{c_t^N} &= \frac{P_t^N}{P_t^T}, \\ y_t^N &= \left[\frac{\beta \gamma P_t^N}{\mu \psi_0 P_{t+1}^N c_{t+1}^N} \right]^{\frac{1}{\psi}}, \\ i_t \left(\tilde{M}_t - P_t^N c_t^N - P_t^T c_t^T \right) &= 0, \end{aligned}$$

together with (2). Here, I have imposed the equilibrium conditions $y_t^N(j) = y_t^N(l) = y_t^N$ and $P_t^N(j) = P_t^N(l) = P_t^N$ for all $l \neq j$. The first equation in (7) follows directly by combining the Euler equation associated with acquiring B_t, equation (4), $(1+r)\beta = 1$ and the log assumption on utility. The second equation, proportionality of expenditure shares on traded and nontraded goods, follows from the unit elasticity of substitution assumption in utility. The third equation follows from the first order condition for $y_t^N(j)$, after taking into account (6) and the equilibrium result, $y_t^N(j) = y_t^N(l) = y_t^N$, $P_t^N(j) = P_t^N(l) = P_t^N$ for all l, j and t. The fourth condition is simply the complementary slackness condition associated with the cash constraint.

Market clearing in the nontradable goods sector requires $y_t^N = c_t^N$, and equality of demand and supply of the domestic currency requires $\tilde{M}_t = M_t$. I define equilibrium in the usual way, as a sequence of prices and quantities such that household and firm optimization is satisfied and markets clear at each date, $t = 0, 1, ...$.

With the initial international debt set to zero, the household chooses a consumption path which keeps it zero: $c_t^T = \bar{y}^T$ for all t.

To do the analysis, I require the model's steady state equilibrium. I assume the stock of money is constant, M, so that money injections are expected to be zero for all time. Then, using (4), $c^T = \bar{y}^T$, and solving (7) for P^N, P^T, c^N :

$$
\begin{aligned}
i &= r, \\
c^T &= \bar{y}^T,\ c^N = y^N = \left(\frac{\beta\gamma}{\mu\psi_0}\right)^{\frac{1}{\gamma(1+\psi)}} \qquad (8)\\
P^T &= \frac{1-\gamma}{c^T}M,\ P^N = \frac{\gamma}{c^N}M.
\end{aligned}
$$

where variables without a time subscript denote steady state values. Here, I have used the fact that the cash constraint is binding, because $i = r > 0$.

An Unanticipated, Temporary Jump in the Stock of Money

I assume that the economy is in the steady state just described. Then, following Krugman (1998), I imagine that in period 0, after P_0^N has been set to P^N, the monetary authority deviates from expectations by increasing the money stock. Once the deviation occurs, it is expected to be temporary, leaving agents expecting that the stock of money in all future periods will be restored to its pre-shock level. The nature of the policy is $X_0 > 0$ and $X_1 = -X_0$, so that $M_0 = M + X_0$ and $M_t = M$ for all $t > 0$. This captures the notion that agents disbelieve any claim by the monetary authority that it will persist in its date 0 unexpected expansionary monetary policy.

I will show that as the monetary authority raises the date 0 money stock, the date 0 level of output increases and the interest rate and exchange rate decline. As X_0 continues to increase, the nominal interest rate eventually hits zero. From that point on, further increases in X_0 have no more effect. The increases simply accumulate as idle cash balances and there is no effect on exchange rates, interest rates, or price levels.[11] Significantly, from the point

[11] Because the cash injection is temporary, it is withdrawn by a tax in the following period. Thus, households keep the idle cash balances in period 0, so that they are in a position to pay the tax in the following asset

of view of McCallum's paper, the exchange rate stops falling in value at precisely the same time that the interest rate hits its lower bound. In particular, the ability to influence the exchange rate does not offer a reprieve from the lower bound constraint in this model.

The values of all variables, including nominal variables, in period 1, 2, ... remain unchanged at their steady state level. Also, as noted above, $P_0^N = P^N$, because that is set before the unexpected date 0 money injection. The equations that characterize the date 0 values of the variables include all equations in (7) except the third one. That equation in period 0 is no longer relevant after nontraded good firms have set their price, P_0^N.

By the first equation in (7), I conclude that $c_t^T = \bar{y}^T$ for $t = 0, 1, 2, \ldots$. That is, the consumption of the traded good is unaffected by the monetary injection. Substituting the proportionality result on traded and nontraded good consumption (the second equation in (7)) into the cash constraint, we find $P_0^T \bar{y}^T \leq (1-\gamma)(M + X_0)$, or

$$(9) \qquad P_0^T \leq \frac{(1-\gamma)(M+X_0)}{\bar{y}^T} \text{ with strict equality if } i_0 > 0.$$

According to this expression, if X_0 is increased while $i_0 > 0$, then expenditures on the traded good increase. But, since the quantity consumed does not change in equilibrium, its price, P_0^T, must increase. Similarly, we also find $P^N c_0^N \leq \gamma(M + X_0)$, or,

$$(10) \qquad c_0^N \leq \frac{\gamma(M+X_0)}{P^N} \text{ with strict equality if } i_0 > 0.$$

That is, if X_0 increases while $i_0 > 0$, then expenditures on the consumption of the nontraded good increases. But, because its price is set in advance and firms are required to accommodate whatever demand materializes ex post, it follows that consumption of the traded good must increase when $i_0 > 0$.

The previous discussion indicates that the response of the economy to an unexpected money injection depends on the magnitude of the interest rate. We need an expression for this variable. Rearranging (4), I obtain:

$$(11) \qquad 1 + i_0 = (1+r)\frac{P_1^T}{P_0^T},$$

with the understanding that $P_1^T = P^T$. From this we see that for small P_0^T, the nominal interest rate is positive. Combining (9) with this expression, we conclude that $i_0 > 0$ as long as

$$(12) \qquad X_0 < \frac{1+r}{\gamma} P^T \bar{y}^T - M.$$

Suppose X_0 increases, starting from a point well below this upper bound, which I assume to be positive. These values of X_0 produce a strictly positive i_0. As X_0 increases, i_0 falls, but remains positive as long as the increase in X_0 is not too great. According to (10), P_0^T and c_0^N increase over this range. In addition, by (5) the nominal exchange rate, s_0, depreciates P_0^T rises. However, as soon as X_0 hits its upper bound in (12), further increases produce no

trading period.

effect on i_0, which has now reached its lower bound of zero. Such increases in X_0 also cannot produce any further change in P_0^T, according to (11). Since further increases in X_0 produce no further increase in expenditures on the traded good, and expenditures on nontraded and traded goods are proportional, it follows that such changes in X_0 also produce no further change in c_0^N. In sum, increases in X_0 beyond the upper bound in (12) produce no further changes in i_0, s_0, c_0^N and P_0^T.

Our interests here are specifically on the nominal exchange rate. From this perspective, it is notable that the ability to influence the exchange rate ceases as soon as the zero bound constraint on the interest rate is achieved. The exchange rate does not provide any new opportunities, beyond what is available with the interest rate, for stimulating the economy.

An Unanticipated, Permanent Jump in the Stock of Money

I now consider the same experiment studied above, modified only so that the increase in money is expected to be permanent. That is, $X_0 > 0$ and $X_t = 0$ for $t > 0$. Starting period 1 on, the model is in a steady state. However, it is a steady state in which the money supply is constant at $M + X_0$, not M, as before. This means that nominal variables are higher, with (8) indicating that $P_1^T = \gamma(M + X_0)/\bar{y}^T$. If we suppose that we begin in a situation where $i_0 > 0$, then (9) implies $P_0^T = \gamma(M + X_0)/\bar{y}^T$, so that $P_1^T/P_0^T = 1$ for all X_0. Substituting this into (11):

$$1 + i_0 = 1 + r > 1,$$

for all X_0. Thus, the effect of increases in X_0 on c_0^N is not constrained any longer by the lower bound constraint on i_0. This shows that for an expansion in the money supply to be effective in stimulating the economy, it must be that private agents believe the expansion will be persistent. If they do not, then the expansionary effect is limited by the zero lower bound constraint on the nominal interest rate.

4. The Zero Bound Constraint and Confidence Crises

The fear about letting the nominal interest rate get too low reflects the concern that in this case, the central bank looses the power to stabilize the economy. Most formal models used to articulate the benefits of central bank stabilization, like McCallum's, focus on mitigating inefficiencies created by the presence of sticky prices. However, informal discussions of the dangers of low interest rates sometimes also focus on another worry: interest rates should be kept high as part of a credible commitment to cut rates in the event of a confidence crisis. The notion is that with such a commitment in place, confidence crises are much less likely to occur in the first place. But, such a commitment is infeasible if the interest rate is too low - in that case the nonnegativity constraint makes the commitment to cut the rate of interest in the case of a confidence crisis non-credible. The concern is that without the ability to credibly commit to fighting confidence crises in this way, their incidence will increase. To better understand these worries, models are needed which can be used to articulate them precisely, to expose the implicit underlying assumptions. I sketch such a model here by building on the non-monetary model in Christiano and Harrison (1999).

In that model, the possibility of a 'confidence crisis' exists because of the presence of strategic complementarities in the private sector.[12] There are many ways these can be captured, and I suspect that the example I develop below is robust to alternative ways of doing so.[13] The approach I choose is particularly convenient because of its analytic simplicity. The model is a version of the one studied in Benhabib and Farmer (1994), and captures the age-old idea that a general sense of pessimism about the health of the economy can act as an independent force, driving the economy into low activity, while optimism can have the opposite effect.[14] In Christiano and Harrison (1999), it is shown that a tax system which produces a high tax rate in a boom and a low rate in a recession can neutralize this mechanism. The basic logic is straightforward. When tax rates are constant, the mechanism by which a general sense of pessimism or optimism can be self-fulfilling works like this: if I think that everyone else is pessimistic and plans not to work or invest, then I have no incentive to work or invest either since I can expect the rate of return on these activities will be low. Similarly, if I expect everyone else to be active, then the return to me of being active is high too. Thus, reports or rumors that there is an economy-wide sense of gloom, or of 'irrational exuberance', can make these sentiments become a reality. The countercyclical tax policy studied in Christiano and Harrison (1999) in effect short-circuits this mechanism: if I think a general sense of gloom is driving everyone else into inactivity, this has no effect on my own incentive to work and invest because I know that my own rate of return to investing and working will be propped up by a tax cut. The procyclical tax policy works in a similar way to prevent an economy-wide pattern of excess 'exuberance' from becoming self-fulfilling.[15] Thus, with the tax policy in place, beliefs about the sentiments of others

---

[12] There exist strategic complemenentarities if any one agent has more incentive to be active when all other agents are more active.

[13] For a recent review of the alternatives, see Christiano and Fitzgerald (1998).

[14] By using the adjective 'independent' here, I mean to differentiate from the situation in which pessimism or optimism is a reaction to other shocks, such as an earthquake or a war. When an external shock like this affects the economy, beliefs no doubt play an important role in transmitting and propagating their effects. However, beliefs are not a triggering mechanism, or impulse, in this case. The scenario under consideration in the text is one in which beliefs are themselves the shock.

[15] The classic example of all this is the bank run. In the absence of deposit insurance, if I hear a rumor that everyone else plans to run on the bank, I have a strong incentive to run even faster so I don't end up with the people at the back of the line who will not get their money. Even a 'good' bank which has invested wisely, is vulnerable to rumors like this. This is because a bank is unlikely to be able to liquidate its assets (loans to the local grocery store, movie theater, etc.) quickly, so people at the end of the line will at least suffer substantial and inconvenient delays in getting their money back. Moreover, it is likely that the attempt to liquidate assets quickly will cause their value to fall (i.e., as the grocery store or movie theater are driven into bankruptcy by the need to quickly repay their loans), resulting in real losses to the people at the end of the line. This is why pessimism about a bank's ability to make good on its deposit obligations can become self-fulfilling. On the other hand, if a rich person (like the Federal Deposit Insurance Corporation) stands ready to pay off the people at the back of the line, then a general sense of pessimism cannot be self-fulfilling. Even if I hear of a rumor that there is a run on my bank, there is no particular incentive for me to run too. In this way, the presence of deposit insurance short circuits the mechanism by which pessimism about a bank can become self-fulfilling. The comment in an early footnote applies here too. I do not have in mind the scenario in which pessimism about a bank is the response to a signal that the bank's officers have made unwise investments. In this case, pessimism is not the primitive, driving shock. Instead, it is part of the propagation mechanism. I am here concerned with the possibility that pessimism is the an independent shock. For the

cease to play an independent role in individuals' economic decisions. These beliefs cease to play an independent role in the economy.

In models of monetary economies, an increase in the nominal rate of interest acts very much like a tax increase, while a decrease acts like a tax cut (Cooley and Hansen (1989).) This suggests that a procyclical interest rate policy has the potential to play a role in stabilizing a monetized version of the Christiano and Harrison model. I show that this is indeed the case.

A. Model

The model has households, firms, a financial intermediary and monetary and fiscal authorities. I now describe each of these in turn.

Households

Preferences of a representative household are given by:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, n_t),\ \ u(c,n) = \log c + \sigma \log(1-n),$$

where c_t denotes consumption and n_t denotes hours worked. The economy's stock of money, M_t, is available to the household at the beginning of the period. This money is divided between funds, D_t, deposited with a financial intermediary and funds, $M_t - D_t$, allocated to spending on goods. The cash constraint in the goods market is:

$$p_t(c_t + I_t) \leq (1-\tau_t)w_t n_t + M_t - D_t,$$

where w_t is the wage rate, p_t is the price level and τ_t is the tax rate on income. Also, I_t denotes investment, which the household applies to increasing the stock of capital, using the following technology:

$$k_{t+1} = (1-\delta)k_t + I_t,$$

where k_t denotes the beginning of period t stock of capital.

The household's financial assets evolve over time according to the following equation:

$$M_{t+1} = R_t(D_t + X_t) + (1-\tau_t)r_t k_t + [(1-\tau_t)w_t n_t + M_t - D_t - p_t(c_t + I_t)] + T_t,$$

where r_t denotes the rental rate on capital, R_t denotes the gross nominal rate of interest, X_t denotes a monetary transfer by the monetary authority that occurs during the period, and T_t represents a transfer from the fiscal authority. Households maximize utility taking prices, taxes, the cash constraint, the asset evolution equation and initial quantities of capital and money as given. The Euler equations for labor, money and capital are, respectively:

$$\frac{(1-\tau_t)w_t}{p_t} = -\frac{u_{nt}}{u_{ct}},\ \ \frac{u_{c,t}}{p_t} = \beta R_t \frac{u_{c,t+1}}{p_{t+1}},\ \ u_{c,t} = \beta u_{c,t+1}\left[\frac{1-\tau_{t+1}}{R_{t+1}}\frac{r_{t+1}}{p_{t+1}} + 1 - \delta\right],$$

where u_{xt} is the partial derivative of u with respect to $x = c_t, n_t$.

---

classic formalization of this bank-run example, see Diamond and Dybvig (1983).

Firms and Financial Intermediary

The representative firm is competitive, and has access to the following technology:

$$y = Y^{\gamma} k^{\alpha} n^{1-\alpha},\ \gamma = 1 - \alpha,$$

where Y is economy-wide average output, and y, k, n are firm output, capital, and employment, respectively. Firms must borrow the wage bill at the beginning of the period, and they repay wR/p per worker to the financial intermediary at the end of the period. Firms' activity in the money market ensures that, in any equilibrium, it must be that $R_t \geq 1$. If it were otherwise, then firms could make infinite profits by borrowing A dollars at the beginning of the period, paying back RA at the end, keeping the positive amount $(1 - R)A$, and driving $A \to \infty$.

Finally, firms finance the rent on capital, rk/p, where r is the nominal rental rate on capital, out of end-of-period cash receipts. In equilibrium, $Y = y$. Incorporating this equilibrium condition into the firm's first order conditions and into the aggregate resource constraint yields:

$$\frac{r_t}{p_t} = \alpha n_t^2,\ \frac{w_t R_t}{p_t} = \gamma k_t n_t,\ c_t + k_{t+1} - (1 - \delta) k_t = k_t n_t^2,$$

after imposing the empirically reasonable value, $\alpha = 1/3$.

The financial intermediary receives funds, D_t, from households and X_t on households' behalf from the monetary authority. It lends these funds on to firms who need to finance their labor bill. Clearing in the money market requires

$$w_t n_t = D_t + X_t.$$

At the end of the period, the financial intermediary receives $(D_t + X_t) R_t$, which it passes on to households.

Monetary and Fiscal Authorities

Monetary policy sets X_t to achieve a particular interest rate target. The fiscal authority faces the following balanced budget constraint:

$$\tau_t \left(w_t n_t + r_t k_t \right) = T_t.$$

Fiscal policy is a strategy for setting τ_t. I will consider constant interest rate and tax policies, and policies that allow these variables to change with the state of the economy. I will require that these rules be *credible*, that is, be feasible in all possible states of the economy. For example, a rule is not credible if it specifies that R_t must be negative for some level of aggregate activity that is not inconsistent with technological feasibility.

Equilibrium

I adopt the usual sequence-of-markets equilibrium concept. It is a sequence of quantities and prices, such that, given monetary and fiscal policy, markets clear and agents optimize. In addition, the monetary and fiscal authorities policy rules must be satisfied and must satisfy credibility.

As emphasized in Christiano and Harrison (1999), the set of equilibria is easy to characterize for this economy. Combining the firm and household Euler equations for labor,

$$(13) \quad \tilde{c}_t = \frac{\gamma}{\sigma}\Gamma_t n_t(1-n_t), \text{ where } \tilde{c}_t \equiv \frac{c_t}{k_t},\ \Gamma_t \equiv \frac{1-\tau_t}{R_t}.$$

Combining the household's intertemporal Euler equation for capital with the firm first order condition for capital yields,

$$(14) \quad \frac{\lambda_t}{\tilde{c}_t} = \beta\frac{\Gamma_{t+1}\alpha n_{t+1}^2 + 1 - \delta}{\tilde{c}_{t+1}},\ \lambda_t \equiv \frac{k_{t+1}}{k_t}.$$

From the resource constraint:

$$\lambda_t = n_t^2 + 1 - \delta - \tilde{c}_t = n_t^2 + 1 - \delta - \frac{\gamma}{\sigma}\Gamma_t n_t(1-n_t).$$

Substituting the expressions for λ_t and for $\tilde{c}_t$ into (14) yields:

$$(15) \quad \frac{n_t^2 + 1 - \delta - \frac{\gamma}{\sigma}\Gamma_t n_t(1-n_t)}{\Gamma_t n_t(1-n_t)} = \beta\frac{\Gamma_{t+1}\alpha n_{t+1}^2 + 1 - \delta}{\Gamma_{t+1}n_{t+1}(1-n_{t+1})},$$

or, after rewriting,

$$(16) \quad \Gamma_{t+1}n_{t+1}^2\left[1 + \kappa(n_t,\Gamma_t)\alpha\right] - \Gamma_{t+1}n_{t+1} + \kappa(n_t,\Gamma_t)(1-\delta) = 0,$$

where

$$\kappa(n,\Gamma) = \frac{\beta\Gamma n(1-n)}{n^2 + 1 - \delta - \frac{\gamma}{\sigma}\Gamma n(1-n)}.$$

It turns out that the dynamic properties of this model economy are essentially the same as those of the Christiano and Harrison model, despite the fact that the latter is non-monetary. The incorporation of money simply modifies the interpretation of Γ. In Christiano and Harrison, Γ reflects only the tax rate on labor, with R implicitly set to 1. With the incorporation of money, we can interpret Γ as also reflecting a gross interest rate different from unity, as in (13). The only thing we have to remember here is the restriction that R cannot be less than unity. There is no analog of this in the real economy.

I shall make use of the following result, discussed in Christiano and Harrison: any sequence, n_0, n_1, n_2, ... which satisfies (16) and has the property, $a \leq n_t \leq b$ for $t = 0, 1, ...$, where $a > 0$ and $b < 1$, is an equilibrium. It is an equilibrium in the sense that prices, quantities, money growth rates, tax rates and interest rates can be found which, together with the given employment sequence, represent a sequence-of-markets equilibrium. Of course, whether a given employment sequence satisfies (16) depends on the associated sequence, Γ_t, $t = 0, 1, 2, ...$.

B. Results

I begin by showing that, when Γ is constant, there is a very large set of equilibria. There are many deterministic equilibria, including chaotic equilibria. In addition, there are stochastic equilibria in which prices and quantities are sensitive to the realization of sunspot random variables. The policy which holds Γ constant is a 'bad' one in that, as shown in Christiano and Harrison (1999), the associated set of equilibria includes equilibria which produce very low utility for the representative household. I then consider a particular class of policies in which Γ is countercyclical, and show how this causes the set of equilibria potentially to collapse to a singleton. I then turn to the issue of interest here, by examining the role that monetary policy can play in generating the necessary countercyclicality in Γ.

Equilibria Under a Constant Policy

Suppose that fiscal policy sets $\tau_t = 0$ and monetary policy sets $R = \bar{R} = 1.20$, i.e., 20 percent. Then, $\Gamma = 1/\bar{R}$. From (16) it is not surprising that there exist two stationary equilibria, i.e., equilibria in which n_t is constant. When $\beta = 1.03^{-.25}$, $\delta = .02$, these are $n_t = n^l = 0.03$ for all t, and $n_t = n^u = 0.25$ for all t, after rounding. But, there are many more equilibria. It is easy to see this. First, note that for each $n_t \in (0,1)$, (16) represents a quadratic equation in n_{t+1}. That is, for each $n_t \in (0,1)$, there exist potentially two equilibrium values of n_{t+1}. These are graphed in Figure 1a - Figure 1b. There, the upper branch represents the high values of n_{t+1} that solve this quadratic equation and the lower branch represents the low values. The lower branch crosses the 45 line twice, once from below at $n = n^l$ and once from above at $n = n^u$. It is hard to see this pattern of crossings in Figure 1a, but the close-up in Figure 1b should make it apparent. Figure 1c provides a close-up view of the lower branch in the neighborhood of $n = n^u$.

The set of sequences which satisfy (16) can be seen in Figure 1. The two constant sequences mentioned in the previous paragraph are apparent. In addition, it is obvious that it is possible to construct many equilibrium sequences in which n_0 is very close to n^u, which converge to n^u. This characteristic of the stationary n^u equilibrium - that there are infinitely many equilibria arbitrarily close to it - implies that that equilibrium is *indeterminate*. Indeterminacy of the n^u equilibrium implies that stochastic sunspot equilibria can be constructed in the neighborhood of n^u. There are other sunspot equilibria which involve stochastic regime switching: for a given n, draw from a random number generator which branch you go to to determine n'. There are also many other non-stochastic equilibria. They can all be found by studying Figure 1.

Equilibria With Responsive Policy

The many equilibria associated with constant Γ in part reflects that there are two n_{t+1} that solve (15) for each n_t. It should be clear from (15) that this feature can be changed by adopting a policy in which Γ_t is inversely proportional to n_t. Consider, for example, the following policy:

$$(17) \quad \Gamma_t = \frac{1}{\bar{R}} \frac{n^u}{n_t}.$$

Substituting this specification of policy into (15), I obtain:

$$\frac{n_t^2+1-\delta-\frac{\gamma}{\sigma}\frac{n^u}{\bar{R}}(1-n_t)}{\frac{n^u}{\bar{R}}(1-n_t)}=\beta\frac{\frac{n^u}{\bar{R}}\alpha n_{t+1}+1-\delta}{\frac{n^u}{\bar{R}}(1-n_{t+1})},$$

or, solving for n_{t+1} given n_t :

$$(18)\quad n_{t+1}=\frac{1-\varphi(n_t)(1-\delta)}{1+\varphi(n_t)\alpha\frac{n^u}{\bar{R}}}=f(n_t),$$

say. Here

$$\varphi(n)=\frac{\beta(1-n)}{n^2+1-\delta-\frac{\gamma}{\sigma}\frac{n^u}{\bar{R}}(1-n)}.$$

It is easy to verify that $n^u=f(n^u)$, so that n^u is a stationary equilibrium under this policy. Straightforward differentiation also verifies that f crosses the 45 degree line from below at $n=n^u$ so that if n^u turns out to be a constant n_t equilibrium, then it is not indeterminate. That is, if it is an equilibrium, it is determinate. The function f is graphed in Figure 2, which shows that it only crosses the 45 degree line once. As a result, the candidate stationary $n=n^u$ equilibrium is the *only* candidate for an equilibrium.[16]

Whether the n^u candidate equilibrium is in fact an equilibrium depends on whether the monetary policy rule is credible. Suppose that the policy authorities attempt to implement (17) by setting $\tau_t\equiv 0$ and $R_t=\bar{R}n_t/n^u$. In principle this should work, since $\Gamma_t=(1-\tau_t)/R_t=n^u/(\bar{R}n_t)$. However, it is easy to see that this policy is in fact *not* credible. If $n_t=n^u$, then $R_t=\bar{R}$, and there is no problem. However, when $n_t<n^u/\bar{R}$, the rule implies a negative rate of interest - something that cannot happen in any equilibrium. In effect, the rule commits the monetary authority to do something that is infeasible for a state of the world that is technologically possible. This is why the rule does not satisfy credibility.

It is possible to construct a credible policy that supports (17). To see this, consider the following example:

$$\left.\begin{array}{l} R_t=\bar{R}\frac{n_t}{n^u} \\ \tau_t=0 \end{array}\right., \text{ for } \frac{n^u}{\bar{R}}\le n_t$$

and

$$\left.\begin{array}{l} R_t=1 \\ \tau_t=1-\frac{1}{\bar{R}}\frac{n^u}{n_t} \end{array}\right., \text{ for } 0\le n_t\le\frac{n^u}{\bar{R}}.$$

It is easy to verify that this policy is credible. Thus, under this policy, the candidate stationary equilibrium, $n_t=n^u$ for all t, is in fact an equilibrium.

[16] Actually, I am only concerned with *interior* equilbria, those in which $n_t>0$ and $n_t<1$ for all t.

Can Monetary Policy Alone Stabilize the Economy?

The results in the previous subsection suggest that it may not be possible for monetary policy to stabilize the economy all by itself. In the example, complete stabilization requires that fiscal policy be used to stabilize too. The problem there is that when the interest rate hits zero, there is no scope for further reduction. That's why at some point fiscal policy has to take over. Here, I consider a monetary policy in which the interest rate hits zero only at $n_t = 0$. Under the given policy, a given fall in employment always generates a fall in R, no matter how low employment is. The formula for and graph of the policy considered are presented in Figure 3b. The policy has the property that when $n_t = n^u$ (see nb in the figure), then $R_t = \bar{R}$. Figures 3a and 3c show that there is a constant, $n_t = n^u$ equilibrium under this policy. Moreover, that equilibrium is *determinate.* That is, the monetary policy succeeds in eliminating all the equilibria close to n^u. However, there are still other equilibria that are far away. Evidently, this policy for setting R_t does not completely stabilize the economy, though it does go a long way in that direction.

Though they do not prove it, these results are consistent with the notion that monetary policy alone cannot stabilize the economy. While it can stabilize fluctuations close to the targeted equilibrium, to stabilize the really large fluctuations requires bringing the conventional tax system into play. Interest rate policy will not prevent a Great Depression.

All the equilibria considered up to now are inefficient, due to the presence of the externality. A negative labor tax rate leads people to internalize the externality and can support the efficient allocations as an equilibrium (Christiano and Harrison (1999)). There are other equilibria too, however, and the others are 'far away' from the efficient allocations. Consistent with the results just described, it appears that a procyclical interest rate policy will not eliminate those other equilibria.[17] A procyclical tax rate policy appears to be needed for that. This suggests again that a procyclical interest rate policy will not eliminate all fluctuations, only the smaller ones.

C. Discussion

I presented an example in which, absent policy intervention, there can be welfare reducing volatility in the economy. The ups and downs of output, consumption and investment in these equilibria can be interpreted as reflecting fluctuations in 'confidence'. I showed that government policy has a potentially constructive role in eliminating these fluctuations. In the example, the monetary authority can play a role stabilizing small fluctuations in output, while tax policy must be relied on to stabilize really big reductions in output. To play this stabilizing role, interest rates must of course be high on average.

In the example, it does not matter whether tax policy or monetary policy is used to stabilize a crisis. Tax policy alone can do the whole job. As a result, a procyclical interest rate policy is not crucial to achieve stabilization in the example. I suspect, however, that in a more plausible version of the example, there may well be a preference for monetary policy. Such a model would incorporate the fact that a central bank can react more swiftly to events than the tax authorities can.[18] In this case, monetary policy may be more effective

[17] To save space, I do not report this work here.

[18] For example, one could consider a version of the model in which the tax rate must be a function of lagged

at combatting confidence crises. If this is the case, then this would constitute a reason to be concerned about a low nominal rate of interest.

5. Conclusion

Various concerns have been raised about the supposed dangers of low nominal interest rates. McCallum argues that these concerns are, in effect, overblown. His argument is not compelling, for several reasons.

First, McCallum's claim that the central bank still has the ability to manipulate the exchange rate, even if the interest rate is stuck at its zero lower bound, is no more than assertion. McCallum does not address the empirical evidence which suggests that the ability to control the exchange rate under these circumstances is, at best, small. In addition, McCallum does not lay out the logical foundations for his assertion. The ability to control the exchange rate is simply represented by a reduced form expression in his model. This is troubling, since standard theory denies that the central bank can still control the exchange rate when it has lost control over the interest rate. Second, McCallum's model rules out a class of reasons that policy makers are concerned about low interest rates. In particular, they are concerned that confidence crises in financial markets can lead to economically costly instability. The notion is that the ability to cut interest rates is important for preventing these crises from occurring in the first place, or at least mitigating their impact if they do occur. The most recent example of this is the Federal Reserve's actions in August 1998 to inoculate the US economy against the 'Russian virus' or the 'Asian flu' by implementing a series of cuts in the federal funds rate. The fear was that these events in far away places might lead to some sort of financial crisis in the US, which might ultimately spill over onto the real economy. Before dismissing concerns like these, it is important to lay them out clearly so that they can be evaluated and assessed.

By asserting that McCallum's arguments are not compelling, I do not mean to imply that I necessarily accept the idea that low interest rates pose a danger. Indeed, the fact that they inhibit the central bank from conducting stabilization policy may actually be a blessing. There is reason to take seriously the arguments in Kydland and Prescott (1977) and Barro and Gordon (1983) that allowing central banks to fine tune the economy only gets us all into trouble (see Chari, Christiano and Eichenbaum (1998)). Low interest rates may well be a mechanism for achieving this. Moreover, there is an extensive literature that argues, following Milton Friedman, that setting the nominal rate of interest to zero is the optimal thing to do (Chari, Christiano and Kehoe (1996)). Considerably more research is needed to sort through the various considerations that give rise to these conflicting implications for interest rate policy.

---

employment, while the interest rate is a function of current employment.

References

[1] Backus, David, and Patrick Kehoe, 1989, 'On the Denomination of Government Debt: A Critique of the Portfolio Balance Approach,' *Journal of Monetary Economics*, 23(3), May, pages 359-76.

[2] Benhabib, J. and R. E. A. Farmer, 1994, Indeterminacy and increasing returns, *Journal of Economic Theory* 63, 19–41.

[3] Barro, Robert J., and David B. Gordon, 1983, 'A Positive Theory of Monetary Policy in a Natural Rate Model,' *Journal of Political Economy* 91, pp. 589-610.

[4] Blanchard, Olivier, 1997, *Macroeconomics*, Prentice Hall.

[5] Blanchard, Olivier, and N. Kiyotaki, 1987, 'Monopolistic Competition and the Effects of Aggregate Demand,' *American Economic Review*, vol. 77, pp. 647-66.

[6] Chari, V.V. , Lawrence J. Christiano and Martin Eichenbaum, 1998, 'Expectation Traps and Discretion', *Journal of Economic Theory.*

[7] Chari, V.V. , Lawrence J. Christiano and Patrick Kehoe, 1996, 'Optimality of the Friedman Rule in Economies with Distorting Taxes,' *Journal of Monetary Economics*, vol. 37, issue 2, pp. 203-223.

[8] Christiano, Lawrence J., and Terry J. Fitzgerald, 1998, 'The Business Cycle: It's Still A Puzzle,' Federal Reserve Bank of Chicago *Economic Perspectives*, 22 (4), 4th Quarter, pages 56-83.

[9] Christiano, Lawrence J., and Sharon Harrison, 1999, 'Chaos, Sunspots and Automatic Stabilizers,' *Journal of Monetary Economics*, 44, pp. 3-31.

[10] Diamond, Douglas W., and Philip H. Dybvig, 1983, 'Bank Runs, Deposit Insurance, and Liquidity,' *Journal-of-Political-Economy*, 91 (3), June, pages 401-19.

[11] Fuhrer, Jeffrey C., and Brian F. Madigan, 1997, 'Monetary Policy When Interest Rates are Bounded at Zero,' *Review of Economics and Statistics*, vol. 79, November.

[12] Krugman, Paul, 1979, 'A Model of Balance of Payments Crises,' *Journal of Money, Credit, and Banking*, 11(3), August, pages 311-25.

[13] Krugman, Paul, 1998, 'It's Baaack! Japan's Slump and the Return of the Liquidity Trap', *Brookings Papers on Economic Activity.*

[14] Krugman, Paul, and Maurice Obstfeld, 1997, *International Economics, Theory and Policy*, 4^{th} edition, Addison-Wesley.

[15] Kydland, Finn E., and Edward C. Prescott, 1977, 'Rules Rather Than Discretion: The Inconsistency of Optimal Plans,' *Journal of Political Economy* 85, pp. 473-91.

[16] Obstfeld, Maurice and Kenneth Rogoff, 1996, *Foundations of International Macroeconomics*, MIT Press.

[17] Orphanides, Athanasios, and Volcker Wieland, 1998, 'Monetary Policy Effectiveness when Nominal Interest Rates are Bounded at Zero,' Manuscript, Board of Governors of the Federal Reserve System.

Figure 1a

Solutions to Intertemporal Euler Equation with Interest Rate Pegging and Zero Income Tax Rate

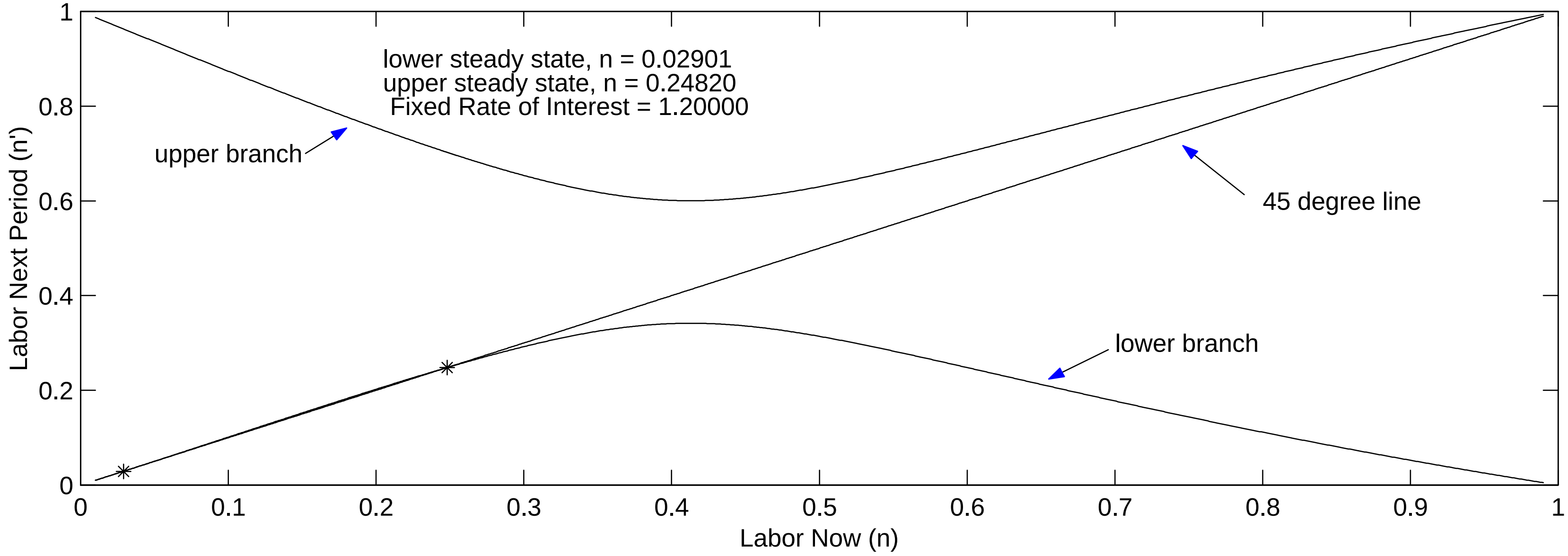


Figure 1b

A Close-up of Lower Branch

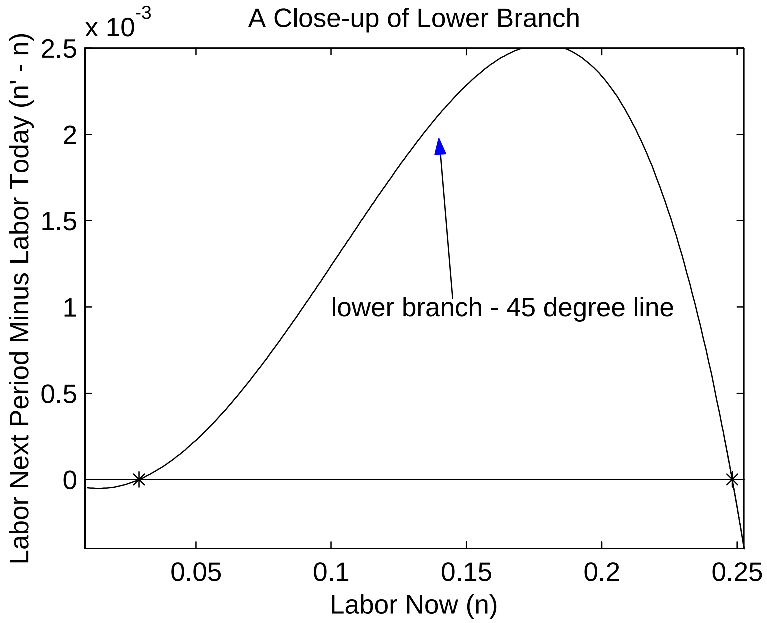


Figure 1c

Another Close-up of Lower Branch

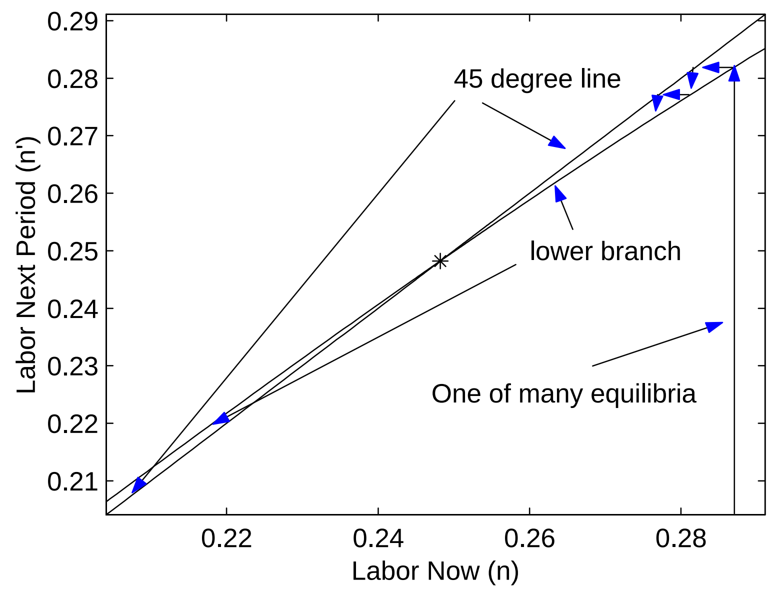


Figure 3a

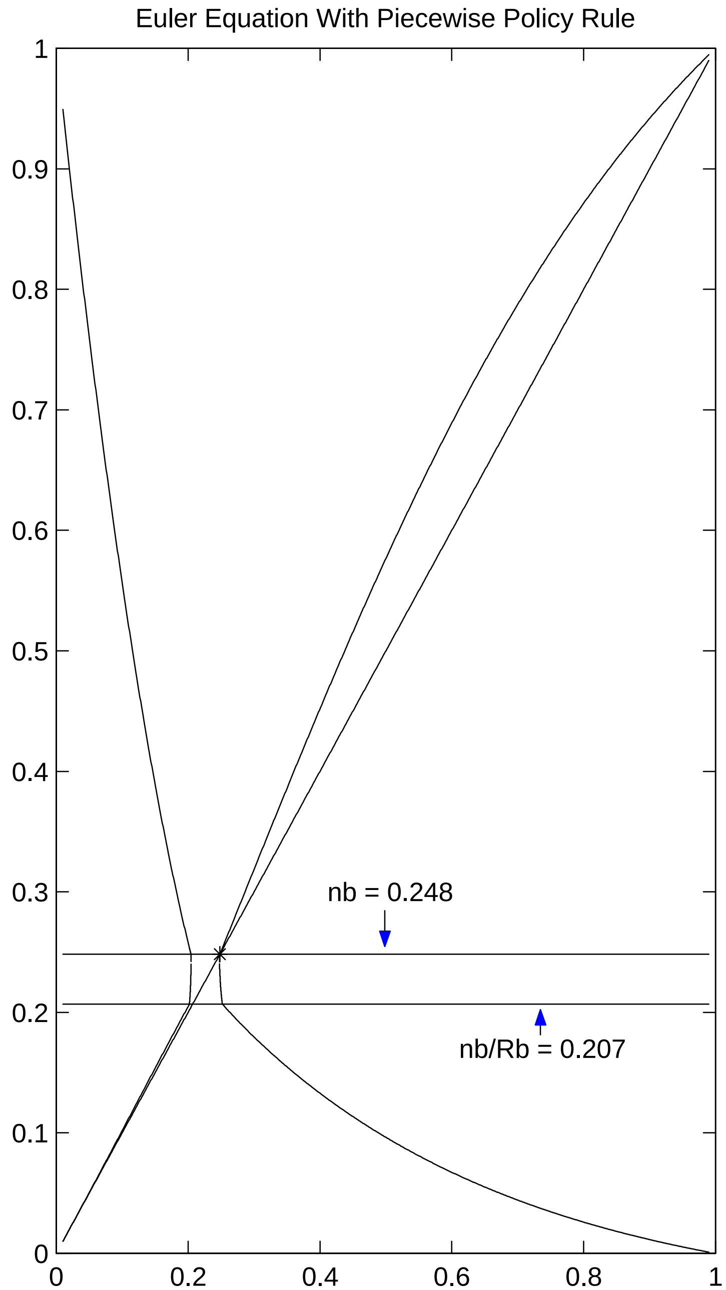


Figure 3b

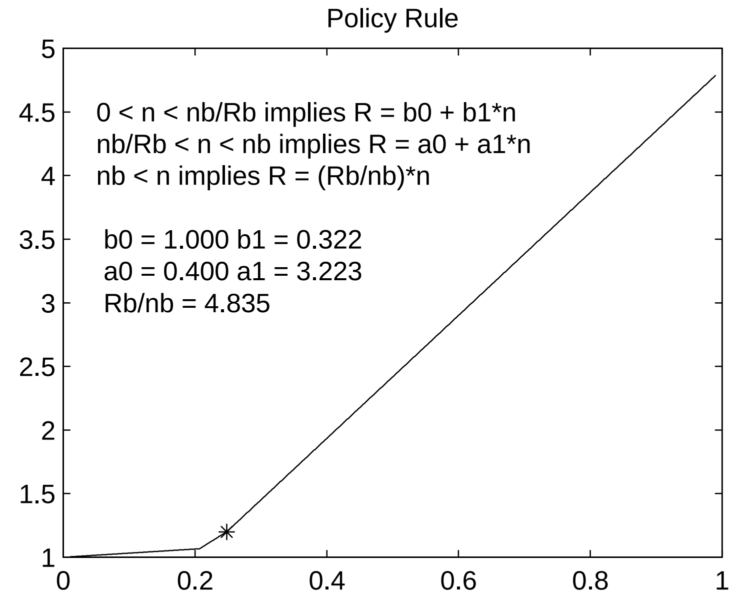


Figure 3c

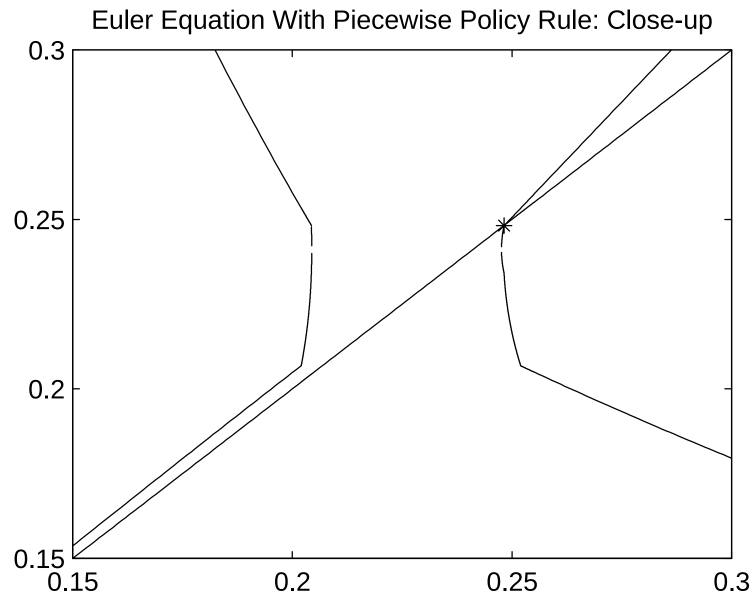
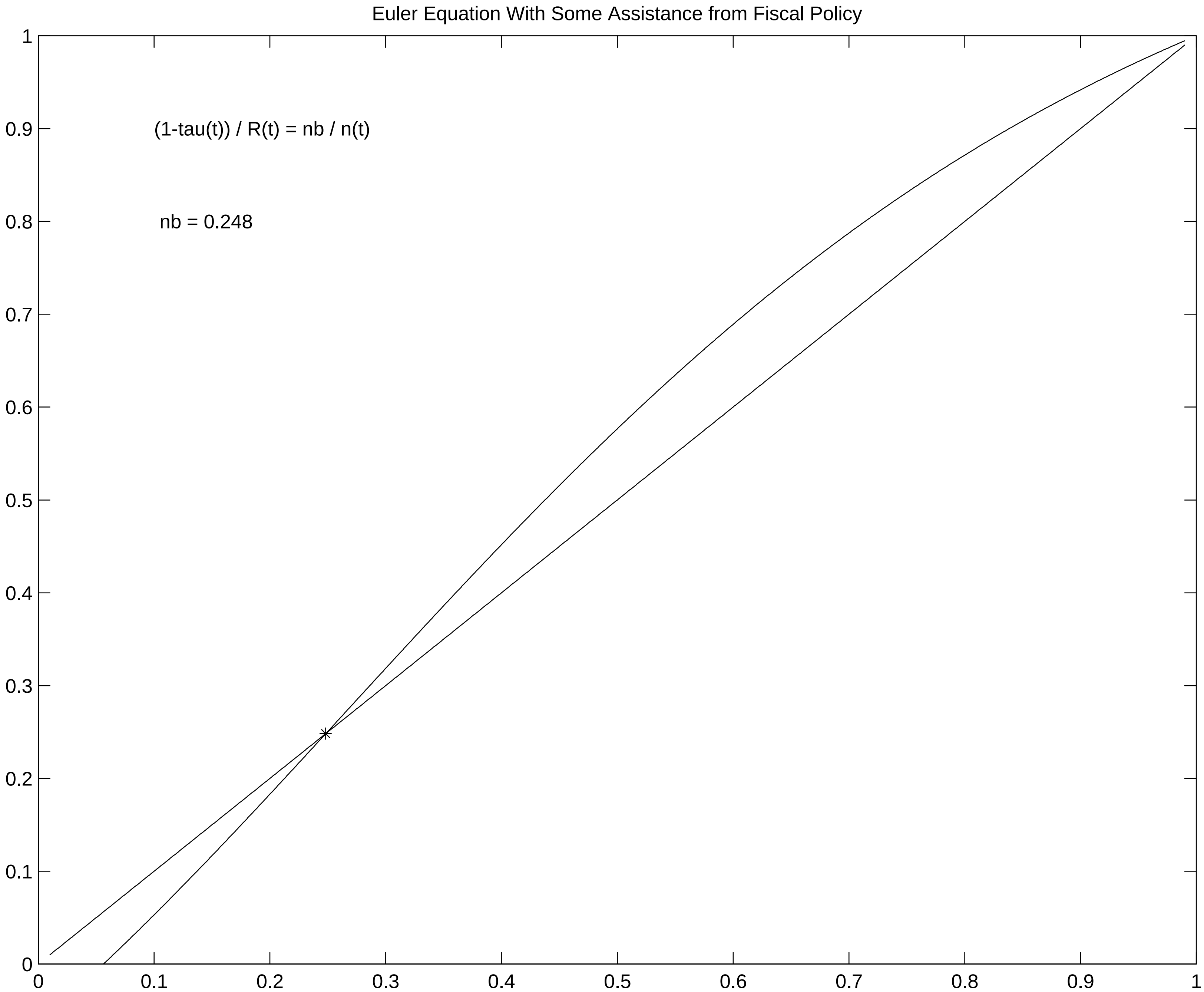


Figure 2



Euler Equation With Some Assistance from Fiscal Policy
(1-tau(t)) / R(t) = nb / n(t)
nb = 0.248
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1