When the textbook is wrong - observations on flaws in the textbook model of the banking system and their implications for economic theory

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Abstract

Fractional Reserve Banking has played an integral role in regulating the supply of money and debt from the commercial banking system for several centuries. However its mechanical behaviour, and the consequent quantitative behaviour of bank deposits and loans over time as a result, appears to be a source of considerable confusion both within current economic theory and outside of it. The description currently provided by most economic textbooks is inadequate, since it only explains the expansion of deposits from initial conditions due to the re-deposit of loan capital, and fails to include either loan repayments, loan defaults, capital holdings or the consequences of inter-bank lending. It also predicts the convergence of the bank deposit and loan supply to an asymptotically stable level over time, in contradiction to empirical statistics from banking systems over the last 200 years which show continuous expansion of the total amount of bank deposits, and bank originated loans, punctuated by occasional rapid contractions.

In this paper we present a version of the textbook model which includes loan repayment. and show that the mechanical behaviour of the system is far more dynamic than the textbook model presents. Stability issues arise from flows of money between banks as a result of loan repayments from the deposits of their customers, an order of evaluation issue presents itself in the processing of loan repayments versus new loans at individual banks, and a race condition is shown in inter-bank lending that can lead to deposit creation within the banking system independent of any deliberate government or central bank actions. Inclusion of loan repayments also demonstrates that the money multiplier for the system is a function of loan duration in addition to the the reserve requirement as described by Keynes, leading to different values for the multiplier than predicted by the standard model, and creating further sensitivites of the system's behaviour to both loan duration and the type of interest calculation being used.

We also review the historical context of economic theory on banking system behaviour which has progressed from 19th century discussions of whether bank deposits should be considered to be money at all, ignoring the money supply implications of bank deposit expansion, to somewhat tautologous discussions on whether bank deposits create loans, or loans create bank deposits. We will suggest that this failure to correctly model the banking system, and by extension the monetary system, has far reaching implications for economic understanding based on money and credit supplies, and any economic measurements where the unit is money.

Introduction

Fractional reserve banking originally developed out of practices used in gold based payment and storage facilities developed by medieval goldsmiths[1]. For the societies that first introduced it,

it was a significant technological development that over time changed the monetary system from one that relied purely on the exchange of physical precious metal monetary tokens, to a system which allowed transfers of money to occur through book keeping and paper based authorisations. Once fractional reserve banking was introduced, what had been a system that relied on physical transfers, became one that effectively had two components: physical money in the form of notes and coins, and book keeping entries representing bank deposits.

Initially though the definition of money used by Economists only included gold and physical notes of exchange. Both 19th century British and American economists make a clear distinction that bank deposits or capital are not money. Baxter[2] for example, writing in 1876, states that:

> The distinction between currency and capital[1] must be carefully borne in mind. Capital is not currency, and our 800 million of capital convey no measure of our currency. Currency is simple the medium by which capital is distributed.

The American Economist, Irving Fisher[3] writing in 1911 has a similar discussion and also concludes that bank deposits are not strictly money in a gold standard system. He then attempts to solve the problem of rapidly varying prices at that time by developing a theory claiming that the velocity of circulation of money contributes to the price level, subsequently formalised as the quantity theory of money, defined as $MV = PT$, where M is the money supply, V is the velocity of circulation of money, P is the price level, and T is the volume of transactions. Some suspicion of this formula might be derived simply from the knowledge that Fisher was writing 20 years before the deposit expansion theory was codified by Keynes, and two years before the establishment of a central banking structure in the United States, but it is nevertheless surprisingly easy to refute. V, the velocity of circulation represents the number of times each monetary unit is used in purchases. However, we know that T, the number of transactions must be a multiple of V the number of times each token of money was used in those transactions, and so V cancels on both sides of the equation.[2] A more accurate formulation is then:

$$P_t \approx \frac{M_t}{T_t}$$

where t is the time period over which the relevant statistics have been gathered although this assumes that all monetary tokens are in continuous use.

It was apparent by the end of the 19th century[4] that bank transactions were by far the larger part of monetary exchange. However the earlier failure to recognise bank deposits as part of the money supply remains significant in the context of discussions over the gold standard system's effectiveness in regulating the behaviour of bank deposits. The gold standard regulatory framework primarily provided a means of regulating the issuances of physical bank notes, records from 19th century England[5] clearly show a continuous expansion in the quantity of money shown as on deposit at banks, punctuated by occasional sharp contractions. Gold standard regulation would have been considerably challenged by this expansion, and its hidden effect on the general price level and on the price of gold in turn influencing the issue of bank notes. Economists such as Irving would have been faced with what they would have perceived as regulatory issues relating to changes in the price of gold and the consequent impact on its regulation of physical currency, without appreciating the significance of the changes in bank deposit quantities operating in the background on the larger money supply. Chequing and inter-bank clearing mechanisms being clearly well developed by 1827[6] in Britain, flows of money between bank accounts, independent of physical currency, were probably dominating well before the 20th century.

A variety of regulatory frameworks have emerged over the centuries as the result of repeated attempts to stabilise the banking system's behaviour, although understanding of that behaviour

[1] Baxter defines capital as bank deposits and shows total deposits in 1874 as being 800 million earlier in the article.

[2] As a thought experiment, imagine a very simple economy with two participants, a single item, and a single token of money. No matter how quickly or slowly the participants exchange the token, it is impossible for velocity to effect the price level in this economy. In the context of the recent introduction of computer driven high frequency stock trading which has considerably increased the frequency of stock trades, this is probably quite fortunate.

has typically focused on the problems at individual banks and lending institutions, rather than the behaviour of the larger system of interlinked lending and money creation. Several regimes can be broadly distinguished, free banking which avoids the use of a central bank, 19th and early 20th century gold standard regulation, where gold was used to control physical currency issuance in conjunction with reserve requirements enforced by central banking regulations, First World War European emergency regimes which removed the direct tie within the system to the price and quantity of gold reserves, the post second world war Bretton Woods treaty which attempted to fix world currencies to both gold and the American dollar, and the current banking system which is based on the Basel series of treaties and generally relies on capital rather than reserve based regulation.

The formal recognition that the process of lending within a fractional reserve system caused an expansion in the amount of money represented on deposit is surprisingly recent. Although the expansion was recognised in the late 19th century and early 20th[7][8] the deposit expansion table typically presented today in introductory economics textbooks[9] appears to have originated with the 1931 Macmillan report to the British Parliament[10] and was most probably authored by Keynes[11]. This expansion table only described deposit multiplication due to lending and its curtailment through reserve requirements. It did not include the effects of either loan repayments or loan defaults, and was probably not intended as anything more than an explanation for deposit expansion. What is interesting is the implication that economic theory prior to its publication must be interpreted with an unrecognised expansion of bank deposits and the consequent impact on any form of monetary measurements as a confounding factor.

Incomplete as the Keynesian model may be though, an alternative description that appears to have originated with Murray Rothbard[12] within the Austrian school of economics, and which has circulated quite widely, is somewhat less useful by virtue of being factually incorrect. Rothbard wrote, as part of a general description of fractional reserve banking:

> Let's see how the fractional reserve process works, in the absence of a central bank. I set up a Rothbard Bank, and invest $1,000 of cash (whether gold or government paper does not matter here). Then I "lend out" $10,000 to someone, either for consumer spending or to invest in his business. How can I "lend out" far more than I have? Ahh, that's the magic of the "fraction" in the fractional reserve. I simply open up a checking account of $10,000 which I am happy to lend to Mr. Jones.

Rothbard's specific claim that in the absence of central banking individual banks are allowed to lend ten times the amount they have on deposit, rather than a fraction, has been widely circulated out of context as a general statement that individual banks can lend a multiple of their deposits. In reality, this is the precise eventuality that bank regulatory frameworks attempt to prevent, and Rothbard's fallacy would lead to extremely rapid exponential deposit expansion, and a consequent rapid collapse, if it was ever allowed in an actual banking system.[3]

Rothbard then then built on this argument to raise the issue that central bank intervention can also trigger the multiplier effect, This is correct, but should not be assumed to be the only way that the deposit supply can be expanded in this system, nor should it be seen as an argument for the gold standard framework, since unstable behaviour was as much a feature of gold standard regulated systems as it is of current ones. Nevertheless, a large literature has arisen based on Rothbard's work within the Austrian school which has to be treated with some care with regard to accuracy about the system that they are describing.

The majority of modern banking systems are based on the three Basel treaties. These introduced a fundamental change to the system by replacing reserve regulation with capital regulation.[4] Capital regulation under the Basel treaties requires that Banks control their lending based

[3] Any amount of lending that exceeds the money on deposit at a local bank can cause monetary expansion in the system, however since monetary loss due to loan defaults is a continuous source of monetary contraction, small amounts may not be too problematic.

[4] Reserve requirements are still used by some Basel based systems, notably China and Brazil, but they have generally been removed or much reduced. Within the American system reserves are only required for Net Transaction Accounts which are a small percentage of total bank deposits.

on a combination of the amount they have on deposit, and a multiple of their regulatory capital, the precise value of which is determined by the type of loans that they have issued against their deposits. Curiously however, there appear to be no system wide controls on the total amount of capital used by the banking system for this purpose, so it is not entirely clear how capital regulation is expected to prevent deposit expansion within Basel regulated banking systems.

The textbook description of the fractional reserve re-deposit process is necessarily the starting point for modelling and explaining the behaviour of fractional reserve based banking systems. Given the considerable complexity of banking systems, a simplified system whose behaviour is clearly understood and which can then be extended for different regulatory frameworks is clearly required. Unfortunately, the Keynesian description predicts a convergence to an asymptotically stable supply of money and loans which has never been observed in any long term time monetary series from fractional reserve based currency systems, fails to include the effects of loan repayment and inter-bank lending, and most seriously fails to explain how loan defaults are handled by the system. Taken literally the first debt default to occur in a textbook banking system would cause the system to irreversibly implode, as the expansionary process shown in the textbook would be reversed into a contractionery one, as money was removed from the system by the loan default, and future lending based on the monetary stock correspondingly reduced as the multiplier effect sharpened the resultant contraction.

It is the absence of any explicit mechanism to handle debt defaults and the consequent monetary contraction within the system, that suggests there must have always have been other mechanisms operating to create money within the system besides the explicit multiplication effect of lending detailed in the textbook model, or central bank intervention. As will be shown below, there are probably several mechanisms responsible for the phenomena that is broadly referred to by modern economists as the "endogenous" growth of money.

Modern economics has moved beyond the textbook model, without necessarily explicitly acknowledging all the issues it poses. Observation of the banking system shows that the money supply is endogenous, and that periodic credit crises are a feature of its behaviour, and this is advanced as an explanation by central bank authorities such as King[13] without detailing exactly why this behaviour is occurring beyond the claim that it arises from the Central Bank's supply of base money. Velocity of circulation seems to be repeatedly used as a fudge factor to explain what cannot be explained by other theories, and the idea that monetary expansion can occur outside of central bank control is rarely discussed. However increasing evidence of regulatory failure can be seen in most central bank statistics of the last 40 years: the rapid increase in the Japanese money supply during the 1980's real estate bubble there, the dramatic expansion of deposits in the Icelandic banking system despite central bank intervention to raise interest rates over 18% during the 2000-2007 period, the continued expansion of the Chinese system over the last 10 years despite reserve requirements being raised to over 20%, to say nothing of various emergency "Quantitative Easing" efforts does not argue in favour of a well understood system.

The effects on money and loan supplies of the fractional reserve system, also poses interesting problems for economic theory. Money is a measure: if the quantity of money is changing in ways that are not recognised or indeed included by economic theory, then economists are in the position of measuring the economy with an elastic band, whilst being wholey unaware of any resultant changes in length. This creates major obstacles to economic understanding, especially for work that derives from measurements made in money over significant periods of time, or between differently regulated currency zones. The analysis of a modified version of the textbook model shown below, indicates that the mechanical behaviour of the banking system with respect to bank deposits and loans is extremely dynamic and dependent on a variety of factors some of which are purely mechanical results of the algorithms being used. If this behaviour is not explicitly included in economic models, then it will necessarily influence them.

It may seem simplistic to suggest that failure to normalise for changes in the money supply presents a challenge to some economic theories, but confusion in this area extends to official statistics of the monetary system, where there appears to be no standardisation of the various M series measurements being used across different currencies to measure the supply of physical

currency and bank deposits. Today's central bank statistics often use different components in different currencies for the same indicator, and in some cases, notably the USA's M2 measure, include components such as money market funds that represent short term debt in a measure of the money supply. Not only is it highly irregular in modern science not to have standardised measurements, but their absence is also indicative of the state of economic measurements that would benefit from being corrected for money supply changes.

There is also considerable confusion within the official figures between money and various forms of financial instrument representing debt. When analysing the fractional reserve system, which creates an explicit relationship between the quantity of money on deposit at banks, and the amount of loans they can have outstanding at any given time, it is critical to maintain the distinction between the two, regardless of any historical encumbrances on the origins of banknotes. For the purposes of banking system analysis in the context of this paper, we define money as a token of exchange, and debt as an asymmetric network flow of money.

1 The Textbook Fractional Reserve System

In the standard textbook model of the banking system, money is deposited with banks which is then lent out to borrowers. Individual banks are only allowed to lend a fraction of their deposits, and are required to keep a regulated percentage in reserve. In this model, the definition of money is the sum of all deposits and reserves held by the banks. As loans are made, additional deposits are created as loan capital is redeposited within the banking system. To prevent unlimited monetary expansion, and also to ensure that banks have sufficient funds to meet day to day demands by customers for access to their funds, a reserve is kept based on the quantity of deposits held by each bank. The possibility of confusion of money with debt within the system - for example by allowing reserves to be held in financial instruments that represent loans (e.g. treasury certificates) which occurs in today's banking system, is not included in the model, which implicitly assumes that money and debt are kept completely separate.

The model is typically presented in the form of a series of deposits, loans and reserves made between a set of banks, with a specified reserve requirement, as shown in Table 1.

Table 1: Expansion of bank deposits with 10% Reserve requirement.

Bank	Deposit (Liability)	Loan (Asset)	Reserve
A	1000	900	100
B	900	810	90
C	810	729	81
D	729	656	72
E	656	590	66
F	590	531	59

As loans are created against each new deposit, the resulting deposit expansion is progressively throttled by the reserve requirement. The limit on total monetary expansion by the banking system is presented in conjunction with this model as the theory of the money multiplier (M), which is expressed as $M = 1/r$ where r is the reserve requirement or ratio expressed as a fraction.[5] For example, where the reserve requirement is 10% or $1/10$ the money multiplier is $M = 1/r = 10$

The formula is derived from the following expansion series, where x is the initial deposit into the system, and r is the fractional reserve requirement :

$$x + x(r) + (x(r))r + ... = x\sum_{k=0}^{\infty}(r)^k \tag{1}$$

[5]Basel treaty regulation used in modern systems has effectively removed the reserve requirement as a regulatory factor, replacing it with capital regulation. Consequently many modern banking systems no longer have full reserve requirements.

which converges to

$$x/(1-r) \tag{2}$$

By extension, and assuming a complete separation of money and debt within the model banking system, the model also predicts limits on the total quantity of loan capital that can be issued against the total amount of money held in deposits by the banking system as shown in Figure 1[14].

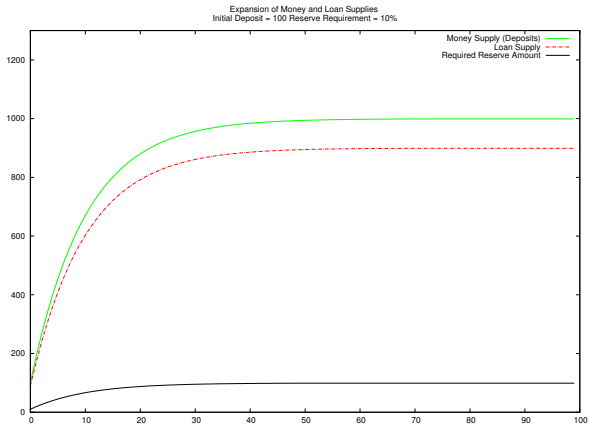

Figure 1: Theoretical limits of total bank deposits and loan supplies.

In particular, the total amount of loan capital originating within the banking system will always be a fraction of the total amount of deposits, provided that all loans issued by banks remain under the control of this regulatory framework. This relationship will be broken for systems that allow bank loans to be moved outside of bank regulation, for example by sale to non-bank entites. In modern banking systems, two mechanisms exist that may allow this, Asset Backed and Mortgage Backed securities, and in continental Europe, covered loans.

2 The Textbook System with loan repayment.

In order to explore the behaviour of the textbook banking system when loan repayment is included, money must be be able to flow through the loans created by the system. In the model presented here, Banks manage a number of deposit accounts held by employees, and can create loans to these employees subject to their regulatory requirements. Reserve percentages, loan interest rates, and loan duration can be set independently. Assuming it has received sufficient interest payments from the previous round of loan repayments, in each round each bank makes salary payments to all loan holders with deposits at the bank, sufficient for them to meet interest and capital repayments for their outstanding loans.

Under different configurations of the model, loans can be made to account holders at other banks, or restricted to only be made to the Bank's own account holders. Optionally, interbank lending can be enabled, allowing short term regulatory imbalnces to be resolved by direct borrowing from other banks when the bank's deposit:loan ratio does not satisfy the reserve requirement. Employees may only have one loan at a time, and in each round banks lend to the maximum allowed by borrower availability and their regulatory requirements. The interest on all loans is calculated using the simple interest formula, $I = P * R * T$ where P is the principal of the loan, R is the interest rate, and T is the duration. Simple interest was chosen as it made checking the output of the model easier.

When loan repayments are included, several issues in the textbook model are encountered. First, as shown in Table 2 there is an order of evaluation issue inherent in the system. If a bank first makes new loans, and then processes the repayment on its existing lending as shown on the left hand side of the table, it will immediately fall out of regulatory compliance when the loan

repayment is processed. Conversely, if it makes the repayment and then processes the new loan, it will stay in regulatory compliance, but the rate of monetary expansion will be reduced as the amount of new loans will be based on a reduced deposit base.

Lend then Repay			Repay then Lend	
Bank	Deposit	Loan	Deposit	Loan
A	1000	800	1000	800
B	*800**	810	800	700
C	810		700	
$\sum$	2610	1610	2500	1500

*Out of regulatory compliance with 10% reserve ratio.

Table 2: Order of evaluation problem with loan repayment.

If the more conservative approach is taken, and loans are made after repayments are processed, regulatory compliance cannot be maintained after the next iteration. The textbook model is somewhat artificial, in that for clarity it presents a loan cascade where each bank makes a single loan to a depositor at the next bank in the series. As a consequence when loan repayments are applied, and assuming all banks are lending at the same rate of interest and loan duration, each bank except for Bank A, is in the position of receiving capital and interest payments on a smaller loan, than its' depositor is making repayments on. Flows of money from all banks with the exception of Bank A, are consequently greater than the flow they are receiving. Banks will consequently fall out of regulatory compliance with respect to the ratio of their deposits to their loans after only a few rounds of loan repayments.

A similar issue could be expected to occur in actual banking systems with any set of banks which allowed loans to be made to customers at other banking institutions. For example, if a single bank exists in a geographically separate area, it will be stable as long as all of its loans are made to its own customers and there are no defaults. If a new bank opens up with access to its customer base, and either bank makes a loan to a customer at the other institution, then instabilities can be expected to arise at some point in the future purely as a result of unbalanced monetary flows between the two institutions as their customers repay their loans. In comparison, a Bank with an identical loan book, but whose loans were made only to its own customers would not experience these issues.

Daily imbalances in deposit/loan regulatory compliance are inevitable in all banking systems comprising multiple independent banking institutions, and are normally resolved by resort to the overnight interbank lending market. This facility in conjunction with the role of a central bank as a lender of last resort is usually regarded as a necessary part of the larger banking system, and must consequently also be included in any models of its behaviour.

There also appears to be a tendency for money to become concentrated at the banks which originate the largest loans, due again to the consequent flows of interest and capital repayments between banks. This can be seen in the historical development of the banking system where in many countries this bank subsequently became the central bank and took on a role as the lender of last resort to the rest of the banking system.

2.1 Examining the predicted value of the money multiplier

In order to isolate the behaviour of money multiplication from the network flow effects described above a restriction was introduced to the model whereby banks only issued loans to their own deposit holders.

With this restriction the behaviour of the money and loan supplies as the system evolved over time could be examined. Two clear patterns emerged, as shown in Figures 2 and 3. Figure 2 shows a run of the simulation with a loan duration of 12 accounting periods, an interest rate of 10% per annum, and 12 depositors. The initial deposits in the system are 10,000 monetary units, 5,000

of which are initially held by a single depositor and 5,000 by the bank. There are no constraints on bank lending beyond regulatory compliance, and the money supply expands to the maximum possible with this duration varying between 4.2 and 4.8 on successive loan repayment rounds.

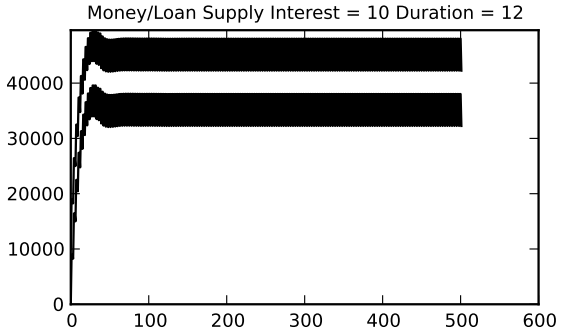

Figure 2: Monetary Expansion with 12 Depositors

In contrast, Figure 3 shows a run with the same parameters, except that there are only 11 depositors. Since loan duration is 12 accounting periods, the bank is unable to make a loan in the 12th period, as no depositor can borrow. (Depositors may only have one loan at a time.) This triggers a cyclic contraction and expansion in the money supply with the money multiplier for the system varying between 3.3 and 4.9 as loans are repaid. This arises purely because there were no qualified borrowers for the bank to lend to, rather than any initial supply issues. This demonstrates the potential for cyclic contraction in the money and loan supply for reasons of loan demand, as well as loan supply.

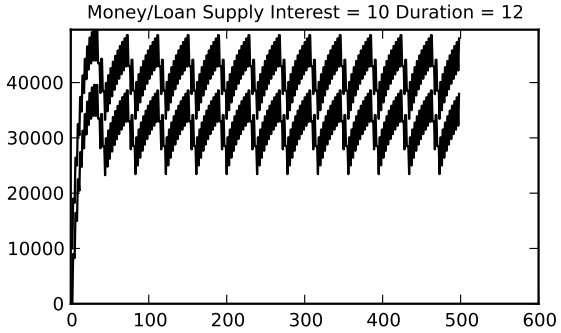

Figure 3: Monetary Expansion with 11 Depositors

In both cases, the money multiplier is less than predicted by the Keynsian model, due to the duration of loans being made, which is not sufficient to allow full expansion to occur. This is significant since loan durations can vary significantly between banking systems, and also between different historical periods.

2.2 Evolution of the Money Multiplier

Within the model, capital repayments are treated as a deduction in the loan amount outstanding and a matching deduction in the deposit amount held by the debtor. Interest payments effectively represent a movement of money between accounts, and so have no effect on the money supply in a simple interest model. With longer loan duration periods, the ability of the system to expand to its limits were explored, and this showed that the money multiplier was not only a function of the loan duration, but was also able to exceed the predicted theoretical limit of the standard model of $1/ReserveRatio$.

In the standard model which does not include any form of capital repayment, each new loan is made as the difference between the total amount of deposits, minus the reserve requirement,

and the amount currently on loan. When loan repayments are introduced to the system, each accounting period causes the loan capital repayment amount to be deducted from both the total loan supply and the total money supply. However, as the money supply is always greater than the loan supply, the percentage change in the amount on loan is slightly lower for the money supply than it is for the loan supply. Consequently, when the next loan is made, based on the difference between the money supply and the loan supply, it is for a slightly larger amount than would have occurred without loan repayments.

For example, as shown in Table 1 with a reserve requirement of 10%, and an initial deposit into the system of 1000, the second loan made without capital repayments is 810. If before the second loan is made, a capital repayment of 100 is made on the first loan, then the total money and loan supplies will be 1800 and 800 respectively. The next loan amount is then $1800 * 0.9 - 800 = 820$, resulting over time and assuming a sufficiently large loan duration in a larger monetary expansion than occurs without capital repayment.[6]

As shown in Figure 4, which is a run with 500 depositors, and a loan duration of 240 accounting periods, since the reserve requirement also acts as a constraint on lending, once the full monetary expansion of the system has been reached, a small cyclic pattern is once again seen in the evolution of the money and loan supplies over time. (Since there are more depositors than loan accounting periods, this run cannot experience a shortage of borrowers.)

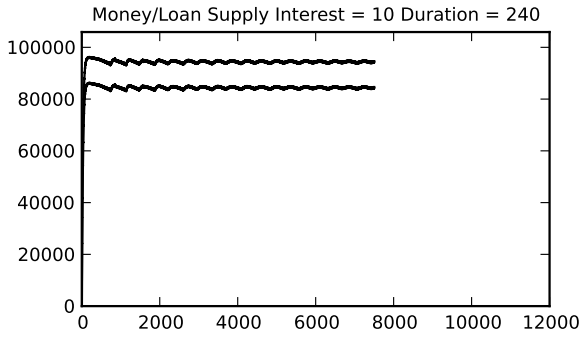

Figure 4: Behaviour with long duration (20 year) loan periods.

A further implication of this finding is that the type of interest calculation would also affect the model's behaviour - since loan repayments using compound interest calculations vary the quantity of the capital repayment component over the course of the loan.

3 Interbank Lending

Interbank lending is not normally treated as part of the standard textbook model, although as the example in Table 2 demonstrates, it is an integral part of the fractional reserve system when separate banking institutions exist within the same currency and can make loans to each other's depositors.

The status of a loan made by one bank to another lending institution, within the fractional reserve model, is not the same as a bank loan to a normal depositor. Consider the following sequence of events, within a reserve regulated banking system with a reserve requirement of 10%.

A loan repayment of 100 is made by Bank B's depositor to Bank A, Bank B is now no longer in regulatory compliance.

Two sequences of events can now occur at Bank A. One is money supply neutral, Bank A simply makes an interbank loan to Bank B, and the regulatory imbalance is corrected. However, Bank A could also make a loan to one its own depositors.

[6]It should however be noted that if the total quantity of money in the system is continuously expanding due to other "exogenous" behaviours then this issue is somewhat irrelevant.

Bank	Deposit	Loans	Reserve
A	1000	900	100
B	1000	900	100

Table 3: Interbank Lending Race Condition - Initial Conditions

Bank	Deposit	Loans	Reserve
A	1000	800	200
B	900	900	0

Table 4: IBL - After Loan Repayment by B's depositor.

Bank A can now make a second loan of 90 to Bank B, and stay in regulatory compliance. This doesn't completely cover the imbalance at Bank B, which is still 10 out of regulation. Both the money supply and the loan supply though have increased as a result of this sequence of actions.

Two observations can be made on this. In day to day banking activity, the system exists as a superposition of states as money flows around the system, and several days are usually allowed for clearing of transfers between banks. No attempt is made to synchronise the state of the entire system, rather regulatory compliance is monitored at each individual Bank. However, without some form of synchronisation, it is impossible to guarantee consistency in this form of distributed system, and so these kind of race conditions are inevitable [15].

In addition, the central bank is allowed to act as the lender of last resort, and in that role can provide funds to bank B to cover temporary imbalances within the system, which Bank B could then repay by virtue of a repeat of the same sequence of steps on a different set of loans and repayments. There is no effective way for the Central Bank to distinguish between the case shown, where money is being created by loans being made within the system, and an imbalance between banks caused by the direct transfer of money between depositor's accounts. Either of these processes can provide enough slip within the rules of the system to allow permanent money creation to occur, purely as a result of inter-actions within the system.

4 Conclusion

Money provides two significant economic functions, it acts as a signal of supply and demand through the price level, and it provides a control function when it is used to purchase goods and services. Changes in the money supply consequently have wide ranging effects, but the nature and duration of these effects also depends to some extent on where in the monetary system these changes occur[16].

Banking system crises are relatively infrequent in terms of day to day economic activity, even though their impact may be prolonged. The periodicity of those crises appears over decades - 19th century England for example experienced major crises in 1793, 1825, 1839, 1847, 1857, 1866, 1873 and 1890. Periodic banking crises were equally a feature of 20th century economies, although the removal of the fixed gold standard, and the introduction of deposit insurance made their immediate impact less catastrophic in some countries. Given the link between loan duration, and the evolution of the system over time, the long frequency of the system is not surprising, but it naturally presents considerable challenges to analysis.

Another complication arises from the direct link within the banking system of a form of money - bank deposits, with the supply of loans. If the Keynesian model's prediction of monetary stability was correct, then this would not be an issue, and building the higher level economic framework on an assumption of money supply stability would be a useful simplifying assumption in the search for explanations for the wide variety of dynamic behaviour linked to lending and credit activities that is seen in the economy. However if the mechanical operation of the banking system itself is a source of dynamic variation, then this assumption fails. Indeed the simplifying assumption is to examine the behaviour of the banking system, and determine its influence on the economic

Bank	Deposit	Loans	Reserve
A	1100	900	200
B	900	900	0

Table 5: IBL - Loan from Bank A to depositor at Bank A.

Bank	Deposit	Loans	Reserve
A	1100	990	110
B	990	900	90

Table 6: IBL - Loan from Bank A to Bank B.

conditions being observed. An important indication that this is indeed the case, is the existence of multiple different states within the system from the same set of inputs, as shown for example with the inter-bank lending issue.

A secondary complication are the determinants of the price level and by extension monetary measurements based on it. Changes in the price level can have multiple causes, as shown in Table 7, and without an examination of complete money supply data it is not possible to determine whether any given price change is a consequence of supply and demand changes, or of monetary instability.

Money Supply	Product Supply	Price level
Increases	Constant	Inflation
Decreases	Constant	Deflation
Constant	Increases	Deflation
Constant	Decreases	Inflation

Table 7: Money and Productivity effects on Price Level

Typically what often appear to be historical periods of price stability are in fact periods where increases in production and the consequent deflationary force, have been sufficient to offset inflationary monetary increases. Whether as is argued by many Economists some level of inflation is economically beneficial is hard to determine since there may never have been any period with actual monetary stability in a communication environment that prevented liquidity issues[17].

Transnational analysis is another area where variations in banking system behaviour can be overlooked. Differences in banking systems between countries are substantial. Housing loans in the USA for example, are often non-recourse, and made at fixed rates of interest. Germany similarly has fixed rate interest loans, but like most European countries has full recourse against borrowers; the UK has full recourse loans with variable interest rates; Icelandic loans are not dischargeable even through bankruptcy, and are also index linked to a consumer price index which includes government taxation as a component.

Then there are the substantial variations in the regulatory framework itself over both time and place, with a a surprising number of economists currently that appear to be unaware of the nature of the changes brought in by the Basel treaties. This often manifests itself with claims about the regulatory behaviour of ”base money” - by definition physical notes and coins, and reserves at the central bank. However, unless the reserve requirement is applied to all accounts in the banking system, and this is often now not the case, base money no longer serves any regulatory purpose and contains very little information about the global state of the banking system. Regulation of lending under the Basel regime is controlled by a risk weighted index of loans and the capital reserves of the Bank and their deposits, and has been decoupled from the reserve requirement on deposits.

One of the problems imposed by the banking system’s behaviour to Economic theory then, is simply one of measurement, since if the total money supply is changing then so is the unit of measurement. If this goes unrecognised then any and all comparisons based on measurements

in units of money are inherently suspect. Given the considerable confusion about the definition of money, and the associated problems that can be seen in central bank statistics of the money supply, it seems fair to assume that this is a very real problem for current Economic theory, since any researcher who did wish to normalise for monetary changes would be faced with the issue that the necessary data to do so is at best difficult to find.

For example, prior to the 2007 banking implosion, the Icelandic economy was often cited as a success story, and economic explanations advanced for this include the introduction of a flat rate tax, widespread privatisation and pension reforms[18]. Success in this context was measured in terms of GDP growth. Growth in Icelandic GDP was indeed remarkable over the 2000-2007 period, unfortunately so was monetary growth with a total expansion in bank deposits in Icelandic Kronur of approximately ten times in the seven year period following Bank deregulation.[7] Even though GDP is often presented as "real" GDP, normalised by the inflation rate, this is not a sufficient adjustment for quantitative monetary expansion. Inflation measurements are subject to government manipulation, and also do not include the price of financial instruments. When rapid monetary expansion originates within the banking system it may well be channeled into stock market or other investments, causing a rise in their value - one that is unfortunately often perceived as an economically beneficial signal, rather than a general increase in the money supply.

Even when monetary expansion is modelled explicitly, it is often assumed to only arise as a deliberate result of government policy and deficits. For example, Krugman when modelling balance of payments behaviour and seeking explanations for sudden currency adjustments[19] assumes money will only be created by government deficit, and models it as a function of government spending minus taxation. The possibility that growth can occur in the money supply independently of deliberate government policy is not considered even though varying rates in individual country's rates of bank deposit expansion must have been a major issue for attempts to fix relative currency values such as the Bretton Woods agreement.

Variation in the commercial bank originated loan supply is also an attendant function of the system, and one that is equally problematic. Debt deflation cascades were identified by Fisher[20] as a contributory problem to the Great Depression, although Hart[21] also identified debt repayment as a larger force on the monetary contraction seen during that period. Business models that rely on the continuous supply of renewable debt will tend to be highly sensitive to variations in loan supply and interest rates. Changes in the supply of loans are also a factor that can be expected to play out over long periods of time. For example, the period prior to the 2007 credit crisis which was described as the Great Moderation[22] by some economists, arose during a period where the widespread introduction of Mortgage and Asset Backed Securities had broken the implicit regulation of commercial bank loans as a fraction of bank deposits, and changed the banking system to one where the total quantity of loans originated from the banking system could excede the total quantity of deposits.[23]. As a direct result, this period is characterised by a continuous expansion in the total quantity of bank originated loan capital that exceeded the accompanying growth in bank deposits, with far reaching effects on the economy as loan funded activities were implicitly advantaged by the underlying changes in the banking system.

Aspects of this problem are reflected in recent papers, Disyatat[24] is one of several recent economists to advance the argument that loan creation causes deposit creation, rather than the textbook presentation of deposits creating loans. In the context of a recursive system this is however a tautologous argument, loans create deposits which then create more loans. What these observations more probably reflect is a growing awareness that the Basel banking system in changing the regulation of bank deposits and loans, has triggered changes in the behaviour of the higher level economic systems within the economy. As Disyatat describes it, "an adequately capitalized banking system can always fullfill the demand for loans if it wishes to", and with the current regulatory framework this does indeed appear to be the case. What it cannot do is guarantee that they will be repaid, and so loan default replaces loan availability as a control mechanism within the system. This would not be as problematic, were it not for the linking of loans to the money supply through

[7] Bank deposit growth over this period appears to be linked to deliberate manipulation of inter-bank lending and fraudulent loan activities into which investigation continues at this time.

bank deposits, and the consequent dangers of systemic failure. One possible explanation for the periodicity in economic behaviour generally referred to as the business cycle, is that it arises as the result of the superposition of two opposing forces within the banking system: the continuous removal of money and loans from the system, balanced by its creation through interbank lending and other leaks within the system. This explanation would need further empirical analysis though given the wide variety of behaviours that systems of this kind can support.

The potential for monetary expansion purely due to race conditions in interbank lending presents one explanation for the historical evidence of the system's expansionary tendencies, and one that would explain why this behaviour was also observed during the gold standard period. There are certainly other mechanisms that can trigger inadvertent deposit expansion by the system. Basel regulated systems for example, allow limited forms of debt to be used in the equity capital holdings which are used to regulate the quantity of debt issued by the system[23] opening up an additional money creating exploit in the system. The establishment of new banks would also be a source of deposit expansion, and banking systems vary quite widely in both the number of banks, and the ease with which new ones can be created.

As a critical component of money and credit regulation then, the mechanical behaviour of the banking system appears to warrent more detailed study in isolation of other economic effects than it is currently receiving. The simulation used for this paper is still relatively primitive as it uses a simple interest repayment model, rather than compound interest which could be expected to cause more dynamic behaviour since it would effect the the relative balance of interest flows versus capital repayment, and might also introduce interest rate dependendencies. It also does not allow the behaviour of different loan periods and interest rates to be explored simultaneously, which could introduce a smoothing effect, although the empirical evidence suggests otherwise. The model also does not attempt to explore the problem posed by loan defaults in any great detail - when loan repayments cannot be met, they are simply skipped, and a more explicit way of analysing their impact needs to be introduced. A potential confounding issue with any software simulation of an unknown system is always the presence of bugs within the code itself - and with a system such as this it would be advisable to independently develop simulations based on the same model for the system so that results can be compared and validated between simulations.

Of particular interest of course, are differences between regulatory frameworks, and aspects of the network elements of debt flows that can affect its behaviour, such as loan flows between banks, the interbank lending topology, and the number of banks in the banking system. Worldwide, and historically, there is evidence supporting very different expansion rates within banking systems that are using nominally similar regulatory frameworks, and more detailed analysis is needed to explain this. Finally the question needs to be addressed of whether fractional reserve banking is indeed sustainable in a 21st century communication environment that permits near instantaneous transfers of money within the banking system, without careful control not only of the regulatory framework, but also the rules surrounding the creation of financial instruments based on debt, and the topological stability of the invisible network of debt paths that route money around the economy.

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