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FINANCIAL CRISES AND LIQUIDITY SHOCKS
A Bank-Run Perspective

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Abstract

In contrast with the financial multiplier literature, this note explores a case in which the shock triggering a financial crisis stems from the financial sector itself; it is not a shock stemming from the real sector which gets amplified by, say, agency problems. The basic intuition is provided by the bank-run literature of the Diamond and Dybvig (1983) variety. Financial development is modeled as a mechanism that endows real assets (e.g., land and capital) with liquidity. However, liquidity can be impaired by shocks that are equivalent to a bank run. Liquidity creation enhances real asset prices, while a liquidity crunch generates asset price collapse. This bubble-looking episode is not driven by standard *fundamentals*, although it is fully in line with rationality. In this context, devoid of other frictions like price stickiness, the note examines the effect of monetary policy in the absence of nominal rigidities. It shows that preventing price deflation is not enough to offset relative (to output) asset price meltdown, but lower policy interest rates increase relative asset prices and steady-state output. Moreover, in the neighborhood of a first-best capital allocation, an increase in the liquidity of capital may *lower* the welfare of the representative individual, even if the higher liquidity of capital is sustainable and, hence, not destroyed by future crash – illustrating the possibility of "excessive" financial innovation. An extension of the basic model supports the conjecture that low policy interest rates may have given further incentives to the development of “shadow banking.”

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I. Introduction

A salient feature of financial crises, especially those that have a systemic character, is that they either seem to come from nowhere, or if a "somewhere" is identified, its impact is surprisingly large. Two recent episodes that illustrate this point are the Russian 1998 crisis and the subprime crisis. In both cases, a crisis that started at a corner of the financial world spread like wild fire across emerging markets in the former, and the whole world in the latter. No wonder, thus, that some prominent economists are calling for a full-fledged revision of the basic tenets of rationality and view these crises as stemming from primitive "animal spirits" (see Akerlof and Shiller (2009)). Admittedly, standard *fundamentals* do not do a good job at explaining these types of episodes. Thus, the "animal spirits" camp cannot be dismissed out of hand. However, I think it would be premature to jump the conventional ship so soon. The ship is undoubtedly dented but not beyond repair.

Obvious reasons for the failure of conventional macroeconomics to account for the start and spreading of financial crises are that either models ignore financial frictions altogether, or financial frictions are seen as *amplifiers*,[1] not as a central *cause* of the macroeconomic meltdown.[2] Mainstream theory has incorporated those imperfections (including price stickiness) as a means to get the models reproduce realistic market volatilities under normal circumstances. However, Great Depressions, Recessions or Sudden Stops in emerging markets, are not in the models' radar screen. Unlike Minsky (2008), for example, there is no mainstream school that got under the hood of the

[1] For example, the *financial accelerator* modeled in Bernanke et al (1999), or the financial multipliers highlighted in Greenwald and Stiglitz (1993).

[2] Minsky (2008) kept warning that the financial system was prone to crisis with serious macroeconomic implications. However, the profession found his warnings easy to dismiss given, I conjecture, the long spell of macro stability in advanced countries after the Second World War.

financial sector and envisioned the success or failure of market mechanisms as being indissolubly tied to the workings of that sector (see Phelps (1990)).

Just a casual perusal of current crisis reveals that the financial sector could have malfunctioned for a variety of reasons. In this paper, I will explore one possible cause of malfunctioning for which there is a well-established *microeconomic* theory that, however, has not been incorporated into conventional macroeconomics, namely, that fractional-reserve banking may give rise to multiple equilibria. The basic insight comes from the seminal paper by Diamond and Dybvig (1983),[3] which shows that fractional-reserve banking has the virtue of producing *liquidity*, possibly contributing to a better allocation of savings; but also that such a structure has feet of clay and can collapse in a bank-run flare. Bank runs do not take place if individuals believe that bank deposits are liquid. However, liquidity of deposits is in the eye of the beholder and breaks down instantly if individuals conclude that liquidity is no more than an illusion. It is worth noting, incidentally, that these are self-fulfilling equilibria. They are totally consistent with rationality assumptions.

Although the Diamond-Dybvig theory was developed to model commercial banks, nothing prevents us from employing it to model any banks-like arrangements like the "shadow banks" system at the center of the current debate. By definition, shadow banks do not have an automatic Lender of Last Resort (LOLR) and, therefore, their liquid financial obligations are liable to lose some of their liquidity in a bank-run flare. This suggests that the financial system that has grown under the cover of trade and financial globalization could have become more prone to bouts of liquidity creation and

[3] For a recent exposition, see Diamond (2007).

destruction.[4] I do not mean to imply that shadow banks were left completely bereft of support from a LOLR. The Fed, for instance, behaved as a loving father figure trying to protect even its distant siblings across the Atlantic from falling by the wayside. But these actions were not written into law and depended on the Fed's assessment of contagion risk in case a large shadow bank was allowed to go under. This lack of policy "precision" or "transparency" is, arguably, an explanation for why the collapse of Lehman Brothers spread like wildfire. I conjecture that the large impact of Lehman's collapse was partly due to the *signal* sent to the market that from then on other large financial institutions might not be bailed out. The signal may have coordinated the bank-run equilibrium.[5]

To capture these phenomena, I will take a conventional representative-individual economy in which utility depends on consumption and real *liquidity* balances. This is a standard workhorse in monetary theory hailing back to the classic models in Patinkin (1965) and Sidrauski (1967). The main difference with the standard model is that liquidity can be produced by money and physical assets. The latter captures the liquidity services associated with collateralized debt obligations (CDOs), for instance. Alternatively, one can assume that liquidity is produced with high-powered money and bank deposits, the proceeds of which take the form of loans for purchasing or renting physical assets (this case is pursued in the Appendix). These assumptions are then employed to trace the general equilibrium implications of an increase or collapse in land's or capital's liquidity in a rational expectations setup.[6]

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[4] For evidence about the relevance of shadow banking and market-based intermediaries, see, e.g., Adrian and Shin (2009).

[5] See Brunnermeier (2008) for a highly didactic exposition of the subprime crisis that supports the view that the financial collapse has Diamond-Dybvig characteristics.

[6] Rational expectations may look like an awkward vessel to encapsulate the discussion. However, in this paper liquidity crises are taken as exogenous and unanticipated. Thus, our agents will be rational but ignorant of the central driving force, i.e., the sudden meltdown of liquidity-enhancing financial instruments.

Implications are straightforward, especially in the basic model in which land is in fixed supply. An increase in land's liquidity increases its relative price, helping to explain a run-up on real estate prices triggered by financial innovation. Likewise, a bank run results in a sharp decline in land price – a bursting of the bubble explained by underlying *financial fundamentals*, not Ponzi games. Moreover, the model shows that preventing cpi deflation may fall short of avoiding serious financial difficulties because the policy may be incapable of restoring the relative price of land. This intuitive implications are lost if liquidity of non-monetary assets is ignored, as is typically the case in mainstream models. Unable to rationalize the fall in the relative price of land as a consequence of liquidity meltdown, mainstream approaches have to go out looking for "overinvestment" or irrational expectations, for example. These factors can indeed be relevant, but for them to be the main culprits for financial crises like the subprime, one has to be prepared to argue that key economic agents were deeply asleep at the wheel.[7]

In a neoclassical putty-putty model, I will show that higher capital liquidity brings about capital accumulation and higher output. Thus, in contrast with the land model, higher liquidity of asset-backed securities have *real* effects. This is in line with the literature supporting the view that financial development and output growth are positively correlated (see, e.g., Demirgüç-Kunt and Levine (2008)). However, I will show an example in which increasing the liquidity of capital may be detrimental to social welfare, even ignoring the social costs of an eventual liquidity crunch. In addition, left to its own devices, the financial sector may become "too" large, in the sense that lowering its size would increase social welfare. The example, however, presupposes that the first-best

[7] It is interesting to note that in the subprime crisis, central banks first fought against cpi deflation, but eventually resorted to buying up toxic assets and commercial paper – which in terms of the land model here would be equivalent to buying up land and attempting to sustain its relative price.

capital stock could be achieved in absence of financial intermediaries. Otherwise, enhancing the liquidity of capital could be socially beneficial. This suggests that liquidity enhancements could be especially helpful in the context of highly distorted capital markets, if the probability of a financial meltdown can be kept sufficiently low.

The model is extended to study the impact of central bank's interest rate policy. Following Calvo and Vegh (1995), the central bank's policy is assumed to be equivalent to paying interest on money, where the interest rate is the central bank's policy interest rate, e.g., the Fed's Federal Funds Rate. I favor this approach over the one adopted in the mainstream literature, in which the Fed controls a short-run interest rate on an asset completely devoid of liquidity services (see Woodford (2003)). This assumption is especially implausible when interest rates on public-sector obligations are exceedingly low, reflecting a massive flight to quality, as is now the case. Treasury bills under those circumstances are indistinguishable from greenbacks. I will show that in this setup the central bank could raise the relative price of land by lowering interest rates, even though monetary policy is conducted under conditions of perfectly flexible prices. Thus, the model is capable of rationalizing the statement made by several observers that Greenspan's lax monetary policy after 9/11 is responsible for the housing bubble, at least in the U.S. (see Taylor (2009)). More generally, this result supports the view that monetary policy could be effective in lowering the costs of an eventual financial meltdown by timely raising interest rates, and thus putting a damper on booming asset prices.

Brief Reference to Related Literature.

There are many models in which capital market imperfections contribute to making business cycle fluctuations deeper and more persistent (see, for example, Greenwald and Stiglitz (1993), Bernanke et al (1999) and Kiyotaki and Moore (1997)). This literature stresses agency problems in which first-best credit allocation is not achieved because of, for instance, asymmetric information between debtors and creditors. A financial crisis of the kind we are experiencing could be modeled in that context by assuming that there is a sudden deterioration in agency problems. There is no doubt that the subprime crisis itself has contributed to worsening the creditworthiness of individuals and firms but it would be hard to argue that the initial kick was given by a sudden deterioration of agency problems. Financial institutions increasingly engaged in non-transparent activities, but this did not occur overnight; these activities took years to reach pre-crisis characteristics. Thus, available models fail to meet a central analytical challenge for rationalizing the current crisis, namely, presenting a case in which behavior discontinuity could be justified in an intuitively plausible manner.[8] The challenge is better met by the model discussed in this paper, because the Diamond-Dybvig bank-run story that underlies the model displays equilibrium multiplicity (in absence of a LOLR).[9] A financial crisis could erupt just because people *expect* that other people expect that financial instruments issued by shadow banks will lose some of its liquidity characteristics. Thus, equilibrium fragility is not obtained by superimposing an ad-hoc

[8] This challenge is also faced by the literature on Sudden Stops in emerging capital markets (see Calvo (2007)). However, the challenge is less critical in that case, because in most instances the initial shock has taken place *outside* most emerging capital markets.

[9] Granted, central banks eventually came to the rescue of "shadow banks," but, as pointed out above, their action would have been much more timely and effective, had rescue operations clearly been mandated in their charters.

assumption on the original model (as it would be the case in the asymmetric-information approach),[10] but as a result of an essential characteristic of the underlying bank-run model. No *real* shock is needed for crisis to happen in this context. Thus, the model provides a rationale for the fact that the triggers behind big-time financial crises in the 30s and late 80s – and even the subprime crisis' global ramifications, not just crisis in the tiny subprime mortgage market – are so hard to forecast and identify. In addition, the model puts a concept like "liquidity" up front in an explicit and straightforward manner. This is important given the relevance of liquidity issues in current debate. Moreover, the impact of liquidity crunch on collateral values could trigger the agency problems highlighted in the credit literature, enhancing its quantitative relevance.[11] Thus, a liquidity crunch could trigger agency problems: the view presented here does not require that we go out to fish for other shocks in the credit market.

An active area of research that could also be claimed to stress "liquidity" considerations stems from the classic Samuelson (1958) paper, in which money is portrayed as a "contrivance" that facilitates trade under incomplete markets. Samuelson's model exhibits multiple equilibriums: one in which money has zero output value, and others displaying positive value. The latter could be called "bubbly equilibriums" because money's value can collapse in a flash without the intermediation of standard *fundamentals*. The model has recently been extended in several interesting directions in, for example, Farhi and Tirole (2011) and Martin and Ventura (2011). The lack of an equilibrium selection mechanism prevents these models from offering a complete boom-

[10] It would not be hard to generate equilibrium multiplicity in asymmetric-information models. However, macro models in that vein do not explore that feature and, thus, implicitly assume uniqueness of equilibrium.
[11] For a related recent paper, see Ranciere and Tornell (2010) in which crisis is triggered by financial fragilities associated with currency-denomination mismatch.

bust cycle theory. A bubble burst, for instance, is portrayed as an exogenous shock that results in the economy shifting to an equilibrium in which the bubbly asset value melts down, a feature also exhibited in the present paper. An advantage of the approach discussed in the present paper is, firstly, simplicity. And, secondly, that the model is very close to the conventional monetary theory paradigm. For example, the approach will allow us to address monetary policy issues along the lines of standard monetary modeling in a straightforward manner. Moreover, the model will be easily extended to study *endogenous* liquidity as a function of monetary policy. Thus, at the very least, the present note could serve as a road map for better micro-founded models along Samuelson (1958) lines that keeps a close link with the mainstream monetary literature.

II. The Basic Model

Consider a standard infinitely-lived, representative-individual model with time-separable utility. The instant utility function depends on consumption c and liquidity; liquidity is produced by real monetary balances (in terms of consumption), m, and pk, where k and p stand for land and its price (relative to consumption), respectively. More concretely, liquidity (in terms of consumption) = $m + \theta pk$, $0 \leq \theta < 1$, where θ is an index of the "moneyness" of land (the linear form is assumed to simplify the exposition and without loss of generality for the present purposes). This assumption is central, and represents the main model innovation in this paper. It captures a central macroeconomic implication of the Diamond-Dybvig model, namely, that financial intermediaries enhance the liquidity of real factors of production.[12] But, again in line with Diamond and Dybvig

[12] A more conventional and laborious way to introduce this feature would be to start assuming that liquidity is produced by real money and bank deposits, z, such that total liquidity is $m + \theta z$; banks take deposits and turn them into loans that firms employ to buy land. Thus, in case in which banks hold no precautionary or

(1983), in absence of a LOLR or equivalent arrangement such liquidity could quickly evaporate during a bank run. Thus, parameter θ increases the liquidity of land when it rises, but it would as well destroy it when it falls.[13] The rise and fall of θ could be the result of self-fulfilling expectations. The literature has focused on arrangements for avoiding this "bad" equilibrium, but the *macroeconomic* implications of liquidity swings have remained relatively unexplored.[14] The present paper is motivated by the intuition that financial crises – especially those that have systemic characteristics and affect a wide swath of the financial sector – contain a large dosage of liquidity destruction. This may help to explain why they are typically hard to rationalize on the basis of standard *fundamentals* (economists are still debating the origin of the *Great Deflation*, for example) and has led some prominent economists (e.g., Akerlof and Shiller (2009)) to conclude that they must stem from some kind of irrationality or just sheer fraud. The approach explored here focuses on a widespread feature of financial systems, namely, the creation of financial liabilities which characteristics are not matched by those of the associated assets. This is a highly profitable activity, which is further stimulated by financial deregulation and improved communications. Most of the paper will focus on the case in which θ is exogenous and explore the impact of (1) changes in θ, and (2) monetary policy in that context. Furthermore, the last part of the paper will discuss the

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regulatory reserves (an innocuous assumption for the present purposes), $z = pk$, which boils down to the assumption stated at the outset. See the Appendix for further discussion.

[13] Notice that, by making $\theta < 1$, real assets are inferior transaction vehicles that would never be demanded as such if they were unproductive. This ensures that multiple equilibrium à la Kareken and Wallace (1981) does not hold in this model despite the linearity assumption.

[14] Interestingly, the link between liquidity and crisis appears to have been largely ignored in the growth literature. For example, in a useful recent survey of the literature, Demirgüç-Kunt and Levine (2008) discuss several theories establishing the link between liquidity and growth without mentioning the possibility that liquidity could be conducive to financial crisis.

issue of endogenizing θ in the special case in which economic agents do not anticipate a financial meltdown.

At time 0, the utility function of the representative individual takes the following form:[15]

$$\int_0^\infty [u(c_t) + v(m_t + \theta p_t k_t)] e^{-\delta t} dt, \ \ \delta > 0, \tag{1}$$

where utility indexes *u* and *v* are twice-differentiable, strictly concave and increasing over the positive interval, and δ > 0 stands for the constant subjective rate of discount.

At time *t* the individual's financial wealth in terms of consumption, *a*, satisfies:

$$a_t = m_t + p_t k_t + b_t, \tag{2}$$

where *b* denotes the stock of (instant maturity) "pure" bonds, i.e., bonds that are not a source of liquidity, in terms of consumption. The instantaneous real interest rate on pure bonds is denoted by *r* (where *r* is the own-rate of interest of output).

Output *y* is produced by land, and the production function is linear and satisfies *y* = ρ*k*, where ρ is a positive constant. Therefore, the evolution of financial wealth *a* satisfies:

$$\dot{a}_t = (\rho + \dot{p}_t) k_t + r_t b_t - c_t - \pi_t m_t + \sigma_t \tag{3}$$

where π stands for the instantaneous (consumption) rate of inflation, and σ denotes lump-sum subsidies; seigniorage is fully rebated to the public and will equal σ. For simplicity and without loss of generality, the government is assumed to hold no net wealth.

Using equations (2) and (3) and ruling out Ponzi games, one obtains a familiar intertemporal budget constraint:

[15] Time 0 denotes the start of the planning period, and does not refer to a fixed calendar time. The individual will thus face the same utility function as he/she replans in the future.

$$\int_0^\infty c_t e^{-\int_0^t r_s ds} dt = a_0 + \int_0^\infty [(\rho + \dot{p}_t - r_t p_t)k_t + \sigma_t - (\pi_t + r_t)m_t] e^{-\int_0^t r_s ds} dt. \qquad (4)$$

Notice that $\pi + r$ = nominal interest rate = opportunity cost of holding real monetary balances; and $rp - (\rho + \dot{p})$ is the opportunity cost of holding land, rp, minus its return, including capital gains, $\rho + \dot{p}$.

Remark. The above budget constraint assumes the existence of perfect capital markets, an assumption that may sound implausible given that the model is intended to cast light on financial crises. This apparent weakness of the model, though, has the advantage of helping to show that liquidity effects *by themselves* go a long way in explaining real-estate bubbles and other stylized facts of financial crises.[16] However, more realistic extensions of the model should include financial multipliers highlighted by Bernanke et al (1999), Greenwald and Stiglitz (1993), and many others.

Maximization of utility (1) with respect to c, m, and k, given initial condition a_0 and the path of the pure interest rate r, subject to budget constraint (4), yields the following first-order conditions:

$$u'(c_t) = \lambda D_t \qquad \text{(a)}$$

$$v'(m_t + \theta p_t k_t) = \lambda(\pi_t + r_t)D_t \qquad \text{(b)} \qquad (5)$$

$$v'(m_t + \theta p_t k_t)\theta p_t = -\lambda(\rho + \dot{p}_t - r_t p_t)D_t \qquad \text{(c)}$$

[16] This model strategy is similar to that followed in several papers on the Great Depression and the current crisis. See, for example, Cole and Ohanian (2004). See also Greenwald and Stiglitz (1993) that assumes a perfect capital market even though the main focus of the analysis are financial imperfections.

where λ is the Lagrange multiplier (a constant) corresponding to constraint (4), and

$$D_t = e^{\int_0^t (\delta - r_s) ds}.$$

In what follows I will focus on interior solutions, make some inconsequential simplifications, and skip some obvious steps in order to streamline the presentation. I will assume that the supply of land is constant overtime, and the subjective rate of discount equals land's marginal productivity, i.e., $\delta = \rho$. Moreover, I will assume that nominal money supply is constant over time (this will be relaxed in Section III.1). One can show that these assumptions ensure that the steady state is the only converging equilibrium path, and that equilibrium inflation $\pi = 0$.[17] Correspondingly, and without loss of generality, the following analysis will focus on steady states.

From equations (5b) and (5c), we have, setting $\dot{p} = 0$,

$$p = \frac{1}{1-\theta},\ 0 \le \theta < 1. \quad ^{18} \tag{6}$$

An alternative, more direct and intuitive, derivation of equation (6) is as follows. At optimum, the representative individual must be indifferent between holding an additional unit of liquidity in any of the two available instruments: money or land. One additional unit of liquidity in the form of land calls for setting d(θpk) = 1, which implies that d(pk) = $1/\theta$ and dk = $1/\theta p$, where d denotes the differentiation operator. Therefore, the cost of the additional unit of liquidity in the form of land is rd(pk) - ρdk = r/θ - $\rho/\theta p$; the first term in

[17] See Calvo (1979) for a detailed analysis of monetary models with perfect foresight. Using similar techniques, one can show that the present model boils down to two differential equations (in m and p), with no initial conditions. The linear approximation at the steady state displays two positive characteristic roots, which ensure that the only equilibrium path that converges to the steady state is the steady state.

[18] Notice that to ensure that $m > 0$, it follows from equations (5) and (6) that $m = \varphi(u'(\rho k)\rho) - \frac{\theta}{1-\theta}k > 0$, where φ is the inverse of v'. This can always be ensured by appropriate choice of functions u and v, given θ.

each of the last two expressions is the opportunity cost of holding land, $r\mathrm{d}(pk)$, while the second, $\rho \mathrm{d}k$, is its return. On the other hand, the cost of holding an additional unit of money is just r, given that the equilibrium inflation rate is zero. Equation (6) follows from equating the marginal costs of land and money, and recalling that at steady state $r = \delta = \rho$.

Hence, if land offers no liquidity services, $\theta = 0$, the equilibrium price of land would be $p = 1$. On the other hand, if $\theta > 0$, the price of land $p > 1$ and rises with θ. This result is intuitive because liquidity services add value to land holdings. In a dynamic setting in which θ rises over time (expectedly or not), one can show that land prices will be increasing over time. Under the present assumptions, by equation (6), the price of land rises without bound as θ converges to 1 (i.e., as land and money tend to become perfect substitutes), which shows that liquidity considerations may have a major impact on the relative price of the associated assets (land in the present example).[19]

Consequently, this model can explain higher land's relative price as a result of financial engineering that makes land or derivatives associated with land (e.g., CDOs) more liquid. However, like in the standard banking model without a LOLR, there could exist a "bad" equilibrium in which, for example, θ collapses to 0. Thus, the present model has all the basic ingredients to produce price bubbles geared to the expansion and collapse of the financial sector (this is in line with the empirical findings in Taylor (2009)). Notice that by increasing money supply (or QE, quantitative easing) the monetary authority could help to prevent price deflation. However, QE will have no

[19] Given function $v(\cdot)$, money holdings may go to zero for $\theta < 1$, i.e., interior solutions would cease to exist. However, given $\theta < 1$, no matter how close to 1, one always find $v(\cdot)$ that ensures the existence of an interior solution in which $m > 0$. These peculiarities are due to the special form liquidity is assumed to take, and would not arise if v was replaced by, e.g., $v^1(m) + v^2(\theta pk)$.

effect on the price of land *relative* to consumption unless, of course, the central bank purchased land ("toxic assets"). Thus, preventing price deflation may not save the economy from financial turmoil associated with the collapse of some key relative price.[20]

III. Extensions of the Basic Model

The basic model can be extended in several interesting directions, as illustrated by the following examples.

1. Interest Rate Policy. Monetary policy in advanced economies is not conducted by directly controlling monetary aggregates but, instead, by manipulating a key (usually short term) interest rate. Consider the type of model developed in Calvo and Vegh (1995) in which the central bank interest rate would be equivalent to paying interest on money.[21] Let the latter be denoted by i_m. The stock of money is assumed, once again, constant over time.[22] In contrast to much of the modern theory of monetary policy (see Woodford (2003)), I will assume that prices are perfectly flexible. This assumption is not prompted by realism, but by trying to focus as sharply as possible on the model's new ingredient, namely, liquidity of productive assets.

[20] Under strict representative-individual conditions, a sudden change in relative prices does not cause financial trouble, because net borrowing is always zero. Extensions to heterogeneous consumers with positive net lending and agency problems are relatively straightforward. The Appendix sketches out a simple model in which consumers are linked to the productive sector through deposits and bank loans.

[21] This can be derived in a model in which m is a composite of non-interest-bearing and interest-bearing liquid assets, the latter being, for instance, short-term treasury bills, see Calvo and Vegh (1995). The Calvo-Vegh approach is an alternative to the more popular approach discussed at length in Woodford (2003), for instance, in which the monetary authority is typically assumed to control a "pure" short-run interest rate. The advantage of the Calvo-Vegh approach is that it does not imply arbitrage conditions (between, say, short- and long-run, or domestic and foreign interest rates) which are strongly rejected by empirical evidence (unless one is prepared to make assumptions on random errors that have no clear economic basis). For a recent application of this approach, see Canzoneri at al (2008).

[22] In terms of the model outlined in footnote 18, this assumption would be consistent with a situation in which the aggregate stock of the two types of monies is constant, but its composition is determined by the private sector taking into account the return on the interest-bearing component. This is consistent with standard procedures followed when interest rates are used as instruments for monetary policy.

Thus, first-order condition (5b) would now read

$$v'(m_t + \theta p_t k_t) = \lambda(\pi_t + r_t - i_m)D_t \tag{5b'}$$

Hence, by equations (5b') and (5c), expression (6) becomes (noticing that at an interior equilibrium $i_m < \rho + \pi$)

$$\theta(\rho + \pi - i_m) = \rho\left(1 - \frac{1}{p}\right). \tag{6'}$$

Therefore, for a given π, a fall in i_m brings about an increase in the relative price of land p. The intuition is that a fall in the return on money i_m shifts demand for liquidity in favor of land, raising its price. This result can be used to rationalize the often-heard statement that easy monetary policy in the U.S. could be blamed for contributing to the real-estate bubble; and it can also be employed to show that monetary easing (i.e., a lower i_m) could offset a meltdown in real estate prices if $\theta > 0$.

Another policy that may succeed at lifting the relative price of land would be a helicopter-type monetary expansion at, say, a constant rate $\mu > 0$ in order to generate inflation – a policy advocated by Krugman for Japan in the 1990s (see Krugman (2009)). One can show that this implies that, once again, the unique converging equilibrium for the model is the steady state, and that the associated rate of inflation equals μ. Moreover, equation (6') becomes, setting $i_m = 0$,

$$(\rho + \mu)\theta = \rho\left(1 - \frac{1}{p}\right). \tag{6''}$$

Hence, an increase in μ yields a higher p, validating Krugman's conjecture.[23] However, this policy as well as the interest rate policy examined above would fail in the extreme (but conventional) case in which land becomes totally illiquid, i.e., $\theta = 0$.[24]

On a separate note, notice that at steady state the rate of return on pure (i.e., no-liquidity bearing) bonds is invariant with respect to i_m. This straightforward result is interesting because it shows that the Calvo-Vegh approach is capable of rationalizing the famous "Greenspan's conundrum," i.e., a situation in which a rise in the policy interest rate has no impact on some of the other interest rates in the system.

2. Capital Accumulation. Suppose that variable k stands for physical capital, and that the latter can be accumulated without adjustment costs (being, thus, of the "putty-putty" variety). To ensure existence of a robust case of interior solutions, I will assume that the production function satisfies $y = f(k)$, where f is a standard strictly concave neoclassical production function. Focusing on interior solutions, one can prove that starting at steady state, a once-and-for-all increase in the liquidity of capital, θ, will induce capital accumulation and higher steady-state welfare. Characterizing steady states is straightforward because first-order conditions (5) hold intact if one interprets ρ as the capital rental (no longer a

[23] Notice that the positive association between inflation and the price of land or capital is in line with Tobin (1965) conjecture, although here it results from assuming that capital yields liquidity services, a feature absent from Tobin's model. If the assumption here was added to Stockman (1981), the latter's anti-Tobin implications may be reverted. I am thankful to Martin Uribe for pointing this out.

[24] It is worth noting that if $\theta = 0$, the model boils down to the standard model in which k yields no liquidity services. Therefore, the effects on the price of land stemming from central bank interest rates or inflation highlighted in the text would *not* hold in the standard model, showing that the results highlighted in this note are intimately linked to financial/liquidity considerations.

parameter but an endogenous variable); thus, at a competitive no-distortions equilibrium $f'(k) = \rho$ and $p \equiv 1$ (because capital is putty-putty and, by assumption, the equilibrium solution is interior). Moreover, at steady state, we have that the rate of interest on pure bonds $r = \delta$, the subjective rate of discount. Hence, substituting $f(k)$ for ρk in expression (4), one can show that equation (6) becomes

$$f'(k) = \delta(1-\theta), \qquad (6''')$$

which, again, makes sense only for $\theta < 1$. Clearly, for positive θ, $f'(k) < \delta$; and the higher is θ, the higher will be steady-state capital k. This trivially shows that, despite its risks, financial liberalization may have some redeeming value.[25]

3. Welfare Effects of θ. In contrast, welfare, as measured by expression (1), may decline. To show this important implication in a simple manner, I will now turn to an open-economy version of the model in which the economy is open to frictionless trade and capital mobility. In addition, I will assume that the exchange rate is constant over time. To make things more interesting, I will assume that the policy interest rate is equivalent to paying interest on money (as in subsection 1); once again, I will denote it by i_m. Seigniorage, net of interest on money, is lump-sum rebated to the public, and the international price level is constant over time – implying that $\pi = 0$. Moreover, I will make the standard simplifying assumption in open macro models that the subjective rate of discount equals the international interest rate. This is equivalent to setting $\delta = r$.

[25] The role of banks in the creation of liquidity and in facilitating more productive investment projects is well understood in the literature, e.g., Diamond and Dybvig (1983), Allen and Gale (2007). A value added of the present model is to stress the output effect in a standard neoclassical framework and, as I will next show, establish its welfare implications.

Under these assumptions, it follows that first-order conditions (5) become (recalling that at equilibrium p = 1)

$$u'(c_t) = \lambda \qquad \text{(a)}$$

$$v'(m_t + \theta k_t) = \lambda(\delta - i_m) \qquad \text{(b)} \qquad (7)$$

$$v'(m_t + \theta k_t)\theta = \lambda[\delta - f'(k_t)]. \qquad \text{(c)}$$

It follows that c, m and k are constant over time and (6''') becomes

$$f'(k) = \delta(1-\theta) + i_m\theta. \qquad (6'''')$$

Moreover, since seigniorage is fully rebated, the budget constraint for the economy as a whole becomes (assuming, without loss of generality, that initial total financial wealth is zero)

$$\int_0^\infty [f(k_t) - \delta k_t - c_t]e^{-\delta t}dt = 0. \qquad (8)$$

Thus, since k and c are constant over time, we have

$$c = f(k) - \delta k \qquad (9)$$

We are now ready to examine the welfare implications of a once-and-for-all increase in the liquidity parameter θ. By equation (6''''), an increase in θ brings about an instantaneous increase in the capital stock k if the economy starts below Friedman's optimal quantity of money (i.e., if $\delta > i_m$), the case on which I will focus the following discussion. By (6'''') and (9), $\partial c / \partial k = [f'(k) - \delta] = (i_m - \delta)\theta < 0$, if $\theta > 0$. In words, if capital is endowed with some degree of liquidity, equilibrium consumption falls as capital rises. Therefore, an increase in θ results in a fall in consumption c. Moreover, by (7a) and (7b), $v' = (\delta - i_m)u'(c)$. Hence, by concavity of functions v and u, the fall in c raises $u'(c)$, which by the equality expression in the previous sentence implies that at equilibrium v' rises and, hence, v falls. Consequently, both utility indexes u and v decline, which, recalling utility function (1), implies that welfare must go down.

Half of the intuition for this result is that as capital becomes more liquid, a larger amount of capital is accumulated to serve as a means of payments. If the economy starts from a situation in which the rate of interest on pure bonds exceeds the marginal productivity capital, capital accumulation will result in lower sustainable consumption. The other half of the intuition is that, by assumption, consumption and liquidity are normal goods, and the opportunity cost of liquidity holding in terms of consumption, $r = \delta$, does not change as θ rises. Therefore, the demand for liquidity falls in tandem with consumption, pushing down welfare as measured by expression (1).[26] Notice that since k rises with θ and the demand for liquidity, $m + \theta k$, falls, it follows that the demand for money, m, falls by more than the increase in θk. In words, the development of more sophisticated financial liquidity-enhancing instruments crowds out old-fashioned money to such an extent that it *destroys* liquidity. It is interesting to note that an increase in the liquidity-enhancing parameter θ is welfare-reducing even though, by assumption, the system fails to achieve the *optimum quantity of money*, i.e., $v' > 0$ holds – and, hence, more liquidity should, in principle, be welcome. The explanation is that in an undistorted environment, welfare could increase by

[26] The second part of the intuitive argument is essential for the result. To prove it, notice that in a non-monetary economy in which $m = 0$, an increase in θ always gives rise to higher, not lower, welfare.

lowering the rate of inflation because its marginal cost is zero. The same cannot be said about an increase in θ because it induces an increase in *k*, which marginal cost is $\delta > 0$, larger than its marginal productivity, $f'(k)$. Incidentally, does it follow that a collapse of θ would be welfare enhancing? The answer is a resounding Yes. However, it would be a mistake to infer that a fall in θ associated with financial meltdown is welfare enhancing, because the model is too simple and ignores the serious collateral damage associated with those types of crises.

In this example, if $\theta = 0$, the economy will reach a first best in which the marginal productivity of capital equals the rate of interest, $f'(k) = r = \delta$. This situation will not hold under distorting output taxes, poor contract enforcement, etc, that could make $f'(k) > r$. Under those circumstances, an increase in θ could be welfare improving since it could help to offset the market distortion.

4. <u>Endogenizing θ</u>. Although a satisfactory model in which θ is endogenously determined exceeds the limits of the present note, one can make some progress by considering the case in which, somewhat unrealistically, individual agents can endow their own land or capital with liquidity properties summarized in parameter θ (ignoring a possible systemic collapse in θ). Think of θ as a brand name that can be attached to land or capital and that makes them more readily accepted as a means of payments. In an open, emerging market economy, for example, the brand name could be provided by some prestigious international financial institution (a fading breed these days!).

Consider the open-economy model in the previous subsection. I will assume that θ carries a consumption cost per unit of *pk* (i.e., the market value of land or capital in terms of consumption) which is given by function $\varphi(\theta)$, where $\varphi(0) = \varphi'(0) = 0$, and $\varphi''(\theta) > 0$. One can show that, in an interior solution, θ is determined by the following condition

$$\varphi'(\theta) = v'(m + \theta k) = \delta - i_m. \tag{8}$$

Thus, θ rises as i_m falls. As shown in previous subsection, the rise in θ lowers welfare even if $\varphi(\theta)k$ is offset by, say, foreign donors' transfers (and *a fortiori* if it isn't) . This illustrates the possibility – often heard in the debate about the origin of the subprime crisis – that low interest rates after 2001 induced the development of new financial instruments, like CDOs. In an undistorted situation the development of those financial instruments lowers welfare, even in a scenario in which there no financial meltdown.[27] The unrealistic case studied here makes this result especially interesting, because it does not involve financial market externalities. Parameter θ does not come from heaven (or hell). It is determined by utility-maximizing individuals. The reason why despite their thorough knowledge of the situation these individuals choose a level of θ larger than the social optimum ($\theta = 0$) is that they do not internalize the lump-sum subsidies they will forgo as the demand for *m* falls. This is a familiar externality in monetary models, which makes an interesting come-back in the present context.[28] Notice,

[27] For the sake of completeness, notice that Friedman's optimal quantity of money is achieved if $i_m = \delta$ or, more generally, $i_m - \pi = 0$. In such a case, $\theta = 0$ which, in an undistorted environment, corresponds to the first-best solution.
[28] The model is a close relative of the one discussed in Ayagari, Braun and Eckstein (1998). In their model, the financial sector endogenously creates a class of goods that requires credit, as opposed to cash in advance. Their model shows, among other things, that higher inflation generates a socially-suboptimal

once again, that the sub-optimality of the financial sector holds even though the analysis has completely ignored the costs of financial meltdowns.

IV. Final Words

The simple framework discussed in this note can help to explain some central stylized facts in recent financial crises, including the subprime and several emerging market crises. It should be stressed, however, that the model is highly incomplete and should only be employed to get new insights about the effects of liquidity creation and destruction. The next natural step is to combine this type of model with others in which the credit channel plays an essential role (like in Kiyotaki and Moore (1997), for example).

The following bullets illustrate some central implications of the model.

1. The development of new liquid financial instruments linked to the real estate sector may raise *relative* real estate prices. This helps to explain the recent housing boom in advanced economies; and the output and asset prices boom in emerging markets after the creation of the market for Brady bonds (see Calvo (2007)). It also helps to explain a collapse in housing prices as financial engineering turns sour, and gives rise to a "bank run." Under this interpretation, the collapse in housing prices is not necessarily due to the uncovering of faulty or corrupt trades but to the absence of a LOLR that would otherwise help to coordinate the "good" no-bank-run equilibrium.

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larger range of credit goods. In the present model, inflation is also welfare-reducing in an undistorted environment because it induces capital over-accumulation. I conjecture that introducing i_m in the Ayagari et al model, one should also be able to show that if i_m falls, the range of credit goods expands, lowering welfare – which would be fully in line with the results presented here. I am thankful to Zvi Eckstein for alerting me about the existence of that paper.

2. High interest rates can be effective in putting a damper on assets' relative prices, even though all prices (and wages) are perfectly flexible.
3. Preventing deflation may be useful to stave off Irving Fisher's *Debt Deflation*. However, it may not be a solution to the *liquidity/credit* problem generated by the meltdown of real estate *relative* prices, especially if the policy interest rate hits the zero bound, but not exclusively under those conditions. For example, interest rate policy may become ineffective if real assets become illiquid, as it may turn out to be the case under severe financial crisis.
4. Once-and-for-all issuance of helicopter money or Quantitative Easing in the current jargon, without changing the policy interest rate or involving purchases of "toxic assets," may prevent price deflation, but it is ineffective in changing the relative price of land. However, the relative price of land could be raised if helicopter money generates inflation, provided land is not totally bereft of liquidity.
5. Assets' liquidity enhancement can lead to higher output. Moreover, if initial conditions in the capital market are not first-best, liquidity enhancements could generate Pareto improvement. However, excessive liquidity enhancement that results in lower social welfare cannot be ruled out, even if financial meltdown can be kept in check.
6. An extension that may be worth pursuing is endogenizing financial crises in which liquidity-enhancing parameter θ suffers a sudden collapse, as in the Diamond-Dybvig world of multiple financial equilibria. This could be done, for

example, by marrying the present model with the approach discussed in Morris and Shin (1998) to pin down a unique equilibrium solution.

7. An alternative strategy would be to postulate that the probability of a bank-run equilibrium is a function of some plausible vulnerability factors. See Calvo, Izquierdo and Mejia (2008), for some evidence that Sudden Stop equilibrium – a close relative to bank runs – increases with vulnerability factors like current account deficit and foreign-exchange denominated debt.

Appendix

I will sketch out a proof that the model employed in the text is equivalent to a model in which one starts by making the more conventional assumption that bank deposits, not land or capital, provide liquidity services – in addition to standard money. The model will also be employed to show that some straightforward extensions may help to rationalize the credit and output difficulties observed during the subprime and emerging market crises.

Recalling footnote 12 and letting z denote bank deposits in terms of consumption, I will now assume that liquidity is given by $m + \theta z$, and denote the utility from liquidity services by $v(m + \theta z)$. To start off, I will assume that banks are competitive, have no operational costs and are subject to no uncertainty which, among other things, drives them to lend bank deposits in their entirety (these extreme assumptions can easily be relaxed). Let s denote the real interest rate on bank loans (in terms of output) which, under the above assumptions is also equal to the real rate of return on deposits. Without loss of generality, I will focus on steady state and the simplest case in which k is identified with "land."

In the present setup it is more natural to think of the representative firm and the bank depositor as separate entities. The firm buys land at market value pk by borrowing from banks at interest rate s per unit of time. Hence, the representative firm's quasi-rents = profits (given that at steady state p is constant over time) are equal to $(\rho - sp)k$. Therefore, at an interior equilibrium the zero-profit condition holds and

$$s = \rho/p. \tag{A1}$$

The first-order conditions for the consumer remain basically the same as in the text, except that now he/she holds bank deposits, z, instead of land, k. Thus, first-order conditions (5a) and (5b) remain intact, but (5c) is replaced by the first-order condition with respect to z,

$$v'(m_t + \theta z_t)\theta = -\lambda(s_t - r_t)D_t. \tag{A2}$$

Hence, setting π = 0, and recalling that at steady state $r = \rho$, equations (5), (A1) and (A2) imply equation (6) in the text, showing that the fundamental results remain the same under these alternative assumptions.

An implicit assumption in the above setup is that banks loans are exclusively directed to the acquisition of land, despite the fact that $s = r/p = r(1 - \theta) < r$ = rate of return on a pure bond (i.e., a bond bereft of liquidity services). If banks were allowed to lend at rate r, equilibrium $s = r$, the price of land $p = 1$, and consumers would hold no cash, $m = 0$. Thus, to justify the model studied above, one should be able to offer a plausible scenario in which banks have incentives to stay away from pure bonds.

In a model with explicit uncertainty, banks and their regulators will also be concerned about the liquidity of bank assets. Suppose that a pure bond is identified with a conventional bank loan that seats on an individual bank's balance sheet but which characteristics are not known by the market, detracting from the bond's liquidity. On the other hand, consider the case in which the bank can purchase mortgage-backed securities which enjoy much wider market recognition, making them easier to sell or use for repo operations. Easier "salability" enhances the liquidity of those instruments.[29] Therefore, in a more realistic setup in which liquidity is also relevant for banks, the latter may have a

[29] See, for instance, Menger (1892) for an early discussion about the relationship between "salability" and liquidity.

preference for asset-backed securities, giving rise to the scenario assumed at the outset of the Appendix. This preference could be further enhanced by Basle-type regulations that make it less costly for banks to hold more liquid assets. These facts, incidentally, give incentives for the development of liquid financial instruments, a phenomenon that hails back to the creation of bank deposits and is behind the creation of the mortgage-backed securities and related modern financial instruments.

Let us now return to the model in which banks specialize in lending for land acquisition. As noted, this situation may be prompted by *micro*-prudential considerations. However, it might subject banks to macro or systemic shocks if, for some reason, liquidity of some of the associated instruments is impaired. Consider the case in which θ falls leading to a collapse in the price of land p. If deposits are not indexed to p, banks' balance sheets will suffer a negative shock on two fronts: (1) bank capital falls, and (2) bank liquidity falls. This may generate a bank run and/or further decline in the perceived liquidity of bank deposits, θ, giving rise to a self-reinforcing downward spiral and a major meltdown of the land price. Moreover, banking difficulties may directly interfere with the credit channel. In a more realistic model one could assume that banks, like our consumers in the body of this paper, have a liquidity preference which involves both pk and m. As p collapses, banks may switch to m, a *flight to quality*, and attempt to roll back previous loans, pushing firms into bankruptcy and causing output loss. This opens up an interesting agenda for future research.

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