

Liquidity Effects in Non-Ricardian Economies

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Abstract

It has often been found difficult to generate a liquidity effect (i.e., a negative effect of monetary injections on the nominal interest rate) in the traditional “Ricardian” stochastic dynamic model with a single infinitely lived household. We show that moving to a non-Ricardian environment where new agents enter the economy in each period allows such a liquidity effect to be generated.

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I. Introduction

The purpose of this paper is to investigate a new mechanism through which liquidity effects can be introduced into dynamic stochastic general equilibrium (DSGE) models.

What we here call “liquidity effects” is the negative response of the nominal interest rate to monetary injections. Such a liquidity effect was already present in the famous IS–LM model, and it appears to be found in the data; see, for example, Christiano, Eichenbaum and Evans (1997). As it turns out, this liquidity effect has been found difficult to obtain in standard monetary DSGE models. The reason is an “inflationary expectations effect” which tends to actually raise the nominal interest rate in response to a monetary injection.

Let us briefly outline the mechanism behind this inflationary expectations effect.¹ The data reveal that money increases are positively correlated in time. So when an unexpected money injection occurs, this creates the expectation of further money increases in the future, which will itself generate the expectation of future inflation. Now, from Fisher’s equation,

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¹ This effect appears more formally in Section V below.

the nominal interest rate is the sum of expected inflation and the real interest rate so that, *ceteris paribus*, this will tend to raise the nominal interest rate.

In spite of this “inflationary expectations effect”, the literature contains a few models and mechanisms which introduce a liquidity effect in DSGE models. Two prominent types are:

- (i) Models of limited participation, as in Lucas (1990), Christiano and Eichenbaum (1992) and Fuerst (1992), where households cannot adapt their financial portfolios immediately when a monetary policy shock occurs.
- (ii) Models of sticky prices, as in Jeanne (1994) and Christiano *et al.* (1997), where prices are preset in advance. In fact, the liquidity effect occurs if the intertemporal elasticity of substitution in consumption is sufficiently low.

What we want to do here is explore a third avenue, which we will call “non-Ricardian”. By non-Ricardian we mean models, like the overlapping-generations model of Samuelson (1958), where new agents are born every period, and where “Ricardian equivalence” *à la* Barro (1974) does not hold, in contrast to the traditional “Ricardian” model where the same agent or dynasty lives from the beginning to the end of time.

We shall argue that the non-Ricardian character of these economies is conducive to a liquidity effect. In a nutshell, the channel is the following: the existence of future, yet unborn, generations creates—as we shall see below—a “wealth effect” akin to those studied by Pigou (1943) and Patinkin (1956). This wealth effect itself produces a liquidity effect.²

In order to demonstrate this formally we use a model due to Weil (1991), which achieves a synthesis between the traditional monetary Ricardian model with an infinitely lived household, as in Sidrauski (1967) and Brock (1975), and the monetary OLG model, as in Samuelson (1958). This model displays the “wealth effect”, and has already been used to study other monetary issues such as price determinacy under interest rate rules; see Bénassy (2000, 2005) and Ireland (2001).³

The plan of the paper is as follows. The non-Ricardian model is introduced in Section II. Section III shows how a wealth effect arises

² An intuitive explanation of this liquidity effect is developed in the Appendix within the framework of an IS–LM-type model.

³ Bénassy (2000) studies price determinacy with pegged non-zero interest rates, while Ireland (2001) emphasizes zero interest rates. Bénassy (2005) investigates under which conditions Taylor rules lead to determinacy.

in this model. The dynamic equations are derived in Section IV. Section V shows how the non-Ricardian economy displays a liquidity effect and Section VI gives a generalization. It is proven in Section VII that the liquidity effect can be quite persistent. Section VIII concludes and the Appendix gives an intuitive derivation of the results in an IS–LM model.

II. A Non-Ricardian Model

Since we would like to have a non-Ricardian structure that “nests” the usual Ricardian model, we use a model adapted from Weil (1987, 1991). Households never die, but new “generations” are born each period. Denote by N_t the number of households alive at time t . Since households do not die, $N_{t+1} \geq N_t$. Below we focus mainly on the case where the population grows at the constant rate $n \geq 0$, so that $N_t = (1 + n)^t$.

Households

Consider a household j (i.e., a household born in period j). Denote by c_{jt} and m_{jt} its consumption and money holdings at time $t \geq j$. This household receives in period $t \geq j$ an endowment y_{jt} and maximizes the expected value of the following utility function:

$$U_{jt} = \sum_{s=t}^{\infty} \beta^{s-t} \log c_{js}. \quad (1)$$

Household j is subjected in period t to a “cash-in-advance” constraint:

$$P_t c_{jt} \leq m_{jt}. \quad (2)$$

Household j enters period t with financial wealth ω_{jt} . He then receives from the government a lump-sum monetary transfer τ_{jt} (if negative this will be called taxes), so that his available wealth is $\omega_{jt} + \tau_{jt}$. There are then two successive “subperiods” where the bonds and goods markets open sequentially.

In the first subperiod, the bonds market opens. All agents can freely exchange money against bonds at the nominal interest rate i_t . So at this stage household j divides his available wealth $\omega_{jt} + \tau_{jt}$ between bonds b_{jt} and money m_{jt} :

$$m_{jt} + b_{jt} = \omega_{jt} + \tau_{jt}. \quad (3)$$

In the second subperiod, the goods market opens. Household j sells his endowment y_{jt} and consumes c_{jt} , subject to the cash constraint (2).

Consequently his budget constraint is:

$$\begin{aligned}\omega_{jt+1} &= (1 + i_t)b_{jt} + m_{jt} + P_t y_{jt} - P_t c_{jt} \\ &= (1 + i_t)(\omega_{jt} + \tau_{jt}) - i_t m_{jt} + P_t y_{jt} - P_t c_{jt}.\end{aligned}\quad (4)$$

Aggregation

Aggregate quantities are obtained by summing the various individual variables. As there are $N_j - N_{j-1}$ agents born in period j , total transfers and assets are:

$$T_t = \sum_{j \leq t} (N_j - N_{j-1}) \tau_{jt}, \quad \Omega_t = \sum_{j \leq t} (N_j - N_{j-1}) \omega_{jt}.\quad (5)$$

Similar formulas apply to aggregate money M_t , bonds B_t , consumption C_t and output Y_t .

Endowments and Transfers

We now describe how endowments and transfers are distributed among households. In most of the paper, all households are assumed to have the same income and transfers, so that:

$$y_{jt} = y_t = \frac{Y_t}{N_t}, \quad \tau_{jt} = \tau_t = \frac{T_t}{N_t}.\quad (6)$$

In Section VI we explore the more general assumption that households' resources diminish at a rate $\xi < 1$. We shall see that this still reinforces our results.

Government

Another important part of the model is the government. The households' aggregate financial wealth Ω_t has as a counterpart an identical amount Ω_t of financial liabilities of the government. The evolution of these liabilities is described by the government's budget constraint:

$$\Omega_{t+1} = (1 + i_t)B_t + M_t = (1 + i_t)(\Omega_t + T_t) - i_t M_t.\quad (7)$$

Monetary Policy

If we aggregate equation (3) across all generations we obtain:

$$M_t + B_t = \Omega_t + T_t.\quad (8)$$

Monetary policy is an “open market” policy whereby all agents, including the government, freely exchange bonds against money on the bonds market. As in all studies on the “liquidity effect”, we assume that the government uses the quantity of money M_t as the policy variable and that, consequently, the nominal interest rate i_t is endogenously determined through the equilibrium on the bonds market. A positive shock on money M_t corresponds to a purchase of bonds by the government.

Following the literature, we assume that M_t is a stochastic process. As an example, it is often assumed in the literature that money increases are autocorrelated in time:

$$\log\left(\frac{M_t}{M_{t-1}}\right) = \frac{\varepsilon_t}{1 - \rho L}, \quad 0 \leq \rho < 1, \quad (9)$$

where L is the lag operator, and ε_t is i.i.d.

As indicated above, we say there is a liquidity effect if a positive shock on M_t leads to a decrease in i_t .

III. The Wealth Effect⁴

As indicated in the introduction, an important part of the story is the “wealth effect” through which financial wealth influences consumption and the dynamic equations.

Of course, one may wonder why part of financial assets, now and in the future, represents actual purchasing power in the non-Ricardian model, whereas it does not in the Ricardian model. The reason is simple: some of the future taxes that are the counterpart of current nominal wealth will not be paid by the agents currently alive, but by future, as yet unborn, generations, so that this part of Ω_t represents actual purchasing power. Let us now formalize this intuition. We begin with the intertemporal government budget constraint, as it plays an important role in the reasoning.

The Government Intertemporal Budget Constraint

In what follows we repeatedly aggregate discounted values. It is convenient to compute in monetary terms, and we thus use the following discount factors:

$$R_t = \prod_{s=0}^{t-1} \frac{1}{1 + i_s}, \quad R_0 = 1. \quad (10)$$

⁴ The existence of a wealth effect for financial assets in a non-Ricardian economy was uncovered by Weil (1991).

Let us consider the government's budget constraint (7) in period s multiplied by R_{s+1} :

$$R_{s+1}\Omega_{s+1} = R_s\Omega_s + R_sT_s - (R_s - R_{s+1})P_sY_s. \quad (11)$$

Now let us define total taxes in period s , Γ_s , as:

$$R_s\Gamma_s = R_s\left(\frac{i_sM_s}{1+i_s} - T_s\right) = (R_s - R_{s+1})P_sY_s - R_sT_s. \quad (12)$$

Total taxes consist of proper taxes $-T_s$ and the money economized by the state because of the cash-in-advance constraint $i_sM_s/(1+i_s)$, the "money tax". Using this definition, (11) can be rewritten:

$$R_s\Gamma_s = R_s\Omega_s - R_{s+1}\Omega_{s+1}. \quad (13)$$

Taking expectation of (13) as of time t , and summing from time t to infinity we get:

$$R_t\Omega_t = E_t \sum_{s=t}^{\infty} R_s\Gamma_s. \quad (14)$$

We see that every single dollar of financial wealth is matched by discounted current and future taxes.

The Consumption Function

Let us now consider household j 's budget equation (4). We assume that i_t is strictly positive, so that the cash-in-advance constraint is always satisfied exactly and $m_{js} = P_s c_{js}$. Applying the discount factor R_{s+1} to this budget constraint, it becomes:

$$R_{s+1}\omega_{js+1} = R_s\omega_{js} + R_s\tau_s + R_{s+1}P_s y_s - R_s P_s c_{js}. \quad (15)$$

Household j maximizes the expected value of its utility (1) subject to the sequence of budget constraints (15). This yields the first-order condition:

$$\frac{1}{R_s P_s c_{js}} = \beta E_s \left(\frac{1}{R_{s+1} P_{s+1} c_{js+1}} \right). \quad (16)$$

We can approximate (16) to the first order as:

$$E_s(R_{s+1} P_{s+1} c_{js+1}) = \beta R_s P_s c_{js} \quad (17)$$

and take the expectation as of time t of both sides:

$$E_t(R_{s+1} P_{s+1} c_{js+1}) = \beta E_t(R_s P_s c_{js}). \quad (18)$$

Now let us take the expectation of (15) as of time t , and aggregate all these constraints from time t to infinity. Assuming that $R_s\omega_{js}$ goes to zero as s goes to infinity (this is the usual transversality condition), we obtain the intertemporal budget constraint of the household (in expected terms):

$$E_t \sum_{s=t}^{\infty} R_s P_s c_{js} = R_t \omega_{jt} + E_t \sum_{s=t}^{\infty} (R_{s+1} P_s y_s + R_s \tau_s). \quad (19)$$

Applying formula (18) repeatedly and inserting it into (19), we find the consumption function for agents born in period j :

$$R_t P_t c_{jt} = (1 - \beta) \left[R_t \omega_{jt} + E_t \sum_{s=t}^{\infty} (R_{s+1} P_s y_s + R_s \tau_s) \right]. \quad (20)$$

Summing over all N_t households alive in t we obtain the aggregate consumption function:

$$R_t P_t C_t = (1 - \beta) \left[R_t \Omega_t + N_t E_t \sum_{s=t}^{\infty} (R_{s+1} P_s y_s + R_s \tau_s) \right]. \quad (21)$$

Now, using the definition of “total taxes” Γ_s (equation (12)), this can be rewritten as:

$$R_t P_t C_t = (1 - \beta) \left[N_t E_t \sum_{s=t}^{\infty} R_s P_s y_s + R_t \Omega_t - N_t E_t \sum_{s=t}^{\infty} \frac{R_s \Gamma_s}{N_s} \right]. \quad (22)$$

We see that generations alive in t will pay at time $s > t$ only a fraction N_t/N_s of total taxes, thereby giving rise to the wealth effect.

The Wealth Effect

Combining equations (14) and (22), we rewrite the consumption function as:

$$R_t P_t C_t = (1 - \beta) \left[N_t E_t \sum_{s=t}^{\infty} R_s P_s y_s + E_t \sum_{s=t}^{\infty} \frac{N_s - N_t}{N_s} R_s \Gamma_s \right]. \quad (23)$$

Note that $N_s - N_t$ is the number of agents alive in period s , but yet unborn at period t . So the wealth of agents currently alive consists of two parts: (i) the discounted sum of their incomes and (ii) the share of taxes that will be paid by future generations in order to reimburse the current financial wealth.

We may now wonder: what part of financial wealth will be regarded as “real wealth” by the generations currently alive? To determine this, let us

insert (13) into (22). We obtain:

$$R_t P_t C_t = (1 - \beta) \left[N_t E_t \sum_{s=t}^{\infty} R_s P_s y_s + R_t \Omega_t + N_t E_t \sum_{s=t}^{\infty} \frac{R_{s+1} \Omega_{s+1} - R_s \Omega_s}{N_s} \right]. \quad (24)$$

Rearranging we find:

$$R_t P_t C_t = (1 - \beta) N_t E_t \left[\sum_{s=t}^{\infty} R_s P_s y_s + \sum_{s=t}^{\infty} R_{s+1} \Omega_{s+1} \left(\frac{1}{N_s} - \frac{1}{N_{s+1}} \right) \right]. \quad (25)$$

Consider the case where, by means of an adequate fiscal policy, Ω_t remains constant in time and equal to Ω_0 . In such a case, the “supplementary wealth” beyond discounted incomes is, from (25), equal to:

$$\left[N_t \sum_{s=t}^{\infty} R_{s+1} \left(\frac{1}{N_s} - \frac{1}{N_{s+1}} \right) \right] \Omega_0. \quad (26)$$

It is easy to see that the coefficient in brackets is between 0 and 1, and, other things equal, larger when the rate of increase in the population is larger.

IV. Dynamic Equilibrium

In equilibrium we have $C_t = Y_t$, so equation (25) becomes, after dividing by N_t :

$$R_t P_t y_t = (1 - \beta) E_t \left[\sum_{s=t}^{\infty} R_s P_s y_s + \sum_{s=t}^{\infty} R_{s+1} \Omega_{s+1} \left(\frac{1}{N_s} - \frac{1}{N_{s+1}} \right) \right]. \quad (27)$$

Let us rewrite it for $t + 1$, take the expectation as of time t , and subtract from (27). We find:

$$E_t(R_{t+1} P_{t+1} y_{t+1}) = \beta R_t P_t y_t - (1 - \beta) \left(\frac{1}{N_t} - \frac{1}{N_{t+1}} \right) R_{t+1} \Omega_{t+1}. \quad (28)$$

Multiplying by N_{t+1}/R_{t+1} , and taking $N_{t+1}/N_t = 1 + n$ we obtain:

$$E_t(P_{t+1} Y_{t+1}) = \beta(1 + n)(1 + i_t) P_t Y_t - (1 - \beta)n \Omega_{t+1}. \quad (29)$$

This is our central dynamic equation. Note that the “non-Ricardian” character appears through the last term, which shows that, unlike in the Ricardian model where $n = 0$, financial wealth does matter.

Now, since the model is non-Ricardian, the dynamics will depend on the actual fiscal transfer policy. To simplify the dynamics below, and since our

focus is on monetary policy, we choose the simplest fiscal policy and assume that the government balances its budget period by period. Fiscal transfers will thus exactly compensate interest payments on bonds:

$$T_t = -i_t B_t. \quad (30)$$

Combining (7), (8) and (30) we find that under the balanced budget policy (30), total financial wealth will remain constant:

$$\Omega_t = \Omega_0, \quad \text{for all } t. \quad (31)$$

The dynamic equation (29) then becomes:

$$E_t(P_{t+1} Y_{t+1}) = \beta(1+n)(1+i_t)P_t Y_t - (1-\beta)n\Omega_0 \quad (32)$$

and since $M_t = P_t C_t = P_t Y_t$, this can be rewritten:

$$E_t M_{t+1} = \beta(1+n)(1+i_t)M_t - (1-\beta)n\Omega_0. \quad (33)$$

V. Liquidity Effects

We now show that the non-Ricardian character of the economy, i.e., the fact that $n > 0$, will produce a liquidity effect.

The Nominal Interest Rate

Equation (33) can be explicitly solved for the nominal interest rate:

$$1 + i_t = \frac{1}{\beta(1+n)} E_t \left(\frac{M_{t+1}}{M_t} \right) + \frac{(1-\beta)n\Omega_0}{\beta(1+n)M_t}. \quad (34)$$

We see that the first term, which is present even if $n = 0$, displays the “inflationary expectations effect”: indeed, the nominal interest rate will rise if a positive monetary shock announces future money growth, i.e., if:

$$\frac{\partial}{\partial M_t} \left[E_t \left(\frac{M_{t+1}}{M_t} \right) \right] > 0, \quad (35)$$

which is what is generally found empirically. In the example above (equation (9)) this will occur if $\rho > 0$. We assume in what follows that the money process satisfies condition (35).

Now the second term, which appears only if $n > 0$, i.e., if we are in a non-Ricardian framework, clearly introduces a liquidity effect, since an increase in money directly decreases the nominal interest rate. The higher n , the stronger this effect.

We can provide an even simpler expression. Assume that money M_t is stationary around the value M_0 . From (33), the corresponding stationary value of the interest rate, i_0 , is related to M_0 and Ω_0 by:

$$M_0 = \beta(1+n)(1+i_0)M_0 - (1-\beta)n\Omega_0. \quad (36)$$

Let us define:

$$\theta = \beta(1+n)(1+i_0). \quad (37)$$

If we want to have a “wealth effect”, net financial assets must be positive, i.e., $\Omega_0 > 0$. As a consequence, from (36), the parameter θ must satisfy:⁵

$$\theta > 1. \quad (38)$$

Now combining (34), (36) and (37), we obtain:

$$\frac{1+i_t}{1+i_0} = \frac{1}{\theta} E_t \left(\frac{M_{t+1}}{M_t} \right) + \left(1 - \frac{1}{\theta} \right) \frac{M_0}{M_t}. \quad (39)$$

We see that expression (39) gives a balanced view between the new non-Ricardian liquidity effect and the traditional inflationary expectations effect. Note that the higher θ (and thus notably the higher n), the stronger the liquidity effect will be.

The Real Interest Rate

The real interest rate r_t is defined as:

$$1+r_t = (1+i_t) \frac{P_t}{P_{t+1}}. \quad (40)$$

Now let us assume, as an example, that endowments per head are constant in time, so that $Y_{t+1}/Y_t = 1+n$. Combining this with $M_t = P_t Y_t$, and equations (36), (37) and (39), we obtain:

$$\frac{1}{1+r_t} = \beta \frac{M_{t+1}/M_t}{E_t(M_{t+1}/M_t) + (\theta-1)(M_0/M_t)} \quad (41)$$

and

$$E_t \left(\frac{1}{1+r_t} \right) = \beta \frac{E_t(M_{t+1}/M_t)}{E_t(M_{t+1}/M_t) + (\theta-1)(M_0/M_t)}. \quad (42)$$

⁵ We may note that condition (38), which is similar to Wallace’s (1980) condition for the viability of money in an OLG structure, appears in relation to other issues concerning money and monetary policy. For example, it is shown in Bénassy (2005) that (38) is a condition for price determinacy when the central bank uses interest rate rules *à la* Taylor (1993).

In view of assumption (35), we see that the real interest rate will react negatively to a positive money shock, in the sense that:

$$\frac{\partial}{\partial M_t} \left[E_t \left(\frac{1}{1+r_t} \right) \right] > 0. \quad (43)$$

VI. A Generalization

We now consider the more general case where households' resources diminish at the rate $\xi < 1$. The income and transfer of an agent of generation j are ξ^{t-j} times those of an agent of generation $t > j$. To be more precise:

$$y_{jt} = \xi^{t-j} y_t, \quad \tau_{jt} = \xi^{t-j} \tau_t, \quad (44)$$

where y_t and τ_t are the income and transfer of a newborn agent in period t .

In such a case it can be shown⁶ that the dynamic equation (33) is replaced by the more general expression:

$$\xi E_t M_{t+1} = \beta(1+n)(1+i_t)M_t - (1-\beta)(1+n-\xi)\Omega_0. \quad (45)$$

We can again solve directly for the interest rate:

$$1+i_t = \frac{\xi}{\beta(1+n)} E_t \left(\frac{M_{t+1}}{M_t} \right) + \frac{(1-\beta)(1+n-\xi)\Omega_0}{\beta(1+n)M_t}, \quad (46)$$

where we see that the second term does indeed produce a liquidity effect. Now, from (45), the stationary value of money M_0 and the stationary interest rate i_0 are related by:

$$\xi M_0 = \beta(1+n)(1+i_0)M_0 - (1-\beta)(1+n-\xi)\Omega_0. \quad (47)$$

We can now give a more general definition of the parameter θ :

$$\theta = \frac{\beta(1+n)(1+i_0)}{\xi}. \quad (48)$$

Combining (46), (47) and (48) we find that the interest rate is given by:

$$\frac{1+i_t}{1+i_0} = \frac{1}{\theta} E_t \left(\frac{M_{t+1}}{M_t} \right) + \left(1 - \frac{1}{\theta} \right) \frac{M_0}{M_t}. \quad (49)$$

This is exactly the same expression as (39), but the expression of θ has been generalized from (37) to (48). We see that a lower value of ξ

⁶ The proof is similar to that for $\xi = 1$ in Sections III and IV. It is available on request from the author.

increases the value of θ and therefore enhances the non-Ricardian liquidity effect. In the extreme case where $\xi = 0$ (i.e., when agents have all their income in the first period of their life), θ is infinite and the liquidity effect totally dominates.

VII. The Persistence of the Liquidity Effect

It can now be shown that our liquidity effect may be quite persistent. Let us log-linearize equations (39) or (49), which yields:

$$\frac{i_t - i_0}{1 + i_0} = \frac{1}{\theta} (E_t m_{t+1} - m_t) - \left(1 - \frac{1}{\theta}\right) (m_t - m_0), \quad (50)$$

where the particular Ricardian case is obtained by taking $\theta = 1$. Let us consider the following stationary money process:

$$m_t - m_0 = \frac{\varepsilon_t}{(1 - \rho L)(1 - \mu L)}, \quad 0 < \rho < 1, \quad 0 < \mu < 1, \quad (51)$$

where ε_t is i.i.d. Then:

$$E_t m_{t+1} - m_t = \frac{(\mu + \rho - 1 - \mu \rho L) \varepsilon_t}{(1 - \rho L)(1 - \mu L)}. \quad (52)$$

If $\mu + \rho > 1$, then a positive monetary innovation $\varepsilon_t > 0$ creates the expectation of a monetary increase next period, which is the assumption traditionally associated with the “inflationary expectations effect”. Hence we assume $\mu + \rho > 1$ so as to have this effect.

Next, combining (50), (51) and (52), we can compute the full effect of monetary shocks on the interest rate:

$$\frac{i_t - i_0}{1 + i_0} = \frac{(\mu + \rho - \theta - \mu \rho L) \varepsilon_t}{\theta(1 - \rho L)(1 - \mu L)}. \quad (53)$$

We first see that if $\mu + \rho > 1$, the Ricardian version of the model ($\theta = 1$) always delivers an increase in interest rates on impact in response to monetary injections. We thus obtain the traditional “inflationary expectations effect”.

Let us now move to the non-Ricardian case $\theta > 1$. Looking at equation (53), we see that the first-period impact $\mu + \rho - \theta$ is negative as soon as:

$$\theta > \mu + \rho. \quad (54)$$

It can be established that this liquidity effect is persistent, and that condition (54) is actually sufficient for a monetary injection to have a negative effect on the interest rate in all subsequent periods. Expression (53) can indeed be

rewritten as:

$$\frac{i_t - i_0}{1 + i_0} = \frac{1}{\theta(\mu - \rho)} \left[\frac{\rho(\theta - \rho)\varepsilon_t}{1 - \rho L} - \frac{\mu(\theta - \mu)\varepsilon_t}{1 - \mu L} \right]. \quad (55)$$

This can be written as a distributed lag of all past innovations in money ε_{t-j} , $j \geq 0$:

$$\frac{i_t - i_0}{1 + i_0} = \sum_{j=0}^{\infty} \kappa_j \varepsilon_{t-j}, \quad (56)$$

with

$$\kappa_j = \frac{\rho^{j+1}(\theta - \rho) - \mu^{j+1}(\theta - \mu)}{\theta(\mu - \rho)}. \quad (57)$$

Next, we want to show that condition (54) is a sufficient condition for $\kappa_j < 0$ for all j . This is done simply by rewriting (57) as:

$$\kappa_j = \frac{\mu + \rho - \theta}{\theta} \left(\frac{\mu^{j+1} - \rho^{j+1}}{\mu - \rho} \right) - \frac{\mu\rho}{\theta} \left(\frac{\mu^j - \rho^j}{\mu - \rho} \right). \quad (58)$$

The second term is always negative or zero. The first term is negative if $\theta > \mu + \rho$. So condition (54) is sufficient for the non-Ricardian liquidity effect to dominate the usual inflationary expectations effect, not only on impact, but for all subsequent periods as well.

VIII. Conclusions

Here, we developed a new mechanism through which liquidity effects are introduced into dynamic monetary models.

In a nutshell, the basic channel is the following: (i) In a non-Ricardian economy, accumulated financial assets represent, at least partly, real wealth to the generations alive, simply because part of the future taxes that are a counterpart to this financial wealth will be paid by the next generations. This is not the case in the ‘‘Ricardian’’ framework since there is no such thing as the ‘‘next generations’’. (ii) This wealth effect gives rise to a liquidity effect as follows. An increase in money raises prices, which decreases the real value of financial wealth. Due to the wealth effect, this reduces aggregate demand. In order to maintain aggregate demand at the market-clearing level, the real interest rate goes down. This creates, *ceteris paribus*, the liquidity effect.⁷

⁷ See the Appendix for a more detailed elaboration of this reasoning in a very simple model.

Appendix

To guide our intuition as to why the wealth effect leads to a liquidity effect, let us consider a simple traditional IS–LM model augmented with a “wealth effect” à la Pigou or Patinkin. To simplify the exposition, we write this model in log-linear form:

$$y = -a(i - \pi^e) + b(\omega - p) + cy \quad IS \quad (A1)$$

$$m - p = -di + ey \quad LM \quad (A2)$$

$$y = y_0, \quad (A3)$$

where π^e is the expected rate of inflation, $\omega = \log \Omega$, $p = \log P$ and

$$a > 0, \quad b > 0, \quad c > 0, \quad d > 0, \quad e > 0. \quad (A4)$$

The third equation expresses market clearing (which has been assumed throughout). The IS equation says that output is equal to demand, which itself depends negatively on the real interest rate $i - \pi^e$, and positively on real wealth $\omega - p$. Note that the presence of this “real wealth” term, i.e., $b > 0$, is specific to the non-Ricardian framework, as was shown rigorously in the text. We can now solve for the nominal interest rate i , the real interest rate $r = i - \pi^e$, and the price level p . Omitting irrelevant constants, this yields:

$$i = \frac{a\pi^e - bm}{a + bd}, \quad r = -b \frac{m + d\pi^e}{a + bd}, \quad p = \frac{ad\pi^e + am}{a + bd}. \quad (A5)$$

After differentiating the expression for i in (A5), we see that:

$$\frac{\partial i}{\partial m} = \frac{1}{a + bd} \left(a \frac{\partial \pi^e}{\partial m} - b \right). \quad (A6)$$

We recognize the two effects identified in the paper: first, the “inflationary expectations effect”, which is positive if a positive money shock raises inflationary expectations ($\partial \pi^e / \partial m > 0$); second, the negative “liquidity effect”, itself due to the wealth effect ($b > 0$).

The underlying mechanism for the liquidity effect is that an increase in money creates a price increase (A5). This price increase reduces demand because of the real wealth effect, the second term in equation (A1). To maintain total demand at the market-clearing level, the first term in (A1) must increase, i.e., the real rate of interest must decrease. This decrease in the real interest rate creates the liquidity effect.

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