E-money: Legal Restrictions Theory and Monetary Policy *

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Abstract

This paper studies the efficiency of electronic money system by focusing on the decentralized setting of issuance. In the model competitive money issuers can create small denominated money (or e-money) backed by large denominated government bonds. Under the decentralized environment the issuers can also produce counterfeit collateral at a proportional cost. This moral hazard incentive requires the more government bonds for the issuers to provide the same amount of money. In general equilibrium the individual money issuers do not internalize the aggregate effect of money supply. Thus the equilibrium allocation is constrained inefficient with the moral hazard incentives. We suggest a pigouvian tax on money supply to correct the externality in aggregate money supply.

Key words: Limited commitment, Moral hazard, Externality, Open-market Operations. **JEL Codes:** E4,E5

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1 Introduction

A recent development in electronic payment system allows people to use an electronic money(e-money) for small amount payments along with currency provided by the government. This technological progress in the payment system reminds us of one fundamental question in monetary economics: Should the government have a monopoly power in money supply? A widely accepted view among economists is that the control of money supply should not be left to the private sector. Friedman (1960) claims that there are good reasons why monetary and banking arrangements cannot be left to the market, and later Friedman and Schwartz (1986) summarize the reasons as the resource cost of management, the risk of fraud and the presence of externalities, etc. They also evaluate those good reasons with historical facts, but admit that this question has not much been developed with a theoretical model.

The introduction of e-money is not just an issue of the normative question. In the United States financial institutions are currently capable of issuing private (electronic) monies by laws.[1] Thus this technological innovation will change not only the practice of hand-to-hand transactions, but also the environment of monetary policy implementation. In this paper we will examine how the competition in e-money issuance can affect the effectiveness of Open-market Operations(OMOs) and find out what kind of regulations are required for the e-money issuers.

In the paper we define e-money as a financial instrument which stores a monetary value in an electronic devise and can be accepted as a medium of exchange by agents other than its issuer.[2] By the definition, e-money in this paper is close to a prepaid card charged by currency rather than digital currency such as bitcoin which is not backed by any financial assets or entity. In reality this type of e-money is widely used in small amount transactions because people can save the cost for carrying small denominated coins. For example, Octopus card in Hong Kong began as a transportation prepaid card, but 50% of its transactions now

[1] In the U.S. most of federal impediments to private bank note issue were already abolished in 1976 and 1994. However, this private money issuance is recently highlighted since the previous prepaid card is limited in its usage while the e-money such as paypal can be used in a various type of purchases.

[2] For further explanation on this type of e-money, see Fung, Molico, and Stuber (2014) and Chiu and Wong (2014).

occur in retail stores. This type of e-money is also useful for on-line transactions because people, who do not have a bank account, can use it for secured transactions when trade and payment do not occur at the same time and location.

[Figure 1 here]

The transaction mechanism of e-money is described in Figure 1: Initially, consumers can have e-money by paying currency to an e-money issuer.[3] Then the consumers purchase goods with e-money in the market and afterwards the e-money issuer provides currency to the seller. In the transaction process, like currency, e-money does not need any consumer's personal information because it is not associated with banking accounts of the consumers.[4] In this respect e-money can be issued by private entities which are not necessarily financial intermediaries such as banks. But, e-money does not circulate over and over among people while hand-to-hand currency does. We pay attention to this feature that the e-money issuers settle the currency after the good trades are completed. As long as the e-money issuers can respond to the settlement, they can purchase assets instead of holding idle cash and waiting for the settlement. For example, the e-money issuers can invest in short-term government bonds which will turn into currency when the settlement is required. In this point the e-money transaction is similar to one of the secured credit transactions, because the value of e-money is backed by the value of promised currency under the limited commitment of the e-money issuers. If the central bank does not have any power to levy taxes, then the currency issued by the central bank has the same status as e-money because currency is also a debt backed by government bonds under the limited commitment of the central bank. Thus the development of e-money technology allows the private sector to provide a payment instrument that can compete with or replace currency issued by the central bank.

There arise two features when we introduce the private e-money issuers. One is perfect competition in issuing e-money in the market. Given free entry of issuing e-money, the profit

[3]In the model consumers can also have e-money by providing their labor or goods.

[4]Although personal information is not recorded, e-money issuers can adjust the discount rate of trade in the specific categories. For example, e-money issuers can provide 5% discount in food transactions, while 3% discount in appliance purchase. Similarly, the government can regulate the discount rate of the specific trade. However, it is beyond the scope of this paper.

of the e-money issuers approaches to zero in equilibrium.[5] This introduction of competition can change the effectiveness of monetary policy implementation, specifically OMOs, which influence real interest rates by adjusting the amount of outstanding government bonds.[6] For example, if the central bank absorbs currency by selling outstanding government bonds then the supply of bonds increases in the market so that the real interest rate on bonds increases. This path could be restricted by introducing the competitive e-money issuers, because the e-money issuers can rewind the operation by providing e-money and purchasing government bonds for profit whenever currency is scarce in the market. So in equilibrium the level of nominal interest rate is fixed and OMOs are no more effective.[7]

The other feature is the difficulty in monitoring the moral hazard of the decentralized e-money issuers. Due to the limited commitment, holding qualified assets as collateral is essential to issue e-money. However, it is difficult to monitor the behavior of all the private issuers when the issuing environment is decentralized. If creating a counterfeit collateral is available at a proportional cost, for example, the e-money issuers have a moral hazard incentive to fake the quality of collateral unless they are well monitored. This moral hazard incentive can restrict the amount of their e-money issuance in equilibrium since a proportion of the assets cannot be trusted as collateral. Therefore, in equilibrium the trade amount supported by e-money could be restricted because a proportion of the assets cannot be used as collateral under the moral hazard incentives.

We use a modified Lagos and Wright (2005) and Rocheteau and Wright (2005) model which can incorporate limited commitment, asymmetric information, and the implementation of monetary policy in a simple way. Some details of the banking structure and the fiscal policy in the model are brought from Williamson (2012, 2016), but we address and focus on the externality in the competitive money supply environment. In the model the agents use e-money in the hand-to-hand transactions while government bonds in the collateral trade.

[5]In practice there must be an entry cost for launching and operating a new type of e-money. Athanassiou and Mas-Guix (2008) point out that this entry cost could be an disincentive for e-money issuance, but the market has a potential for growth because of its low transaction cost and seigniorage.

[6]See Williamson (2012) and Rocheteau, Wright, and Xiao (2016) for the further intuitions.

[7]The nominal interest rate is determined in equilibrium unlike Kareken and Wallace (1981) because money and government bonds are used in the different types of trades under limited commitment in the model. Thus the ineffectiveness of OMOs is also not a result of Modigliani-Miller theorem as shown in Wallace (1981). This paper shows that OMOs can be ineffective even though Modigliani-Miller theorem fails.

The fiscal authority provides a constant real amount of government bonds which is not sufficiently large to support the whole hand-to-hand transactions and collateral transactions in the economy. The competitive e-money issuers are able to provide e-money as the central bank issues currency by holding government bonds as a collateral. But they can also create counterfeit government bonds at a proportional cost.

In the model if there is no collateral misrepresentation, the nominal interest rate is zero in equilibrium and the equilibrium allocation is constrained optimal with competitive e-money issuers. Without the moral hazard incentive, the marginal benefit of the e-money is equal to the opportunity cost of holding government bonds which is not used in collateral transactions. Since this opportunity cost of holding government bonds must be the same as the marginal benefit of the government bonds in collateral transactions, the marginal rate of substitution between hand-to-hand transactions and collateral transactions is one and the nominal interest rate is zero. Moreover, this marginal rate of substitution between hand-to-hand transactions and collateral transactions is well-aligned with the social welfare function. With moral hazard incentive, however, the more quantities of government bonds are required to support e-money transactions. For e-money issuers the cost of holding government bonds exceeds the benefit of providing e-money for hand-to-hand transactions, so the nominal interest rate is strictly positive. In this case the competitive equilibrium is constrained suboptimal, because the e-money issuers do not account for the effect of e-money issuance on the aggregate supply of assets in the general equilibrium. The more the e-money issuers provide e-money, total assets for transactions become scarcer because the moral hazard incentives reduce the availability of the government bonds for transactions. Thus e-money issuers must not provide e-money too much in the economy for optimality, but individual issuers keep providing e-money until there is no profit.

We confirm that OMOs is ineffective as shown in Wallace (1983) when the private e-money issuers are introduced. Since the private issuers will provide e-money by purchasing government bonds until there is no profit, the central bank cannot raise real interest rates by selling government bonds and absorbing currency in the market. However, if the central bank maintains a negative budget balance by relying on the power to tax, then only currency circulates in the economy and OMOs becomes effective. When OMOs is no longer effective

with the competitive e-money issuers, a proportional tax on e-money issuers can be an alternative to implement monetary policy. Raising a tax on money supply makes the e-money issuance more costly, so that the excess supply of e-money can be restricted in competitive equilibrium.

This environment for issuing e-money is similar to a situation in the U.S. banking history. During the period of pre-Civil War there was no central bank yet and a large number of state banks issued their own bank notes which were used as a medium of exchange.[8] E-money in this paper resembles the bank notes in this "Free-Banking"era, from 1837 to 1862.[9] At that time a variety of bank notes circulated with distinct discount rates because counterfeit on bank notes was rampant and the banks frequently failed or went out of business. Except for the Suffolk Banking system in New England, there was no centralized clearing house to monitor or screen their bank notes. So this paper can provide a theoretical framework to analyze the aggregate money supply in the Free-Banking era.

Related Literature The role of the government in providing money has been discussed by Friedman (1959), Friedman and Schwartz (1986) and Hayek (1999) with historical facts in the Free-banking era. Here we address an answer for the same normative question, but we provide a justification for the government role with a theoretical model. For the ineffectiveness of OMOs, Wallace (1983) shows that without legal restrictions rates of return dominance does not exist and OMOs is no longer effective. This is because private financial intermediaries can rewind the operations by issuing small denominated bank notes backed by large denominated government bonds.[10] Wallace claims that a decreasing cost of inhibiting counterfeit can provide a reason for a single supplier in the paper. Here in the model issuing e-money is costly because a proportion of collateral, government bonds, cannot be used for back-up

[8]For further details, see Weber(2014)

[9]While the monetary system in this "Free-Banking" era has been thought as chaotic, the Suffolk Banking system in 1824-1858 and the Scottish free-banking era in 19th century have been evaluated as a well-functioned private monetary system. However, those successful experiences are not closely related to the paper: the Suffolk Banks have a clearing house system to monitor each other and most of Scottish banks are under unlimited liability.

[10]Goodhart (2000) revisits this issue and argues that the central bank can control money supply because the government can levy tax. Kahn (2009) shows that as much as private issuers provide efficient payment methods, the central bank will lose its ability to control because the central bank cannot decrease the cost for transactions further.

because of the moral hazard incentives of e-money issuers. So the rationale for monopoly central bank comes from an externality in providing e-money, because the assets become scarcer in aggregate as much as e-money is issued.

For the competitive money issuance, Monnet and Sanches (2015) study the environment with unobservable asset portfolio and limited commitment. In this case a positive franchise value of an issuer is required to supply money, so the competitive equilibrium is inefficient because the return on bank liabilities must be low. Villaverde and Sanches (2016) explore the case where entrepreneurs will mint additional outside money as long as it is profitable, although the production of additional money is socially wasteful. This result is generated by the pecuniary externality in providing money: When newly minted money is introduced, the rate of return in money decreases so that a liquidity premium in money arises. Thus it is still profitable to provide additional outside money which is away from social optimality. Here we also show that competition among e-money issuers can end up with suboptimality, but it focuses on the externality in producing inside money, which is based on limited commitment and observable asset portfolio.

The rest of sections are as follows. Section 2 describe the environment of the model and section 3 explains the problems of the competitive money issuers. In section 4 we consider the competitive monetary equilibrium and find out the suboptimality of the equilibrium allocation through welfare analysis. In section 5 we discuss about policy tools to improve the welfare and in section 6 we conclude.

2 Model

The basic structure of the model is related to Rocheteau and Wright (2005) in which ex ante heterogeneous agents trade assets in decentralized meetings and adjust their asset portfolio in the competitive markets. Time $t = 0, 1, 2, \ldots$ is discrete and the horizon is infinite. Each period is divided into two sub-periods - the centralized market (CM) followed by the decentralized market (DM). There is a continuum of buyers, sellers, and money issuers, each

with a unit mass. An individual buyer has preferences

$$E_0\sum_{t=0}^{\infty}\beta^t[-H_t+u(x_t)],$$

where $H_t \in \mathbb{R}$ is the labor supply of the buyer in the *CM*, $x_t \in \mathbb{R}_+$ is the consumption of the buyer in the *DM*, and $0<\beta<1$. Assume that $u(\cdot)$ is strictly increasing, strictly concave, and twice continuously differentiable with $u^{'}(0)=\infty, u^{'}(\infty)=0$, and $-x\frac{u^{''}(x)}{u^{'}(x)}=\gamma<1$. Each seller has preferences

$$E_0\sum_{t=0}^{\infty}\beta^t[X_t-h_t],$$

where $X_t \in \mathbb{R}$ is the consumption of the seller in the *CM*, and $h_t \in \mathbb{R}_+$ is the labor supply and production of the seller in the *DM*. An individual money issuer has preferences

$$E_0\sum_{t=0}^{\infty}\beta^t[X_t^i-H_t^i],$$

where $H_t^i \in \mathbb{R}_+$ is the labor supply of the money issuer in the *CM*, and $X_t^i \in \mathbb{R}_+$ is the consumption of the money issuer in the *CM*. All the agents can consume and produce in the *CM*. But in the *DM* buyers can consume, but cannot produce while sellers can produce, but cannot consume. One unit of labor input produces one unit of perishable consumption good either in the *CM* or in the *DM*.[11]

In the *DM* each buyer meets one seller, and vice-versa, bilaterally. The terms of trade are determined by bargaining between buyers and sellers. For simplicity it is assumed that buyer has all bargaining power.[12] There is no record-keeping technology for buyers and sellers. Also, under limited commitment no one can be forced to work. Thus, recognizable assets are essential for trade in the *DM*, and the trade must be *quid pro quo*. Similar to Sanches and Williamson (2010), there are two different types of transactions in the *DM*. In a fraction ρ of *DM* meetings, only small-denominated money can be verified while in a

[11] *CM* and *DM* consumption goods are not necessary to be the same.

[12] The price of *DM* good and the asset price in the *DM* are not shown explicitly in the model. However, given the bargaining structure sellers provide β unit of *DM* good in the *DM* for 1 unit of *CM* good in the next *CM* so that the implicit price of *DM* good is equal to one in terms of the current period *CM* good.

fraction $1-\rho$ of DM meetings only large-denominated government bonds can be traded. At the beginning of the CM, buyers do not know what type of DM meetings they will be in the DM, but they learn their types at the end of CM after the centralized asset market is closed.

Given this idiosyncratic shock, there naturally arises a banking arrangement in order to provide insurance. Any buyer can play a role as a bank by providing a banking contract and share a minimum amount of information such as names and addresses in the CM to distribute money and government bonds to the other buyers.[13] The money issuers cannot participate in the DM trade, but they can provide an amount of record about their names, addresses and asset holdings for the buyers and sellers. Thus issued money can be recognized and used as a medium of exchange in the fraction ρ of DM meetings. This money can circulate among buyers and sellers in the CM, but if requested the money issuers must pay a promised amount of currency to the holder of money in the next CM. In this respect money issuers invest in one-period government bonds if it provides higher return than money.

Given limited commitment, if the money issuers abscond in the next CM, the underlying assets would be seized and transferred to the holder of the money. We assume that the money issuers can provide money by producing counterfeit assets, such as fake government bonds at a proportional cost of δ per unit of assets. In equilibrium counterfeit of assets will not occur, but the money issuers cannot borrow up to the full value of their asset portfolio in order to show that they are honest. Thus only the rest, $1-\delta$, proportion of the underlying assets are used as a collateral to support money.[14]

There are two kinds of assets in the model: money and one-period government bonds. The fiscal authority issues the government bonds in the CM and pays the principal and interests in the next CM. The central bank and the money issuers can provide their monies by purchasing government bonds at the market in the CM and those monies are perfect substitute since they are well supported by government bonds.[15] In order to make the

[13]The seller can also work as a bank, but in this case the seller must not recognize their depositors in the DM.

[14]This can be interpreted as follows. First, the moral hazard problem does not arise because the money issuers are reliable. Second, the money issuers do not have an incentive to counterfeit since the monitoring authority can perfectly observe their portfolio and verify the authenticity of portfolio.

[15]Although we introduce a seller-side heterogeneity between currency and e-money in the small-denominated meetings, the result does not change. For example, some sellers receive only currency whereas

central bank equivalent with the money issuers, We assume that the fiscal authority can collect a lump-sum tax, but the central bank cannot. Money sells at price ϕ_t in terms of goods in the *CM* of period t and there is no interest on money.[16] One unit of government bond is traded at price z_t in terms of money in the *CM* of period t and promises one unit of money in the *CM* of period $t+1$.[17]

Timing is as follows. In the beginning of the period t *CM*, all agents meet together. The previous obligations such as government bonds are paid off with the promised assets and the fiscal authority provide a lump-sum transfer, which could be negative, to buyers. Then a competitive asset market opens and the central bank conducts OMOs whereas the money issuers provide money. At the time *CM* goods are produced, assets are traded and buyers deposit goods or assets into a bank. The bank invests in money, and government bonds by using their deposits. At the end of the period t *CM*, the buyers who will participate in the fraction ρ meeting in the *DM*, meet the bank and withdraw money.[18] The rest of buyers who will participate in the fraction $1-\rho$ meeting in the *DM*, meet the bank and withdraw government bonds. In the *DM* buyers and sellers meet bilaterally and trade. In the period $t+1$ *CM* the sellers sell the asset holdings in the competitive asset market.

3 Maximization Problems

In the model we have two maximization problems, one for the money issuers and the other for the buyers. The money issuers can provide a small denominated payment instrument, money, which is useful for the fraction ρ of *DM* meeting transactions. Since the money issuers are exposed to the same limited commitment problem that a buyer or seller has, money issuers must hold assets such as government bonds for the promise to give currency in the next period. In this respect these money issuers are similar to the central bank, so

the other sellers receive both currency and e-money in the small-denominated meetings. If the competitive issuers can provide both monies by holding government bonds, then the relative price between currency and e-money must be equal as long as both monies are useful for some sellers.

[16]Note that the result does not change if there is an interest on money. Only the relative price between money and government bonds is used to pin down the equilibrium allocation.

[17]The fiscal authority can purchase money in the *CM* to provide it to the holder of the government bonds.

[18]We assume that the buyers can meet at most one bank before they move into the *DM*. If they can meet more than one agent, then the banking contract will be unraveled as shown in Jacklin (1987).

that here a continuum of money issuers are competitive in conducting OMOs. As described in the environment the money issuers can produce one unit of counterfeit asset at a cost of δ. This incentive to counterfeit generates an endogenous limited commitment constraint in the model as shown in Li, Rocheteau and Weill (2012) and developed in Williamson (2016). Note that this counterfeit assumption captures the moral hazard of the private sector and allows us to explore the relevance of regulations for the money issuers.

In the model a representative money issuer solves the following problem in the *CM* of period t:

$$\underset{b_t^i,\theta_t}{Max} - z_t b_t^i + \frac{\beta\phi_{t+1}}{\phi_t} b_t^i + \bar{m}_t - \frac{\beta\phi_{t+1}}{\phi_t}\bar{m}_t \tag{1}$$

subject to collateral constraint,

$$\frac{\beta\phi_{t+1}}{\phi_t}\theta_t b_t^i - \frac{\beta\phi_{t+1}}{\phi_t}\bar{m}_t \geq 0 \tag{2}$$

and counterfeit constraint,

$$-\delta b_t^i + \theta_t b_t^i \leq 0 \tag{3}$$

and non-negative constraints

$$b_t^i, \bar{m}_t, \theta_t \geq 0. \tag{4}$$

All quantities in (1)-(4) are expressed in units of the *CM* consumption good in period t. In (1)-(4), b_t^i denotes the real quantity of government bonds purchased by the issuer and $\bar{m}_t$ denotes the real quantity of money that the money issuer supplies. The representative money issuer maximizes its objective function (1) which includes the net payoff on the purchase of government bonds and the issuance of money. Eq. (2) is a collateral constraint for the issuer, which states that the payoff on the money in the *CM* of period $t+1$ cannot exceed the value of the collateral discounted by $1-\theta_t$. If the backed assets are scarce, then this collateral constraint would bind in equilibrium.[19] Eq. (3) is a counterfeit incentive constraint which

[19]In the paper we focus on the equilibrium case that the supply of assets is scarce in the economy.

states that the net payoff of an issuer for faking the backed assets and issuing money backed by faked assets must not be strictly positive. Note that the haircut, $1-\theta_t$, in (2) could be strictly positive if the issuer's incentive constraint (3) does bind.

In the model we have another maximization problem for the buyers.[20] Given the idiosyncratic shock on the preference of buyers, ρ fraction of buyers want to have money for hand-to-hand transactions while $1-\rho$ fraction of buyers want to have government bonds for collateral transactions.[21] So buyers (or sellers) can suggest a banking arrangement which provides insurance for the *ex ante* buyers. In equilibrium the banking contract, which provides the different kinds of assets by the types of buyers, maximizes the expected value of *ex ante* buyers.[22]

The representative bank solves the following problem in the CM of period t as providing a contract term of (d_t, x_{mt}, x_{bt}):

$$\underset{d_t, m_t, b_t, x_{mt}, x_{bt}}{Max} \; -d_t + \rho u(x_{mt}) + (1-\rho)u(x_{bt}) \tag{5}$$

subject to participation constraint,

$$d_t - m_t - z_t b_t + \{\frac{\beta\phi_{t+1}}{\phi_t} m_t - \rho x_{mt}\} + \{\frac{\beta\phi_{t+1}}{\phi_t} b_t - (1-\rho)x_{bt}\} \geq 0 \tag{6}$$

and collateral constraints,

$$\frac{\beta\phi_{t+1}}{\phi_t} m_t - \rho x_{mt} \geq 0 \tag{7}$$

$$\frac{\beta\phi_{t+1}}{\phi_t} b_t - (1-\rho)x_{bt} \geq 0 \tag{8}$$

and non-negative constraints

[20] Note that the seller's decision is made passively without any bargaining power.

[21] We introduce the idiosyncratic preference shock in the model to have a representative buyer's problem instead of two separated buyers' problems. For the welfare analysis, it is advantageous to have the single representative buyer's problem.

[22] In the maximization problem we abbreviate the self-selection constraints because those constraints for both types do not bind in equilibrium.

$$d_t, m_t, b_t, x_{mt}, x_{bt} \geq 0. \tag{9}$$

Similarly, all quantities in (5)-(9) are expressed in units of the CM consumption good in period t. In (5)-(9), d_t denotes the quantity of goods deposited by the representative buyer, and x_{mt} and x_{bt} are the quantity of consumption goods that the buyer can trade in the ρ fraction of DM meeting and $1-\rho$ fraction of meeting, respectively. The variables m_t and b_t denote the quantities of money and government bonds purchased by the representative bank, respectively. The maximization problem (5) subject to (6)-(9) states that the banking contract (d_t, x_{mt}, x_{bt}) is chosen to maximize the expected value of the representative buyer subject to the bank earning a non-negative net payoff over the period, subject to bank's incentive constraints (7)-(8) and non-negative constraints (9).[23]

The Government We make assumptions for two separated entities in government, the fiscal authority and the central bank, in order to differentiate their power and policy rules. The fiscal authority can levy tax and issue government bonds, while the central bank can only issue money(currency) backed by government bonds. So in the model the central bank is just the same as the money issuer under the same limited commitment. The fiscal authority can control the total amount of outstanding government bonds, as the fiscal authority can collect a lump-sum tax from buyers or provide a transfer to buyers in the CM.[24] In period $t=0$ the fiscal authority issues the initial government bonds by providing lump-sum transfer,τ_0, and then in the following periods outstanding amount of government bonds are supported by a lump-sum tax or transfer. The government budget constraint for $t=0$ is

$$\phi_0 z_0 B_0 = \tau_0,$$

and for $t = 1, 2, 3, \ldots$

$$\phi_t(z_t B_t - B_{t-1}) = \tau_t,$$

[23]Note that the representative bank maximizes the expected value of buyers because the banks are subject to the perfect competition.

[24]Tax or transfer is available only with consumption goods.

where B_t denotes the nominal quantities of outstanding government bonds held in the private sector in time t, and τ_t denotes the real value of the lump-sum transfer to each buyer in period t. We assume that the fiscal authority keeps the real value of the government debt constant as V in every period and V is small enough to maintain the scarcity of the assets in the model. [25] Then the government budget constraints for $t = 0, 1, 2, 3, \ldots$ is

$$\phi_t z_t B_t = V. \tag{10}$$

The required lump-sum transfer to maintain the constant value, V, for $t = 0$ is $\tau_0 = V$ and for $t = 1, 2, 3, \ldots$ is calculated as

$$\tau_t = \underbrace{(1 - \frac{\phi_{t+1}}{\phi_t})V}_{seigniorage} \quad \underbrace{+ \frac{\phi_{t+1}}{\phi_t}(z_t - 1)\phi_t B_t}_{real\, interest\, payment}$$

and the lump-sum transfer consists of seigniorage from inflation and real interest payment for government bonds.

4 Competitive Equilibrium

In this section we describe the equilibrium conditions of the competitive monetary equilibrium given the fixed supply of assets. We focus on a stationary equilibrium where $\frac{\phi_{t+1}}{\phi_t} = \frac{1}{\mu}$ for all t, and μ denotes the gross inflation rate. We will restrict our attention to the cases in which the first-best allocation is infeasible. So we assume that total supply of the assets in this economy, V, is not sufficient to support the efficient amount of transactions in the DM, x^*, where $u'(x^*) = 1$, as

$$x^* \;>\; V \;. \tag{11}$$

From the money issuer's counterfeit incentive constraint (3), the haircut on money, $1-\theta$,

[25] There are two reasons for this assumption. One reason is to restrict the commitment power of the fiscal authority in the model. Otherwise, the government can help the private agents to overcome the limited commitment friction. The other reason is to keep the supply of total assets scarce in the model. If not, the agents can always achieve the first-best allocation.

is determined as

$$\theta = min\{1, \delta\}, \tag{12}$$

which means that if the cost of counterfeit is sufficiently low, then the money will be backed by only $\theta < 1$ proportion of the issuer's assets such as government bonds. Eq. (12) shows that the moral hazard of the money issuers will restrict the pledgeability of their assets under limited commitment. Note that there is no amplification effect in the collateral misrepresentation. Given the scarcity of assets, a misrepresentation of collateral reduces the pledgeability of assets, but it does not exacerbate the problem by making the collateral misrepresentation more profitable.[26]

In equilibrium the net payoff to the money issuers must be zero, so from (1)-(3) the following equation for government bonds, b_t^i, must hold,

$$(b_t^i) \quad z \;=\; \tfrac{\beta}{\mu} + (1 - \tfrac{\beta}{\mu})\theta. \tag{13}$$

Note that given no arbitrage condition $\mu \geq \beta$, if $\delta \geq 1$ then $z = 1$ whereas if $\delta < 1$ then $z < 1$ in Eq. (13). So the nominal interest rate will not be strictly negative since it is not profitable for money issuers. If it is costly to issue money by holding government bonds, the nominal interest rate will be strictly positive, $\frac{1}{z} > 1$, because money is more valuable than government bonds for issuers.

From the buyer's problem we have the first-order conditions by m_t, b_t as

$$\begin{aligned} (m_t) \quad \mu &= \beta u^{'}(x_m), \\ (b_t) \quad z &= \tfrac{\beta}{\mu} u^{'}(x_b). \end{aligned} \tag{14}$$

In Eq. (14) the marginal rate of substitution between money trade and government bonds trade is equal to the level of nominal interest rate, $\frac{1}{z}$.

In equilibrium asset markets clear in the CM for all t, so that the demands of the representative banker for money and government bonds are equal to the supply of money

[26]This is because the real value of the collateral, government bonds, is fixed. If a private asset such as a Lucas tree, is introduced with a fixed supply then there could be an amplification effect in mispresentation, because the price of the asset can change the real value of the collateral.

and the supply of outstanding government debts, respectively, as

$$\begin{aligned} b + b^i &= \phi B, \\ m &= \bar{m}. \end{aligned} \tag{15}$$

With Eq. (15) the government budget constraint (10) turns into

$$z(b + b^i) = V. \tag{16}$$

Since the collateral constraints (2), (7)-(8) always binds in equilibrium given the scarcity of assets, equations (2), (7)-(8) can be transformed into $\rho x_m = \frac{\beta}{\mu}\bar{m} = \theta\frac{\beta}{\mu}b^i$ and $(1-\rho)x_2 = \frac{\beta}{\mu}b$. Along with the first-order conditions (14) and the government budget constraint (16) we can have a feasibility equilibrium condition,

$$\rho x_m\{u^{'}(x_m) + \frac{1-\theta}{\theta}\} + (1-\rho)x_b u^{'}(x_b) = V. \tag{17}$$

Definition 1. *Given (V ,δ) a stationary competitive equilibrium consists of quantities x_m, x_b, μ, z, θ which satisfy equations (12)-(14) and (17).*

In order to understand the effect of introducing the competitive money issuers we will concentrate on the equilibrium cases with $\bar{m} > 0$.

4.1 Without Moral Hazard($\delta \geq 1$)

Suppose that the cost of counterfeit is sufficiently high, $\delta \geq 1$, so that there is no haircut in the money or currency, $\theta = 1$. If $\bar{m} > 0$ then $b^i > 0$. So the nominal interest rate, $\frac{1}{z}$, is equal to 1 since $z = 1$ holds in (13). So from (14), we have

$$u^{'}(x_m) = u^{'}(x_b), \tag{18}$$

in equilibrium. Since $\theta = 1$, Eq. (17) turns out to be

$$\rho x_m u^{'}(x_m) + (1-\rho)x_b u^{'}(x_b) = V. \tag{19}$$

In equilibrium consumption levels x_m and x_b, which are less than x^*, are determined from (18)-(19) and the gross inflation rate, μ, is determined from (13). Note that in this model zero profit condition of the money issuers pins down the nominal interest rate, $\frac{1}{z}$, and the total supply of assets(government bonds), V, pins down the gross inflation rate, μ.

4.2 With Moral Hazard($\delta < 1$)

Now suppose that the cost of counterfeit is sufficiently low, $\delta < 1$, so that there is a haircut in the money, $\theta = \delta < 1$. If $\bar{m} > 0$ then $z = \frac{\beta}{\mu}(1-\delta) + \delta < 1$ holds in (13) with $\mu \geq \beta$. By plugging (13) into (14) we have

$$(1-\delta) + \delta u^{'}(x_m) = u^{'}(x_b), \tag{20}$$

in equilibrium, which implies that the marginal benefit of purchasing the government bonds to issue money, $(1-\delta)+\delta u^{'}(x_m)$, is equal to the opportunity cost of holding the government bonds, $u^{'}(x_b)$. Since $\theta = \delta$, Eq. (17) becomes

$$\rho x_m \{u^{'}(x_m) + \frac{1-\delta}{\delta}\} + (1-\rho) x_b u^{'}(x_b) = V. \tag{21}$$

In equilibrium consumption levels x_m and x_b are determined from (20)-(21) and the gross inflation rate, μ, and the nominal interest rate, $\frac{1}{z}$, are determined from (13)-(14) as well.

Discussion

In the model the zero profit condition for the money issuers pins down the equilibrium allocation and specifically, the level of the nominal interest rate, $\frac{1}{z} - 1$. This is because competitive money issuers provide small-denominated money by purchasing government bonds until the marginal benefit of issuing money is equal to the marginal cost of holding government bonds. So this zero profit condition can pin down the relative price between money and government bonds in the model.

Moreover, OMOs of the central bank is ineffective as long as the profit of the central bank is non-negative.[27] If the central bank purchase money in the market by selling their

[27]If the central bank can operate with negative profits, then OMOs are effective since money issuers will

government bonds holdings, then the money issuers rewind the operation by providing money and purchasing those government bonds until there is no profit.

Since there is a moral hazard incentive in money issuance, the costs for providing money and government bonds can be different by whether the counterfeit incentive constraint binds or not. If the counterfeit incentive constraint does not bind, there is no cost for transforming one payment method to the other payment method without moral hazard, so that the nominal interest rate becomes zero as described in Wallace (1983). If the counterfeit incentive constraint binds, in equilibrium with moral hazard there is a return dominance with a strictly positive nominal interest rate which is shown in Ferraris and Mattesini (2014) in a similar way under limited commitment. However, in this paper it is costly to transform government bonds to money rather than just costly to purchase government bonds.

Finally, note that this result is robust in the case of introducing a currency of the central bank explicitly in the model. The currency is a perfect substitute of e-money and the central bank cannot collect a strictly positive lump-sum tax in the model, so that the role of the central bank in issuing a medium of exchange is the same as the one of the private e-money issuers and the central bank can be considered as one of the private issuers.

4.3 Welfare

In this model OMOs is ineffective with competitive money issuers, but this result cannot allow us to have a rationale for legal restrictions and a single supplier. Here we analyze the welfare property of the competitive equilibrium, which might give us a rationale for appropriate regulations.

By adding expected utilities across agents in a stationary equilibrium we have the welfare function,

$$W = \rho\{u(x_m) - x_m\} + (1-\rho)\{u(x_b) - x_b\}, \tag{22}$$

which can be shown as the W curve in Figure 2.

Suppose $\delta \geq 1$ without the moral hazard. Define (x_m^n, x_b^n) as the equilibrium allocation

not provide money when a negative profit is expected.

which satisfies with (18)-(19), when the counterfeit incentive constraint does not bind. This equilibrium allocation can be described as the point A in Figure 2 in which the 45 degree line stands for $x_m = x_b$ in (18) and the V curve represents the feasibility condition (19). Note that since V is sufficiently small in (19), the point FR in Figure 2, i.e. the Friedman rule allocation where the surplus from both money and bond trades is maximized, is infeasible. The slope of the feasibility condition (19) at the equilibrium allocation (x_m^n, x_b^n) can be calculated as

$$\frac{\partial x_b}{\partial x_m} \mid_V = -\frac{\rho u^{'}(x_m^n)}{(1-\rho)u^{'}(x_b^n)} = -\frac{\rho}{(1-\rho)}, \tag{23}$$

by using $u^{'}(x) + xu^{''}(x) = (1-\gamma)u^{'}(x)$ and $x_1^n = x_2^n$. At the point of (x_m^n, x_b^n) the slope of the welfare indifference curve is

$$\frac{\partial x_b}{\partial x_m} \mid_W = -\frac{\rho\{u^{'}(x_m^n) - 1\}}{(1-\rho)\{u^{'}(x_b^n) - 1\}} = -\frac{\rho}{(1-\rho)}. \tag{24}$$

Note that from (23)-(24) if $x_m > x_b$, the slope of the feasibility condition is steeper than the slope of the welfare indifference curve as $\frac{\partial x_b}{\partial x_m} \mid_W > \frac{\partial x_b}{\partial x_m} \mid_V$ while if $x_m < x_b$, the slope of the welfare indifference curve is steeper than the slope of the feasibility condition as $\frac{\partial x_b}{\partial x_m} \mid_W < \frac{\partial x_b}{\partial x_m} \mid_V$. Thus the welfare is maximized at the competitive equilibrium allocation (x_m^n, x_b^n), the point A in Figure 2. Although the central bank cannot adjust the equilibrium outcome by implementing monetary policy, the allocation is constrained efficient as the welfare indifference curve has a tangency in the point A.

[Figure 2 here]

Now suppose $\delta < 1$ with the moral hazard of the money issuers. Define (x_m^c, x_b^c) as the equilibrium allocation which satisfies with (20)-(21), when the counterfeit constraint binds. This equilibrium allocation with the moral hazard incentives can be described as the Point B in Figure 3. $z = z^c$ line represents more cost for supplying money in (20) because $z^c = \delta + \frac{(1-\delta)}{u^{'}(x_m^c)} < 1$, while the $V^{'}$ curve implies less feasible allocations in (21). Then the slope of the feasibility condition (21) at the point B can be calculated as

$$\frac{\partial x_b}{\partial x_m} \mid_{V^{'}} = -\frac{\rho\{u^{'}(x_m^c) + \frac{1}{1-\gamma}\frac{1-\delta}{\delta}\}}{(1-\rho)u^{'}(x_b^c)} = -\frac{\frac{\rho}{\delta}}{(1-\rho)}\frac{\{u^{'}(x_m^c) + \frac{1}{1-\gamma}\frac{1-\delta}{\delta}\}}{\{u^{'}(x_m^c) + \frac{1-\delta}{\delta}\}}, \tag{25}$$

by using $u^{'}(x) + xu^{''}(x) = (1-\gamma)u^{'}(x)$ and $(1-\delta) + \delta u^{'}(x_m^c) = u^{'}(x_b^c)$. At the point B the slope of the welfare indifference curve, $W^{'}$, is calculated as

$$\frac{\partial x_b}{\partial x_m} \mid_{W'} = -\frac{\rho\{u^{'}(x_m^c) - 1\}}{(1-\rho)\{u^{'}(x_b^c) - 1\}} = -\frac{\frac{\rho}{\delta}}{(1-\rho)}. \tag{26}$$

by using $(1-\delta) + \delta u^{'}(x_m^c) = u^{'}(x_b^c)$. In this case the competitive equilibrium allocation (x_m^c, x_b^c) is suboptimal because the feasibility curve is steeper than the welfare indifference curve, i.e. $\frac{\partial x_b}{\partial x_m} \mid_{W'} > \frac{\partial x_b}{\partial x_m} \mid_{V'}$, at the point B as shown in Figure 3.

[Figure 3 here]

Proposition 1. *A competitive equilibrium allocation with moral hazard is constrained suboptimal.*

The Proposition 1 is the central result of the paper. This inefficiency is caused by an externality associated with the collateral misrepresentation under limited commitment. The money issuers provide money by considering the benefits of both hand-to-hand transactions and collateral transactions under perfect competition. However, the individual money issuers do not account for the impact of money issuance on the aggregate supply of the assets in the general equilibrium.

With the moral hazard incentives, providing money requires additional quantity of government bonds to secure the transactions. Given the fixed supply of government bonds, as the money issuers provide more money, holding the government bonds becomes more costly. In a liquidity perspective given the level of insufficient liquidity to support social optimum, collateral misrepresentation further reduces the liquidity in the economy because the money issuer should hold more government bonds as collateral that cannot be used as a means of payment in the *DM*. Thus, for social optimum the individual money issuers must not provide money too much in the economy, but they provide money until there is no profit.[28]

[28]Wallace (1983) points out that a decreasing cost of inhibiting counterfeit can give us a reason for a single supplier because of externality. However, the externality from the limited commitment in this paper does not depend on the feature of the specific cost function.

5 Regulations

In this section we address the optimal monetary policy of the central bank given the legal restrictions and consider a pigouvian tax on money supply as an alternative solution to improve the welfare when the counterfeit constraint binds.

5.1 Legal Restrictions

If private money issuance is prohibited, then the benevolent central bank can provide money backed by government bonds with moral hazard. Thus the maximization problem of the central bank looks similar to the representative money issuer, but the non-negative profit condition (20) may not bind in equilibrium as

$$(1-\delta)+\delta u^{'}(x_m) \geq u^{'}(x_b). \tag{27}$$

and also the central bank can conduct OMOs to maximize the social welfare as long as the profit of the central bank is positive.

Suppose that one central bank can choose the optimal nominal interest rate, $\frac{1}{z}-1$, to maximize the social welfare. Given the same feasibility condition (21), the central bank chooses z which follows

$$zu^{'}(x_m) = u^{'}(x_b) \tag{28}$$

from the first-order conditions (14) to have a tangency between the slope of the welfare function and the slope of the feasibility curve as

$$\frac{\partial x_b}{\partial x_m}\mid_V = -\frac{\rho\{u^{'}(x_m)+\frac{1}{1-\gamma}\frac{1-\delta}{\delta}\}}{(1-\rho)zu^{'}(x_m)} = -\frac{\rho\{u^{'}(x_m)-1\}}{(1-\rho)\{zu^{'}(x_m)-1\}} = \frac{\partial x_b}{\partial x_m}\mid_W . \tag{29}$$

We can derive the optimal nominal interest rate z^* from (29) as

$$z^* = k+(1-k)\frac{1}{u^{'}(x_m^k)} \tag{30}$$

where $k=\frac{\delta-\delta\gamma}{1-\delta\gamma}$ and x_m^k solves (29). Note that since $u^{'}(x_m^k)>1$ in equilibrium, $z^*<1$.

Moreover, since $k < \delta$, $z^* < z^c$ holds. This equilibrium allocation with $z = z^*$ can be described as the point C in Figure 3 where the welfare function, $W^{''}$, has a tangency with the feasibility curve $V^{'}$.

Corollary 1. *A benevolent monopoly issuer can improve the welfare of equilibrium allocation with binding counterfeit constraint by raising nominal interest rates.*

5.2 Tax on Money Issuance

In this paper we introduce competitive money issuers to discuss the effect of the structural change to decentralized environment. So if the legal restrictions are unavailable, we need to consider an alternative solution to correct the externality problem. Here we suggest a pigouvian tax on money issuance to recover constrained efficiency in the competitive equilibrium.

Suppose the government(or fiscal authority) levies a proportional tax on money supply, τ_m, to the issuers in terms of goods and makes a transfer to the buyers in the *CM*. Then the maximization objective function of money issuers turns into

$$\underset{b_t^i,\theta_t}{Max} - z_t b_t^i + \frac{\beta\phi_{t+1}}{\phi_t} b_t^i + \bar{m}_t(1-\tau_m) - \frac{\beta\phi_{t+1}}{\phi_t}\bar{m}_t(1-\tau_m), \tag{31}$$

and the transfer to buyers will not change the decision of buyers because of the linearity in the *CM*. This changed objective function of the money issuers will transform the zero profit condition (20) into

$$\{1-(1-\tau_m)\delta\} + (1-\tau_m)\delta u^{'}(x_m) = u^{'}(x_b). \tag{32}$$

So given the same feasibility condition (21), by choosing τ_m we can adjust the nominal interest rate level and the equilibrium allocations. In order to recover the constrained efficient allocation point C in Figure 3, the optimal tax rate is

$$\tau_m^* = \frac{1-\gamma}{1-\gamma\delta}, \tag{33}$$

which is independent from the total supply of government bonds, V. Note that this tax must depends on money supply rather than government bonds holdings because the buyers

can also hold and use government bonds for trade purpose.

Proposition 2. *A pigouvian tax on money issuance can improve the welfare of equilibrium allocation with binding counterfeit constraint.*

Discussion

We show that given the moral hazard incentives of the issuers, the legal restriction and the pigouvian tax on the issuers are effective to achieve the constrained efficient allocation, i.e. the point C in Figure 3. Note that the nominal interest rate in this equilibrium allocation is strictly positive unlike the zero nominal interest rate in the case without the moral hazard incentives. In this model the nominal interest rate implies the relative price between the rates of return in money and government bonds. If the nominal interest rate goes up, the rate of return in money decreases and the rate of return in government bonds increases. So the hand-to-hand transactions with money are reduced whereas the collateral trade amount with government bonds is raised. These adjusted transactions with strictly positive nominal interest rates are welfare-enhancing under the moral hazard incentives. When the counterfeit constraint binds, it is more costly for the issuers to transform government bonds to money. The hand-to-hand trade with money is more expensive than the collateral trade with bonds for the same marginal utility, so it is beneficial for the whole society to reduce the hand-to-hand trade with money and raise the collateral trade with bonds.

6 Conclusion

We revisit the longstanding question about the role of government in distributing money in this paper. In the paper we focus on two features of private money system, competition in creating money and limited commitment of the private issuers. This paper shows that the OMOs is no more effective when the e-money issuers are introduced, because the perfect competition among the issuers pins down the equilibrium allocation. This ineffectiveness of OMOs itself cannot justify the monopoly in money issuance since this equilibrium allocation is constrained efficient under the limited commitment. However, the moral hazard of the e-money issuers can generate an externality under limited commitment, so the equilibrium

allocation is constrained inefficient when the counterfeit incentive constraint binds. This externality result is also mentioned in Friedman and Schwartz (1986) as one of the good reasons for monopoly in issuing currency, but not much examined in the previous literature:

"[1] the resource cost of a pure commodity currency and hence its tendency to become partly fiduciary; [2] the peculiar difficulty of enforcing contracts involving promises to pay that serve as a medium of exchange and of preventing fraud in respect to them; [3] the technical monopoly character of a pure fiduciary currency which makes essential the setting of some external limit on its amount; and finally, [4] the pervasive character of money which means that the issuance of money has important effects of parties other than those directly involved and gives special importance to the preceding features."

In this paper we just provide an answer for the legal restrictions in a respect of externality. Nevertheless, there exist other perspectives to evaluate the private money system such as elasticity of money supply or coordination in liquidity management. Furthermore, if the monopoly in providing money is unavailable and private money supply is also unobservable then we might ask what will be the next generation of monetary policy. We hope that we can explore these issues in near future.

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Figure 1. Transactions Mechanism

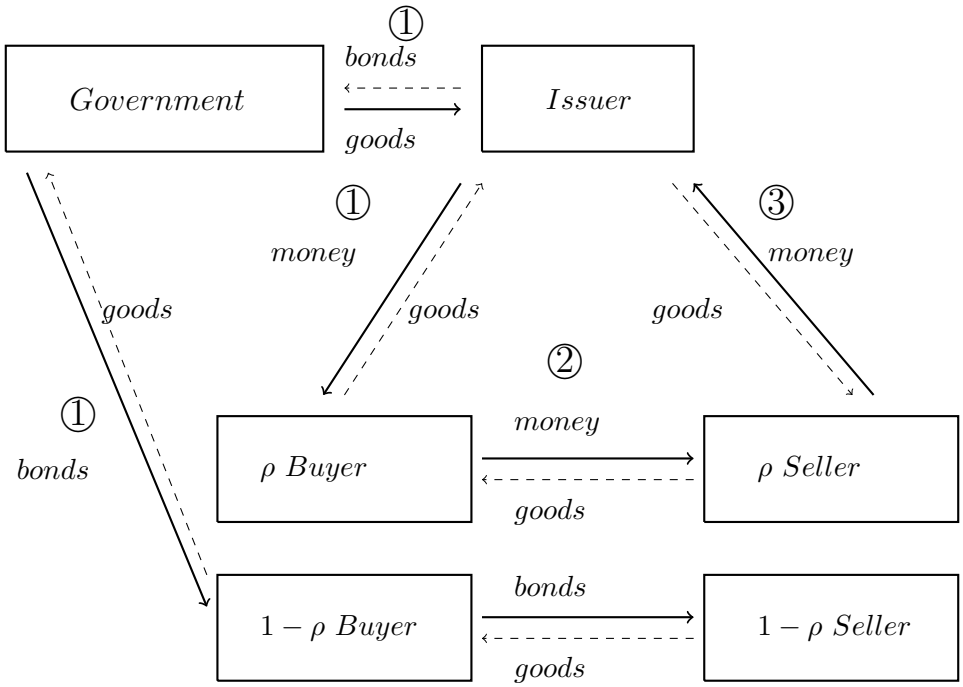

Figure 2. Equilibrium with $\delta \geq 1$

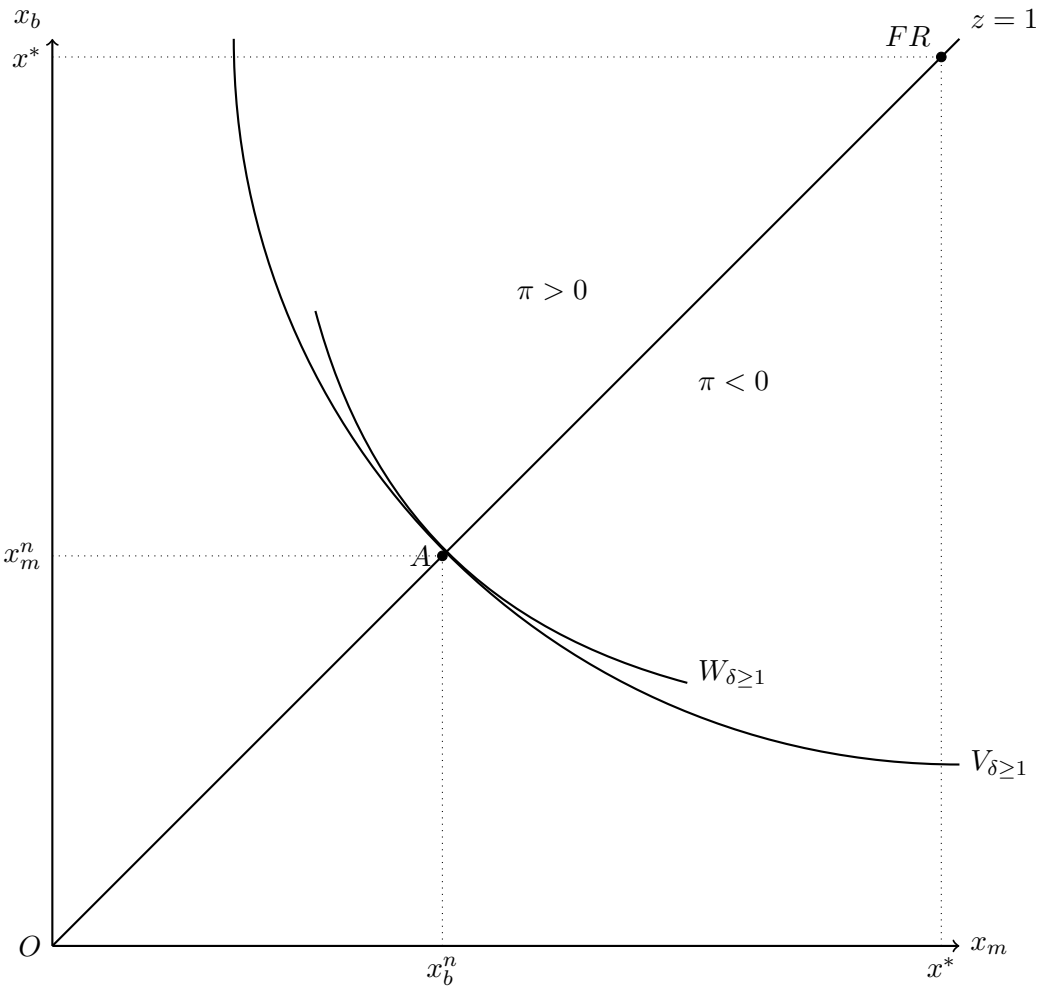

Figure 3. Equilibrium with $\delta < 1$