The Liquidity Trap in an Open Economy[*,**]

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Abstract

The paper analyses how a small open economy with a floating exchange rate, perfect international mobility of financial capital and sluggish price level and inflation adjustment can hit the zero lower bound for the nominal rate of interest on non-monetary securities and get stuck in a liquidity trap. One sure way of avoiding the zero lower bound and the liquidity trap is the payment of negative nominal interest on currency or 'taxing money'. The generalized shoe leather costs of taxing money have to be balanced against the cost of orbiting the liquidity trap steady state and suffering periodic inflation and disinflation.

Introduction

The economy is said to be in a liquidity trap when monetary policy has no effect on any nominal or real variable of interest - price or quantity (see e.g. Keynes [1936] and Hicks [1936]).[1] The liquidity trap had become a theoretical curiosum, living mainly in intermediate undergraduate macroeconomics textbooks, by the late 1960s. Towards the end of the 1990s there has been a revival of interest in the subject (see e.g. Fuhrer and Madigan [1997], Krugman [1998a,b,c,d; 1999], Orphanides and Wieland [1998], Wolman [1998], McKinnon and Ohno [1999], Meltzer [1999], Buiter and Panigirtzoglou [1999], Porter [1999], Benhabib, Schmitt-GrohJ and Uribe [1999a,b], Clouse, Henderson, Orphanides, Smann and Tinsley [1999], MacCallum [2000, 2001], Cristiano [2000], Svensson [2000], Hondroyiannis, Swamy and Tavlas [2000], and Shigeru and Wu [2001]). Much of this newer literature is focussed on the so-called zero bound for the short nominal rate of interest. For the short nominal rate of interest to be constrained by a lower bound or floor (at zero or at some other level) is only a necessary condition for monetary policy to be ineffective. There are potentially a number of transmission channels through which monetary policy can affect the economy. Longer maturity interest rates are one such channel. Other financial and real asset prices, such as stocks provide another transmission mode. In an open economy, the exchange rate is a key part of the transmission mechanism of monetary policy. If there is financial market segmentation, monetary policy can also work through the credit channel, that is, the cost and availability of bank credit to firms.

[1] It can still, of course, influence the nominal stock of money or the stock of nominal government debt.

A low inflation experience that has lasted a decade or longer in many parts of the world has been the cause of this revival of interest in the liquidity trap. Japan, in the grips of deflation, that is, negative inflation rates, has had its short nominal interest rate very near to zero for much of 2000 and for the first half of 2001. Longer-term nominal yields on Japanese government bonds have also been low, but have remained positive, at levels between 1.0 percent and 2.0 percent per annum over the past two years.

In Euroland, the implicit inflation target is somewhere between 0 and 2 percent per annum on the HICP index measure. In the UK, the explicit inflation target is 2.5 percent per annum on the RPIX measure. Translating this into a HICP measure would probably (if recent differences between the two inflation indices are an accurate guide to the longer-term differential) imply a UK HICP target of just over 1.5% per annum. The US does hot have an implicit or explicit inflation target, but the Fed appears to be working with an inflation 'comfort zone' of between 1 percent and 3 percent per annum on the CPI measure. Inflation, in the UK, in Euroland and in the US, has been reasonably close to the target, the target range or the comfort zone for several years.

There is a concern that a low inflation economy could more easily fall victim to the liquidity trap. If the long-run real interest rate is, say, 3 percent per annum, then, ignoring term premia and risk premia, one would expect the short nominal interest rate in Euroland to range between 3 and 5 percent per annum, and in the UK around 4.5 percent per annum.[2] With short nominal rates at these kinds of levels during normal times, how likely is it that the economy would be hit by a deflationary shock that would cause the lower bound on the short nominal interest rate to become a binding constraint? If this

[2] Assuming for simplicity that the HICP measure of inflation is the one used by the market to translate nominal rates into real rates.

lower bound is given by the nominal interest rate on currency (that is, zero), as much of the new literature either assumes or deduces from simple models of the demand for money, how likely is it that the economy is hit by a contractionary shock that cannot be countered effectively by reducing the short nominal interest rate to zero?

The model developed in the next section has the property that the economy is in a 'full' liquidity trap only if nominal interest rates at all maturities, from zero till infinite, are zero. However, there exist equilibrium solutions where the zero lower bound on the short nominal interest rate is a binding constraint only part of the time and where longer-maturity nominal interest rates remain positive. The behaviour of the economy when it is in a 'partial liquidity trap of this kind and orbits a liquidity trap steady state is still quite different from that of the same economy from which the zero bound and the liquidity trap have been removed.

While the liquidity trap, and the problem of the zero bound on nominal interest rates in a closed economy, have been extensively studied in recent years, much less work has been done on the way the liquidity trap manifests itself in an open economy. Among the exceptions are McKinnon and Ohno [1999], Hondroyiannis, Sway and Tavlas [2000] and Svensson [2000]. The purpose of the paper is to show how the behaviour of a familiar workhorse of open economy macroeconomics, the Dornbusch [1976] model, is modified when the possibility that the zero bound on the short nominal interest rate becomes a binding constraint is recognised. I also show how a policy of paying a negative nominal interest rate on currency, that is, taxing currency, would eliminate the zero bound constraint and the associated liquidity trap.

I. The Model

The model given in equations (1.1) to (1.4) is a variant of the simple Dornbusch overshooting model. I consider a small open economy with a floating exchange rate and perfect capital mobility. There is price level and inflation inertia. The key modification is that the existence of a floor for the instantaneous nominal interest rate is recognized. This modification introduces an unavoidable non-linearity into the model. As a result, the state space of the model consists of two distinct regions: the *normal* region, where the lower bound on the short nominal interest rate is not binding and the *floor* region, where the short nominal rate is constrained at its floor value.

Notation

y : real output
$\bar{y}$: capacity output (exogenous and constant)
f : exogenous component of aggregate demand
s: nominal spot exchange rate (domestic currency price of foreign exchange)
p : domestic GDP deflator
p^* : foreign GDP deflator
s *:* real exchange rate; $s \equiv s + p^* - p$
p : domestic rate of inflation; $p \equiv \dot{p}$
p^* : foreign rate of inflation; $p^* \equiv \dot{p}^*$
$\hat{p}$: domestic long-run target rate of inflation
i : instantaneous domestic nominal rate of interest
i_M : instantaneous domestic nominal interest rate on money
r : instantaneous domestic real rate of interest; $r \equiv i - p$
r^L : domestic long-run real rate of interest
i^* : instantaneous foreign nominal rate of interest
i_M^* : instantaneous foreign nominal interest rate on money
r^* : instantaneous foreign real rate of interest; $r^* \equiv i^* - p^*$
m : domestic nominal money stock
m^* : nominal stock of foreign currency held by domestic residents
All variables other than interest rates are in natural logarithms.
d, b, k, l, y, h and q are positive parameters

$$y = ds + f \tag{1.1}$$

$$\dot{p} = b(y - \bar{y}) \tag{1.2}$$

$$i = i^* + \dot{s} \tag{1.3}$$

$$\begin{gathered} i = \max\left\{ i_M, r^* + \hat{p} + h(p - \hat{p}) \right\} \\ h > 1 \end{gathered} \tag{1.4}$$

The exogenous variables are $i^*, p^*, \bar{y}, f$, $\hat{p}$ and i_M. The model is reducible to two state variables, the predetermined rate of inflation, p, and the non-predetermined real exchange rate, s.

Equation (1.1) specifies aggregate demand as an increasing function of international competitiveness, as measured by the real exchange rate.[3] Equation (1.2) is an accelerationist Phillips curve. The inflation rate rises (falls) when there is a positive (negative) output gap. Both the price level and the rate of inflation are treated as predetermined, that is, there is short-run nominal rigidity both in the level and in the rate of change of prices. Equation (1.3) represents uncovered interest parity (UIP). International financial capital mobility is perfect and the expected rate of depreciation of the nominal exchange rate equals the differential between domestic and foreign nominal interest rates.

Equation (1.4) represents the policy rule governing the short nominal interest rate.

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[3] I could have added the long-term real interest rate, r_L, as a further determinant of aggregate demand. Using the arbitrage condition $r = r_L - \frac{\dot{r}_L}{r_L}$ would yield $r_L(t) = \left(\int_t^\infty e^{-\int_t^v r(u)du} dv \right)^{-1}$. The long real rate is an average of expected future short real rates. The real exchange rate also incorporates the effect of expected future short real rates, so for expositional simplicity I omit the long real rate as an argument in the aggregate demand function.

According to (1.4), the short nominal interest rate on non-monetary securities, i, is governed by a simplified Taylor rule, as long as this rule does not imply that the short nominal interest rate on non-monetary securities is less that the own nominal interest rate on money, i_M. If the rule implies that the short nominal interest rate on bonds would be less than the own nominal interest rate on money, the short nominal interest rate on bonds instead equals the own nominal interest rate on money. Money is to be thought of as the non-interest-bearing component of narrow money or base money. Under the prevailing institutional practices, the currency component of base money bears a zero nominal rate of interest. Commercial bank reserves with the central bank can have a non-zero nominal rate of interest.

This floor on the short nominal interest rate on bonds is based on a money demand function that makes the demand for real money balances go to infinity when the opportunity cost of holding money, $i - i_M$, goes to zero. A typical money demand function with that property would be the following

$$\begin{gathered}\frac{e^m}{e^p} = \left(\frac{k}{i - i_M}\right) e^y \\ e^m, e^p \geq 0\end{gathered} \tag{1.5}$$

With such a money demand function, there is a liquidity trap at $i = i_M$.[4] Until further notice, I treat the nominal interest rate on money as exogenous and constant, that is,

[4] In Buiter and Panigirtzoglou [2001], a simple optimising model with domestic real money balances in the instantaneous felicity function yields the following demand function for domestic money:

$$\begin{gathered}\frac{e^m}{e^p} = \left(\frac{k}{i - i_M}\right) C \\ e^m, e^p \geq 0\end{gathered}$$

, where C is the level of private consumption. In an open economy version of that

$$i_M = \overline{i}_M \tag{1.6}$$

Letting $\overline{r}$ denote the domestic steady state real rate of interest, the standard Taylor rule for the short nominal interest rate (when the constraint $i > i_M$ is not binding) is given by

$$i = \overline{r} + \hat{p} + h(p - \hat{p}) + q(y - \overline{y}) \tag{1.7}$$

While for many policy issues, the responsiveness of the short nominal interest rate to the output gap is an important feature of the rule, for the purpose of analysing the liquidity trap it is irrelevant. By Occam's razor I therefore leave it out, that is, in (1.4) I have set $q = 0$. The specification of the intercept in our simplified Taylor rule (1.4) anticipates the property of our model that the steady state domestic real interest rate equals the world real interest rate ($\overline{r} = r^*$). This follows immediately from UIP and the constancy of the real exchange rate in steady state.

II. Dynamics and Steady States

The equations of motion for the system are as follows

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model, where domestic agents hold both domestic and foreign money, I have in addition the following demand for foreign money. $\dfrac{e^s e^{m^*}}{e^p} = \left(\dfrac{k}{i - \dot{s} - i^*_{M^*}}\right) C$. Here e^{m^*} is the foreign nominal money stock held
$e^m, e^p \geq 0$
by domestic private agents and $i^*_{M^*}$ is the nominal rate of interest on foreign money. From UIP it follows that $\dfrac{e^s e^{m^*}}{e^p} = \left(\dfrac{k}{i^* - i^*_{M^*}}\right) C$. Thus, as long as the rest of the world is not in a liquidity trap ($i^* > i^*_{M^*}$),
$e^s, e^{m^*}, e^p \geq 0$
and as long as direct currency substitution is not perfect (i.e. as long as I do not require $i_M - \dot{s} = i^*_{M^*}$), there is no need to keep track of the demand for foreign currency by domestic residents.

For $p \geq \frac{i_M - r^* + (h-1)\hat{p}}{h}$

$$\begin{bmatrix} \dot{p} \\ \dot{s} \end{bmatrix} = \begin{bmatrix} 0 & bd \\ h-1 & 0 \end{bmatrix} \begin{bmatrix} p \\ s \end{bmatrix} + \begin{bmatrix} -b(\bar{y} - f) \\ (1-h)\hat{p} \end{bmatrix} \tag{1.8}$$

For $p \leq \frac{i_M - r^* + (h-1)\hat{p}}{h}$

$$\begin{bmatrix} \dot{p} \\ \dot{s} \end{bmatrix} = \begin{bmatrix} 0 & bd \\ -1 & 0 \end{bmatrix} \begin{bmatrix} p \\ s \end{bmatrix} + \begin{bmatrix} -b(\bar{y} - f) \\ i_M - r^* \end{bmatrix} \tag{1.9}$$

The steady state conditions are

$$y = \bar{y} \tag{1.10}$$

$$r = r^* \tag{1.11}$$

$$s = \frac{1}{d}(\bar{y} - f) \tag{1.12}$$

and either,

$$i = r^* + \hat{p} \tag{1.13}$$

$$p = \hat{p} \tag{1.14}$$

$$\dot{s} = \hat{p} - p^* \tag{1.15}$$

or

$$i = i_M \tag{1.16}$$

$$p = i_M - r^* \tag{1.17}$$

$$\dot{s} = i_M - i^* \tag{1.18}$$

Thus there are two regions for the inflation rate. The *normal* region,

$p > \frac{i_M - r^* + (h-1)\hat{p}}{h}$, where the floor on the short nominal interest rate ($i \geq i_M$) is not a binding constraint and where the Taylor rule operates normally, and the *floor* region $p < \frac{i_M - r^* + (h-1)\hat{p}}{h}$ where the short nominal interest rate is constrained at the level set by the short nominal interest rate on money, i_M. The dynamics are different in the two regions.

There is a unique steady state solution for real output, the real interest rate and the real exchange rate, given respectively by (1.10), (1.11) and (1.12). Steady state output is equal to its exogenous capacity level. The steady state real interest rate is equal to the world real rate of interest. The steady state real exchange rate depreciates when there is an increase in capacity output or a cut in exogenous demand.

In the normal steady state, the rate of inflation equals the long-run target rate of inflation (1.14). There is also a liquidity trap steady state in the floor region, where the nominal interest rate equals the nominal interest rate on currency (1.16) and the rate of inflation equals the nominal interest rate on domestic currency minus the long-run real rate of interest (given by the world real interest rate) (1.17). This is, of course, the steady-state inflation rate corresponding to Friedman's rule for the optimum quantity of money.

While, in principle, the long-run target rate of inflation could be anything, I will only consider configurations where the long-run target rate of inflation exceeds the liquidity trap steady state rate of inflation, that is, I assume $\hat{p} > i_M - r^*$. With $i_M = 0$, and a positive long-run real interest rate, this appears to be a reasonable constraint.

The dynamics in the normal region, given in (1.8), have a saddlepoint configuration provided $h > 1$. The determinant of the state matrix in (1.8) is $(1-h)bd$ which is negative if and only if $h > 1$ (as I assume to be the case). This restriction on the Taylor rule means that a higher rate of inflation will call forth a greater than one-for-one response of the short nominal interest rate. The short real rate of interest therefore rises. This will dampen demand through its effect on the real exchange rate and bring down inflation again.

The dynamics in the floor region, given in (1.9), centered on the liquidity trap steady state, represent a neutral cycle. The two characteristic roots, l_1 and l_2 of the state matrix in (1.9) are the pure imaginary numbers $l_{1,2} = \pm i\sqrt{bd}$.

Figure 1a illustrates the key features of the model.

FIGURE 1a,b here

The assumption that the long-run target rate of inflation exceeds the rate of inflation in the liquidity trap steady state ($\hat{p} > i_M - r^*$) implies that the boundary between the normal region and the floor region, denoted *NF* in Figure 1a lies between the two steady state inflation rates. It can be either at a position above or below $p = 0$, since on the *NF* locus, $p = \dfrac{i_M - r^* + (h-1)\hat{p}}{h}$.

Both the normal region's and the floor region's $\dot{p} = 0$ loci are given by

$$s = \frac{g(h-1)}{d}p + \frac{1}{d}(\bar{y} - f) \tag{1.19}$$

The solution curves in the normal region are given by

$$\frac{1}{2}(h-1)p^2 + (1-h)\hat{p}p = \frac{1}{2}bds^2 + b(f-\bar{y})s + k \tag{1.20}$$

where k is an arbitrary constant of integration.

The solution curves in the floor region are given by

$$-\frac{1}{2}p^2 + (i_M - r^*)p = \frac{1}{2}bds^2 + b(f - \bar{y})s + k \qquad (1.21)$$

where k is again an arbitrary constant of integration.

The liquidity trap configuration is a *center*. Some neighbourhood of this steady state is completely filled by closed integral curves, each containing the steady state in its interior.

The left-hand panel of Figure 1a (to the left of the NF locus) shows the behaviour of the system when governed by the dynamics of the floor region; the right-hand panel of Figure 1a (to the right of the NF locus) shows the behaviour of the system when governed by the dynamics of the normal region. On the boundary of the two regions (when $p = \frac{i_M - r^* + (h-1)\hat{p}}{h}$) and at a given level of the real exchange rate, the slope of the integral curve in the normal case, $\left.\frac{ds}{dp}\right|^N$ is the same as the slope of the integral curve in the liquidity trap case $\left.\frac{ds}{dp}\right|^L$.[5] This means that the centre orbits of the liquidity trap region and the saddlepoint solution trajectories of the normal region merge smoothly into each other at the boundary between the two regions. Figure 1a shows the 'merged', global solution trajectories spanning the two regions. The stable branch SS' and the unstable branch UU' through the normal steady state merge on the boundary NF into an orbit drawn with reference to the liquidity trap steady state. The lowest inflation rate

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[5] It is easily checked that $\left.\frac{ds}{dp}\right|^N_{p = \frac{i_M - r^* + (h-1)\hat{p}}{h}} = \left.\frac{ds}{dp}\right|^L_{p = \frac{i_M - r^* + (h-1)\hat{p}}{h}} = \frac{(h-1)(i_M - r^* - \hat{p})}{hb(ds + f - \bar{y})}$

achieved on this orbit, $\underline{p}$, is the lowest starting value of the inflation rate for which well-behaved solutions are defined. Any path starting below $\underline{p}$ will eventually lead to an explosive solution, with inflation and consumption rising without bound.[6]

To understand the possible multiplicity of non-explosive solutions that may occur in this model, two properties of admissible solutions deserve emphasising. First, explosively divergent solutions are ruled out, if non-explosive solutions exist. Second, the inflation rate is a predetermined state variable while the real exchange rate is non-predetermined (because the nominal exchange rate is non-predetermined). This means that discontinuous changes in the rate of inflation are never allowed and that discontinuous changes in the level of the real exchange rate are permitted only at instants that news arrives. In what follows, news arrives only once, at the initial date.

For all initial inflation rates below $\underline{p}$, there only exist explosive solutions. EE' in Figure 1a is one such explosive solution. For all initial rates of inflation less than $\frac{i_M - r^* + (h-1)\hat{p}}{h}$ (to the left of the *NF* locus) but above $\underline{p}$, there exists a continuum of solution trajectories that always stay completely within the floor region. *LL'* is one such solution. Nominal interest rates at all maturities will be zero.[7] For any initial rate of inflation below the normal steady state rate of inflation ($\hat{p}$) but above $\frac{i_M - r^* + (h-1)\hat{p}}{h}$, there will be a continuum of possible solution orbits, all of which are at partly in the floor region. The instantaneous short nominal rate will be zero on that part of the solution

[6] The accelerationist Phillips curve does not bound actual output y, which is demand-determined and can, taken literally, exceed capacity output, $\bar{y}$, without bound. A richer model would rule out such explosive real output dynamics.

curve *LL'* that lies to the left of $\frac{i_M - r^* + (h-1)\hat{p}}{h}$, but there will be longer maturity nominal interest rates that are positive. When the solution trajectory is to the right of $\frac{i_M - r^* + (h-1)\hat{p}}{h}$, even the instantaneous nominal interest rate will be positive.

Figure 1a shows that for any initial rate of inflation below the target level (the normal steady state level $\hat{p}$) but above $\underline{p}$, there also exists a unique orbit (and two values of s) that will take the system to the normal steady state. That is the solution trajectory given to the right of the *NF* locus (and to the left of $\hat{p}$) by the stable branch *SS'* and the unstable branch *UU'* drawn with reference to the normal steady state Ω^N, and to the left of the *NF* locus by that closed orbit, drawn with reference to the liquidity trap steady state, Ω^L, that has tangencies to *SS'* and *UU'* on the *NF* locus at *T* and *T'* respectively. Thus, even if I (rather arbitrarily) restrict admissible solutions to those that converge to the normal steady state, there will be, for any initial rate of inflation below $\hat{p}$ and above $\underline{p}$, two initial values of the real exchange rate that are consistent with this requirement. In addition, there also exists a continuum of solution orbits like *LL'* that cycle, either partly in the normal region and partly in the floor region (like *LL'*) or completely in the floor region. These orbits never reach the normal steady state. When the initial rate of inflation equals $i_M - d$, the continuum of solutions for the real exchange rate, ranging between e^H and e^L, includes the liquidity trap steady state, Ω^L.

For any initial inflation rate above the normal steady state rate of inflation, $\hat{p}$, there is a unique non-explosive solution trajectory. That solution puts the real exchange

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[7] I assume for concreteness that $i_M = 0$ here.

rate on the stable branch through the normal steady state, *SS'*. There is no non-explosive solution trajectory that moves the system from an initial rate of inflation above p^* into the liquidity trap region.

It is interesting to investigate what happens when the target rate of inflation implicit in the Taylor rule, $\hat{p}$, equals $i_M - r^*$, the steady state inflation rate in the liquidity trap case. When the target rate of inflation equals Friedman's optimum rate of inflation, the configuration shown in Figure 1b occurs. The normal steady state, with its local saddlepoint configuration coincides with the liquidity trap steady state with its local centre configuration. Indeed, $\bar{p}^N = \hat{p} = \bar{p}^L = i_M - r^* = \underline{p}$ in this case. Any solution starting from an inflation rate above $\hat{p}$ now converges along the stable branch SS' towards the unique steady state Ω^{NL}. Any solution starting from an inflation rate below $\hat{p}$ (and therefore also below $\underline{p}$) now diverges explosively.

It is not sensible to have parameter configurations where the target rate of inflation implicit in the Taylor rule is below the steady state inflation rate that supports Friedman's optimum quantity of money. Assume the contrary, i.e. that $\hat{p} < i_M - r^*$. The inflation rate defining the boundary between the normal and the floor regions, p^{NF}, say, is given by: $p^{NF} = \dfrac{i_M - r^* + (h-1)\hat{p}}{h}$. With $h > 1$ it follows that

$\bar{p}^N = \hat{p} < p^{NF} < \bar{p}^L = i_M - r^*$. The steady state for the Taylor rule would lie outside the range of inflation rates for which the Taylor rule is defined. In what follows, I only consider parameter configurations supporting the solution trajectories shown in Figure 1a.

III. The Liquidity Trap

We want to consider shocks that can cause the liquidity trap to be sprung, that is, shocks for which the constraint $i \geq i_M$ can become binding. I consider an economy that is initially in the normal steady state, at Ω_1^N in Figure 2, and is hit by an unexpected demand shock that lowers current aggregate demand below current capacity output. As an example, I consider the unanticipated announcement, at $t = t_0$, of an immediate and temporary fall in the exogenous component of aggregate demand, f, which is reversed again at $t = t_1 > t_0$. This exogenous contraction of aggregate demand could originate in the domestic private sector, in the domestic public sector or abroad. For concreteness, I refer to it as a cut in exhaustive public spending.

FIGURE 2 here

The real exchange rate in our model is given by

$$s(t) = \lim_{T\to\infty}\left(s(T) - \int_t^T [r(v) - r^*(v)]dv\right) \tag{1.22}$$

Here $\lim_{T\to\infty} s(T)$ is the long-run real exchange rate. Since the demand shock is temporary, the long-run real exchange rate does not change (see equation (1.12)). The value of the real exchange immediately following the announcement and implementation of the public spending cut is therefore driven just by the integral of future (expected) internal-external short real interest rate differentials. Monetary policy affects the real exchange rate to the extent that changes in current and anticipated future short nominal rates can affect current and anticipated future short real interest rates. With short-run nominal rigidities, monetary policy will have transitory real effects.

To determine what happens in response to an immediate, temporary public spending cut, consider first the benchmark of an unexpected, immediate and permanent cut in public spending. In this case there would be a depreciation (increase) in the long-run real exchange rate according to equation (1.12).

There exists just one vertical displacement of the real exchange rate following an unanticipated immediate and permanent cut in public spending that will not lead to subsequent explosive behaviour of the system. That is an immediate movement from the initial steady state at Ω_1^N in Figure 2 to the new normal steady state corresponding to the lower level of public spending at Ω_2^N. Any smaller or larger increase in the real exchange rate (let alone any discrete fall in s) will lead to explosive behaviour. This unique equilibrium real exchange rate depreciation and instantaneous move to the new steady state is the same that would be produced by the textbook static Mundell-Fleming model with perfect capital mobility and a floating exchange rate.

When the unexpected public spending cut is immediate but of finite duration, there exists a unique initial depreciation of the real exchange rate that causes the system to converge to the new normal steady state, which in this case is also the initial normal steady state. For a public spending cut of the same magnitude as before, the initial response of the real exchange rate would be a discrete depreciation to a level Ω_{12}^N below Ω_2^N. From Ω_{12}^N, the system would travel from t_0 till t_1, when the spending cut is reversed, along that divergent solution trajectory, drawn with reference to Ω_2^N, that will take it to the convergent saddlepath $S_1S_1^{'}$ at the instant the public spending cut is reversed at t_1. This happens at Ω_{13}^N in Figure 2. From there on the system converges smoothly back to Ω_1^N. While the public spending cut is in effect, the economy is in recession, and inflation falls. After the initial discrete depreciation of the real exchange rate, the real exchange rate appreciates steadily - at an increasing rate from t_0 till t_1, and at a decreasing rate after t_1. From ‘real UIP’ (the real interest rate differential equals the expected rate of depreciation of the real exchange rate), it follows that the domestic real interest is lower everywhere along the adjustment path than in the initial steady state. This means that, when public spending returns to its initial level after t_1, there is excess demand and the rate of inflation rises again. Figure 2 bears this out.

The behaviour of the domestic short real rate of interest along this solution trajectory can also be motivated with our Taylor rule for the short nominal rate of interest. Following the contractionary fiscal shock, inflation decline gradually along the solution path. Through the Taylor-style nominal interest rate reaction function, the short nominal interest rate falls more than one-for-one with the inflation rate. Consequently, the profile of expected future short real rates is indeed lower with the public spending cut than without, and the real exchange rate depreciates on impact, although not by enough to negate the negative effect on aggregate demand of the public spending cuts.

In addition to this unique solution that converges to the initial normal steady state Ω_1^N, there is a continuum of solutions that put the system, at t_1, on a closed orbit that will lie partly in the normal and partly in the floor regions. One such solution is shown in Figure 2. At the initial date, t_0, there is a jump depreciation of the real exchange rate to some level below Ω_{12}^N, say Ω_{12}^L. From Ω_{12}^L the system travels along a divergent trajectory, drawn with reference to Ω_2^N, that will put it on the orbit *LL’* at t_1. Note that this solution trajectory intersects $S_1S_1^{'}$, the stable branch through Ω_1^N, before it reaches the orbit *LL'* at $t = t_1$ at the point Ω_{13}^L. There exists a continuum of possible initial jumps in the real exchange rate, to a position between Ω_{12}^N and Ω_1^N, that will put the economy on one of a continuum of closed orbits around the liquidity trap steady state.

The analysis so far shows that, as long as $p > \underline{p}$, there exist either, if $\underline{p} < p < \hat{p}$, two values for the real exchange rate or, if $p \geq \hat{p}$ a single value for the real exchange rate from which the economy will converge to the normal steady state. However, if $\underline{p} < p < \hat{p}$, there also exists a continuum of solutions that do not diverge explosively but that don't converge to the normal steady state either. These solutions orbit the liquidity trap steady state.[8] There is no obvious mechanism to ensure that the private agents whose expectations drive the model will co-ordinate on any one of this multiplicity of equilibria. There is nothing in the model, therefore, that rules out as inadmissible those solution trajectories that circle the liquidity trap steady state.

Monetary policy actions to avoid or escape a liquidity trap in our model can take various forms. First, a one-off increase in the inflation target, $\hat{p}$. Under our Taylor rule, this amounts to a reduction in the intercept term in the Taylor rule. Second, a one-off reduction in the nominal interest rate on money, i_M. Third, a change in the responsiveness of the nominal interest rate to the rate of inflation, that is, a change in h. Finally, the adoption of a *rule* for the nominal interest rate on money that ensures that it will always be below the nominal interest rate on non-monetary assets. Only the last of these measures turns out to eliminate the liquidity trap problem.

[8] This includes the case where the solution is at the liquidity trap steady state, when $p - i_M - r^*$.

An increase in the target rate of inflation shifts the normal steady state horizontally to the right, one-for-one. The *NF* locus, marking the boundary between the normal and the floor regions also shifts to the right, but less than one-for-one. Raising the target rate of inflation therefore *reduces* the range of initial inflation rates for which there exist non-explosively divergent solutions that do not converge to the normal steady state.

Lowering the nominal interest rate on money leaves the normal steady state (and the dynamics in the normal region) unchanged. It shifts the liquidity trap steady state horizontally to the left, one-for-one, and it also shifts the *NF* locus to the left, but less than one-for-one.

Raising h, the responsiveness of the nominal interest rate to the rate of inflation, while leaving the target rate of inflation unchanged also does not qualitatively affect the behaviour of the system.[9] To ensure that, provided the system starts off in the normal region ($i > i_M$), it cannot end up in the floor region, the Taylor rule must be modified or, more accurately, *augmented* by a rule ensuring that the nominal interest rate on money always stays below the nominal interest rate on non-monetary securities.

A simple modification (or amplification) of the Taylor rule that avoids the liquidity trap is as follows. The exogenous own nominal interest rate assumption for money is replaced by the following simple rule:

$$\begin{aligned} i_M &= i - a \\ a &> 0 \end{aligned} \qquad (1.23)$$

[9] Provided $r^* + \hat{p} - i_M > 0$ it will shift the *NF* locus to the right.

The Taylor rule for the short nominal interest rate on non-monetary securities (given in (1.4)) now simplifies to (1.24), because the constraint $i > i_M$ is never binding because of (1.23).

$$i = r^* + \hat{p} + h(p - \hat{p}) \tag{1.24}$$

The rest of the model is as before. Note, however, that there is now no restriction on the domain of the nominal interest rate function. Equation (1.23) ensures that the constraint that the short nominal interest rate on non-monetary instruments cannot fall below the short nominal interest rate on money never becomes binding. Specifically, since the own rate of interest on money moves up and down one-for-one with the short nominal interest rate on non-monetary instruments, there is no (zero or other) lower bound to the level of the short nominal interest rate on non-monetary securities.

The 'floor region' and the liquidity trap have been abolished at a stroke, by assuming that the monetary authorities follow a rule for the own nominal interest rate on money which ensures that the nominal interest rate on non-monetary securities is always above the own nominal interest rate on money. Only the simplest kind of rule, maintaining a constant wedge between the two interest rates, is considered here. This *prima facie* minor change in the specification of the monetary policy rule implies that there now is just the normal region, with its saddlepoint configuration, and that only the normal steady state exists.

The rule for the two short nominal interest rates given in equations (1.23) and (1.24) may require the payment of non-zero (positive or negative) nominal interest rates on money, that is, taxing money. In Section IV I consider briefly what the practical obstacles to paying negative interest on money may be.

IV Taxing Money[10]

Financial instruments, henceforth *securities*, can be divided into two categories: bearer securities and registered securities. Registered securities are financial instruments for which the identity of the owner or holder is known to the issuer and can be verified by third parties. Bearer securities are financial instruments for which the owner or holder is anonymous. In particular, the identity of the owner is unknown to the issuer and cannot be verified by third parties.

Paying interest, at a positive or a negative rate on registered securities is a simple task. Take, for instance, checking accounts or deposit accounts. The bank knows the owner of each account. Payment of interest at any rate, positive, zero or negative, is administratively straightforward. The bank periodically credits or debits the account.

With bearer securities, paying any non-zero interest rate is administratively non-trivial. If the interest rate is positive, care must be taken that the interest is paid only once during a given payment period. Since the identity of the owner is unknown to the issuer, the same security could be presented multiple times during any given payment period, either by the same holder or by a sequence of holders. The way around this is to identify the security rather than the owner. The security in question is marked in a verifiable (and preferably non-forgeable) manner by the issuer or his agent, whenever the security is presented for payment of interest due. Historically, securities had coupons attached to them that were cut off (clipped) one at a time whenever an interest payment was made.

[10] A more extensive discussion of this issue can be found in Buiter and Panigirtzoglou [1999].

Other ways of identifying bearer securities as being 'ex-interest'[11], such as stamping, or more high-tech identification methods can be thought of and have been used historically.

If the interest rate on the bearer security is negative, the issuer has the opposite problem of the holder not presenting himself to pay the issuer the negative interest due on the security. The solution is to find a way first of identifying the bearer security as being ex-interest and second to ensure that securities that are not ex-interest are unattractive to potential owners.

The reason for the second condition becomes clear when I think of the bearer security that is of special interest for this paper: currency, that is the monetary liabilities of the central bank that are generally accepted as means of payment and medium of exchange in the central bank's jurisdiction.[12][13] Currency is fiat money. It has no intrinsic value as a consumer good, a capital good or an intermediate input, other than the value of the paper it is printed on. It has value today only because the public believe it will have value tomorrow. For the issuer (the central bank) to put an expiry date on a bank note would be ineffective if the public chose to ignore it. To make paying negative interest on currency possible it must (a) be possible to identify bank notes as being ex-interest and (b) be possible to attach a sufficiently severe penalty to holding money that is not ex-interest after the date the interest is due. Fines, and, in the limit, confiscation or worse, would be required to enforce negative interest on currency.

[11] I use 'ex-interest' analogously with 'ex-dividend' for common stock. A security is ex-interest for a given payment period if the interest due on it (positive or negative) has been paid.
[12] And at times are accepted outside that jurisdiction, as with the US dollar and the DM today.
[13] The monetary liabilities of the central bank consist of currency in circulation and commercial bank balances with the central bank. Banks' balances with the central bank are registered securities. The identity of the owner is known to the issuer. Any interest rate, positive or negative, can be charged on it with negligible administrative expense.

Paying negative interest on currency, or taxing currency, amounts to having periodic 'monetary reforms' in which the old money is retired and replaced by new money, with an exchange rate of more than one unit of old money for each unit of new money. The new money could simply be the old money with a suitable stamp or other mark on it. Continued use of the old money after the 'conversion date' would have to be subject to appropriate penalties for this to work.

The idea of taxing currency is not new. It goes back at least to Gesell and the Social Credit movement in the second ad third decades of the 20th century. No less an economist than Irving Fisher viewed the idea sympathetically. (See Gesell [1949], Douglas [1919], Fisher [1933], Hutchinson and Burkitt [1997], Porter [1999]).

V Conclusion

The zero lower bound on the short nominal rate of interest can become a binding constraint on the ability of the monetary authorities to influence the economy in a small open economy for the same reason as in a closed economy. With the nominal rate of interest on currency fixed by policy at zero, the pecuniary opportunity cost of holding money is the short nominal interest rate on non-monetary securities. When this opportunity cost goes to zero, the demand for money becomes unbounded. The government's control of the short nominal interest rate affects the real economy because sluggish price and inflation adjustment mean that, at least for a while, short real interest rates move in the same direction as short nominal interest rates. Changes in current and anticipated future short nominal interest rates lead to temporary movements in the same direction of current and future short real interest rates and thus in current long real rates.

In the open economy, the real exchange rate provides another transmission channel through which monetary policy has a transitory effect on aggregate demand. This is the channel focussed on in this paper. When the economy is in a liquidity trap, that is, when the entire term structure of nominal interest rates is stuck at zero, monetary policy also loses its ability to affect the exchange rate.

When an economy is stuck at the zero nominal interest rate floor, there are two solutions. Either get off the floor, or lower the floor. Policies to get off the floor include expansionary fiscal policy and other exogenous expansionary shocks to aggregate demand. Policies that lower the floor are unconventional and administratively cumbersome. They involve paying a negative nominal rate of interest on currency, that is, taxing money, in the spirit of Silvio Gesell.

There are circumstances when fiscal policy becomes ineffective. Changes in the (lump-sum) taxation-borrowing mix can fail to stimulate aggregate demand if the conditions for Ricardian equivalence are satisfied. Even temporary increases in exhaustive public spending can loose their capacity for stimulating aggregate demand. This will be the case if public and private spending are perfect *direct* substitutes, or when the increased public debt associated with increased public spending raises default risk premia, increases private sector uncertainty and boosts precautionary private saving. For whatever reason, expansionary fiscal policy of any kind appears to have lost its capacity for stimulating aggregate demand in Japan.

In our model of a small Dornbusch-style open economy with perfect international capital mobility and a freely floating exchange rate, I show how multiple equilibria exist for any initial inflation rate below the 'target rate of inflation' – the long-run rate of inflation supported by the Taylor rule when the zero lower bound on the nominal interest rate is not a binding constraint. Among the multiple solutions orbits, only one converges to the 'normal' steady state under the Taylor rule. All other solution orbits are either partly or wholly in the region where the zero bound on the short nominal interest rate is a binding constraint. One-off measures, such as an increase in the target rate of inflation or a (one-off) reduction in the nominal interest rate on currency, do not eliminate this multiplicity of solutions. When a *rule* is adopted for the nominal interest rate on currency to ensure that the pecuniary opportunity cost of holding money is always positive, all equilibria other than the unique equilibrium that converges to the normal steady state are eliminated. This rule may require the payment of a negative nominal interest rate on currency. Its implementation would be subject to considerable administrative, enforcement and shoe leather costs. These costs would have to be balanced against the cost of being locked in orbit around the liquidity trap steady state, with alternating periods of excess demand and excess capacity.

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