Threadneedle: A Simulation Framework for Exploring the Behaviour of Banking Systems.

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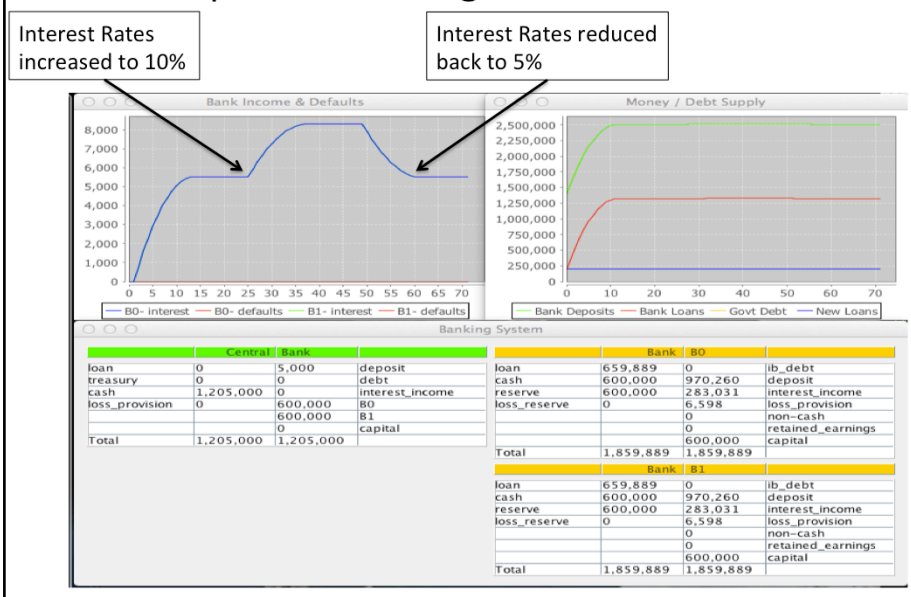
Developments in Economics Education, 2013

Goal: Create a framework for monetary experiments.

What happens if loan interest rates are increased?
How do different regulatory frameworks interact?
What is the result of changes to the regulatory framework?
Does the type of loan effect the system's behaviour?
What percentage of loans can be made to borrowers at a different bank?
What is the impact of the interbank lending rate?
What level of loan defaults can be absorbed by the system?

The financial system is extremely complex, and has a lot of moving parts, which differ both between banking systems, and sometimes within the same system. The results over time of the many and various interactions between the different elements of this system make it difficult if not impossible to model correctly. By building a framework that instead attempts to accurately reproduce the detailed operations of progressively more complex banking systems, we hope to be able to isolate and identify the various contributory behavioural and regulatory factors influencing its behaviour, as well as providing a valuable educational tool for how banking systems actually operate.

Response to Changes in Interest Rates:



Compound Interest, Fixed Rate 12 period loans, 120 Borrowers, Constant Capital Reserve, No loan defaults. No interest payments to depositors.

This chart shows the results from a simple 2 bank system with fixed rate lending, showing its response to central bank changes of the interest rate. In this example, where Banks do not change their capital reserve, the influence of interest rate changes on the money and debt supply is negligible, and we will show why this is later in the presentation. [The small change shown is due to the increase in interest income, which is classified as capital here.] The main results of the change is a gradual increase in bank profits as new loans are made, since the interest on the existing fixed rate loans does not change. This is essentially how the US banking system behaves. However in a banking system such as England where loans are often directly linked to the Bank of England's interest rate, this change would have immediate effect, resulting in a much sharper response.

How does the Banking System Work?

19th Century Banking Manuals

- Complete double entry book keeping examples
- Details of daily operational procedures.

Ginko-Boki-Seiho (Book Keeping System of Banks)	Alexander Shand (1874)
Book Keeping Banking	George W. Minder (1902)
Practical Banking Operations	L. H. Langston (1920)
Bank Book Keeping and Accounts.	Meelboom & Hannaford (1904)

20th Century:

- 1931 Macmillan Report to Parliament appears to be the origin of today's text book description (Keynes).
- It's incorrect.

21st Century:

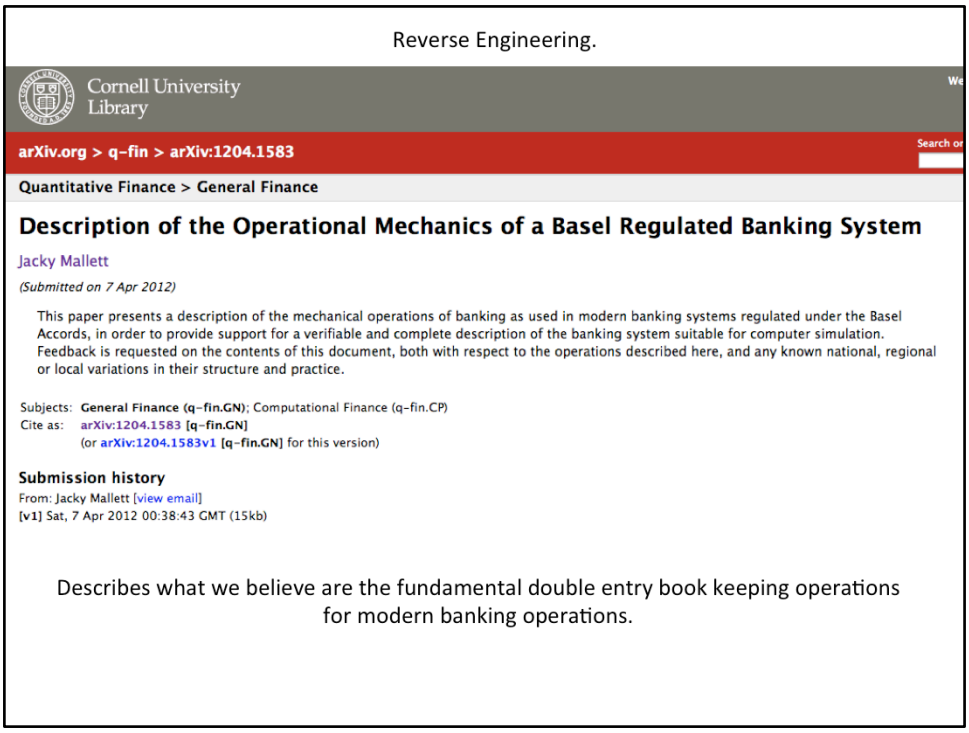
- Stop at organisational layer above double entry book keeping
- Regulatory & legal framework

Bank Controller's Manual	Mecimore & Deutsch (2005)

Unable to locate any complete & reliable source for modern banking systems.

It was surprisingly difficult to find reference material the provided detail on exactly how the book keeping for the various banking operations is performed. There does not appear to be any recent work on this, and although the older 19th and early 20th century references are interesting, they cannot be relied on to be definitive for the modern banking system whose regulatory framework has changed significantly from that time.

Reverse Engineering.



Describes what we believe are the fundamental double entry book keeping operations for modern banking operations.

So we wrote our own. Following the example of Alexander Shand, we attempted to isolate and describe in detail the fundamental operations of banking, with worked examples of our understanding of each operation. This document has been reviewed by senior accounting and commercial bank employees, and we believe it to be correct – but it also provides a clear and falsifiable point of common reference that should allow mistakes, or differences in local implementation to be identified.

Fundamental Accounting Equations

Assets = Liabilities + Equity

Assets = Liabilities + Common Stock + (Income – Expenses – Dividends)

	Debit	Credit
Asset	***Increase***	***Decrease***
Liability	Decrease	Increase
Income(revenue)	Decrease	Increase
Expense	***Increase***	***Decrease***
Capital	Decrease	Increase

Account Classification:	Loans to Customers	Asset	
	Physical Cash	Asset	
	Customer Deposits	Liability	
	Interest Income	Liability	*(to shareholders)*
	Bank Capital	Liability	*(to shareholders)*
	Loan ***to*** Bank	Liability	

Quick review of double entry book keeping - from the computer science perspective essentially a single error correction/detection mechanism. Using it provides significant advantages if only from a software perspective since it eliminates, or at least makes very easy to detect, a significant class of software errors that would otherwise be quite nasty to track down.

Transfer of 20 from depositor at Bank A to depositor at Bank B(1)

Central Bank

Assets	Liabilities
	220
420	
420	420

Bank A

	Assets	Liabilities	
Loans	10000	5000	Deposit A.C1
		5000	Deposit A.C2
Reserves	220		
Cash & Eq	780	1000	Capital
Total	11000	11000	

Bank B

Loans	10000	5000	Deposit B.C3
		5000	Deposit B.C4
Reserves	200		
Cash & Eq	800	1000	Capital
Total	11000	11000	

This chart shows how a depositors money is transferred from one bank to another, using asset money as an intermediary. Reserves at the central bank are an asset account, customer deposits are a liability. It is not possible to directly transfer liability deposit money to an asset, - there must be a credit/debit tuple for each operation that operates on two ledgers simultaneously. The reserve requirement in these examples is 2%

Transfer of 20 from depositor at Bank A to depositor at Bank B(2)

Central Bank

Assets	Liabilities
	200
420	
420	420

Bank A

	Assets	Liabilities	
Loans	10000	4980	Deposit A.C1
		5000	Deposit A.C2
Reserves	200		
Cash	780	1000	Capital
Total	10980	10980	

Bank B

	Assets	Liabilities	
Loans	10000	5020	Deposit B.C3
		5000	Deposit B.C4
Reserves	220		
Cash & Eq	800	1000	Capital
Total	11020	11020	

@ Central Bank: [Credit Reserve Account Bank A, Debit Customer Deposit A.C1]
[Debit Bank A Reserve, Credit Bank B Reserve]
[Debit Reserve Account Bank B, Credit Customer Deposit B.C3]

Consequently transferring money between banks involves 3 distinct book keeping operations – and the clearing operations used to perform the transfer can vary between countries. (Target 2 et. al.)

Deposit Creation through Lending – Bank A makes a loan of 500 to customer A.C1

Central Bank			Bank A		
Assets	Liabilities		Assets	Liabilities	
		Loans	10500	5500	Deposit A.C1
				5000	Deposit A.C2
	210	Reserves	210		
410		Cash	790	1000	Capital
		Total	11500	11500	

			Bank B		
		Loans	10000	5000	Deposit B.C3
				5000	Deposit B.C4
	200	Reserves	200		
		Cash & Eq	800	1000	Capital
410	410	Total	11000	11000	

This shows how money/customer deposits are created through lending, and the corresponding operations on the central bank reserves. Note, contrary to many economic textbooks, central bank reserves are a percentage of customer deposits (2% in the Eurozone circa 2012), held in asset money. They are not money that is directly retained form the customer liability deposits. (The what is money problem again.)

Borrower A.C1 repays 40 loan principal

Central Bank

Assets	Liabilities
	200
400	
400	400

Bank A

	Assets	Liabilities	
Loans	9960	4960	Deposit A.C1
		5000	Deposit A.C2
Reserves	200		
Cash & Eq	800	1000	Capital
Total	10960	10960	

Bank B

	Assets	Liabilities	
Loans	10000	5000	Deposit B.C3
		5000	Deposit B.C4
Reserves	200		
Cash & Eq	800	1000	Capital
Total	11000	11000	

[Credit Loan Principal, Debit Deposit A.C1]

Principal repayment decreases Loans, Deposits and allows Banks to make new Loans

Principal is just deducted on both sides – the missing part of the textbook description

Borrower A.C1 pays 60 interest on loan

Central Bank			Bank A		
Assets	Liabilities		Assets	Liabilities	
		Loans	9960	4900	Deposit A.C1
				5000	Deposit A.C2
	200	Reserves	200	60	Interest Income
400		Cash & Eq	800	1000	Capital
		Total	10960	10960	

		Bank B		
	Loans	10000	5000	Deposit B.C3
			5000	Deposit B.C4
200	Reserves	200		
	Cash & Eq	800	1000	Capital
400 400	Total	11000	11000	

[***Debit Deposit Account A.C1, Credit Bank Interest Income Account***]

Interest repayments are money supply neutral – they may increase bank's income.

Interest repayment is more interesting. Interest repayment in and of itself is money supply neutral, contrary to some claims. This does not necessarily mean that interest rates have no influence on the long term behaviour of the system, since there may be second order effects. If higher interest rates increase bank profitability – and this will depend on the spread between loan interest rates, payments to savers, and additionally the rate of loan default – then banks may be able to increase their capital reserves more quickly, allowing them to lend more. This mechanism is the exact reverse of the demand relationship, where higher rates may discourage borrowing. However, only if borrowing demand is sufficiently discouraged that the available supply is not saturated will this affect the system. Especially in conjunction with the effects of money creation from any excess of lending over repayment, and consequent influence on the price level and also on loan defaults. Taken together, this suggests that the response of the system over time to interest rate changes will be sensitive to multiple conditions. The Icelandic Banking system's rapid expansion between 2005-7 despite interest rate rises to 18% supports a direct interest rate/ expansion relationship in Basel systems.

Loan Defaults

Assets = Liabilities + Equity

Assets = Liabilities + Common Stock + (Income – Expenses – Dividends)

Loan Defaults are an expense:

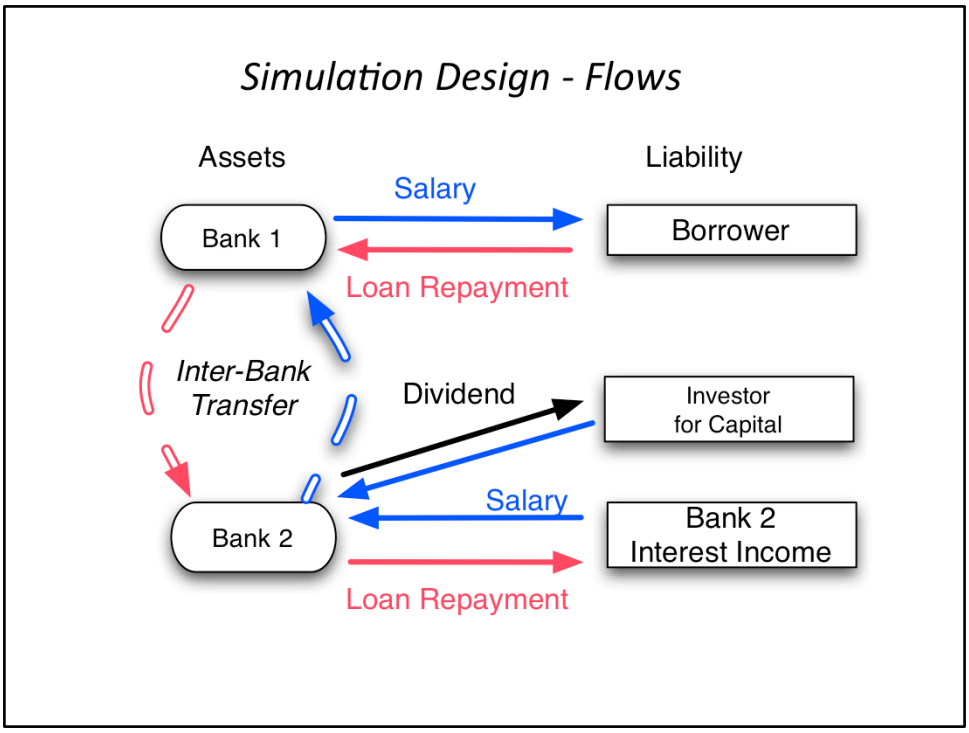
Write-off order is vs.

1) loss provisions
2) Earnings, retained earnings.
3) Capital.

If a loan can be written off against loss provisions or earnings, only effect is on bank's profits:

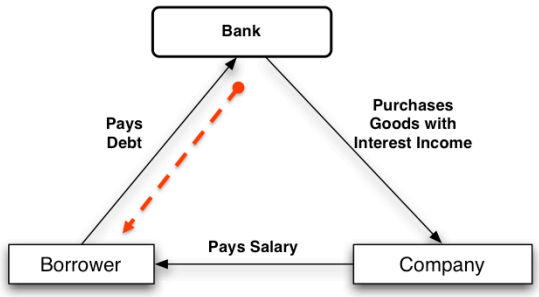
"Quantum" zone – money written off is then re-created by lending.

Loan defaults are usually completely absent from textbook descriptions of the banking system, which is a little unfortunate as they are possibly one of the most critical aspects of its behaviour. Unfortunately for such a critical system, the banking system seems to operate in two zones – one where as defaults can be absorbed with profits, and any money written off is re-created with the next loan, they have little effect on the larger system besides reducing bank profits. However, if it is not possible to do this, the system created by these rules quickly implodes because of the highly leveraged relationship between bank capital and bank lending allowances. This is best viewed as a mathematical consequences of these rules, rather than having any particular economic significance, even thought the real world effects can be catastrophic for the monetary system. In this respect, capital regulation appears to have exactly the same problems that the older reserve regulation had, and it remains an open question as to how much protection the higher capital levels required for Basel 3 will provide.



A critical design problem is how to arrange flows of money within the simulation that exercise the debt repayment relationships. We do this by paying a salary each round to the borrower from a designated bank (under the modeler's control), which allows the borrower to meet their debt obligations that round, if an only if the bank has available funds. This allows the inter-bank lending and clearing relationships to be isolated as required, and allows us to answer questions about the results of changes in the bank's regulatory mechanisms. It does not allow us of course, to make predictions about what the economic consequences of such changes would be – we can say that money supply expansion may increase with Icelandic indexed linked loans, but not how that will affect the Icelandic economy.

Shortcuts flows in the real Economy



Allows us to exercise the Banking System regulatory mechanisms independently.

In practice, this artifice is essentially short cutting the actual flows of money within the larger economy. Our goal at this time is not economic realism, but to understand the behaviour of the banking system and the actions of its regulatory mechanisms.

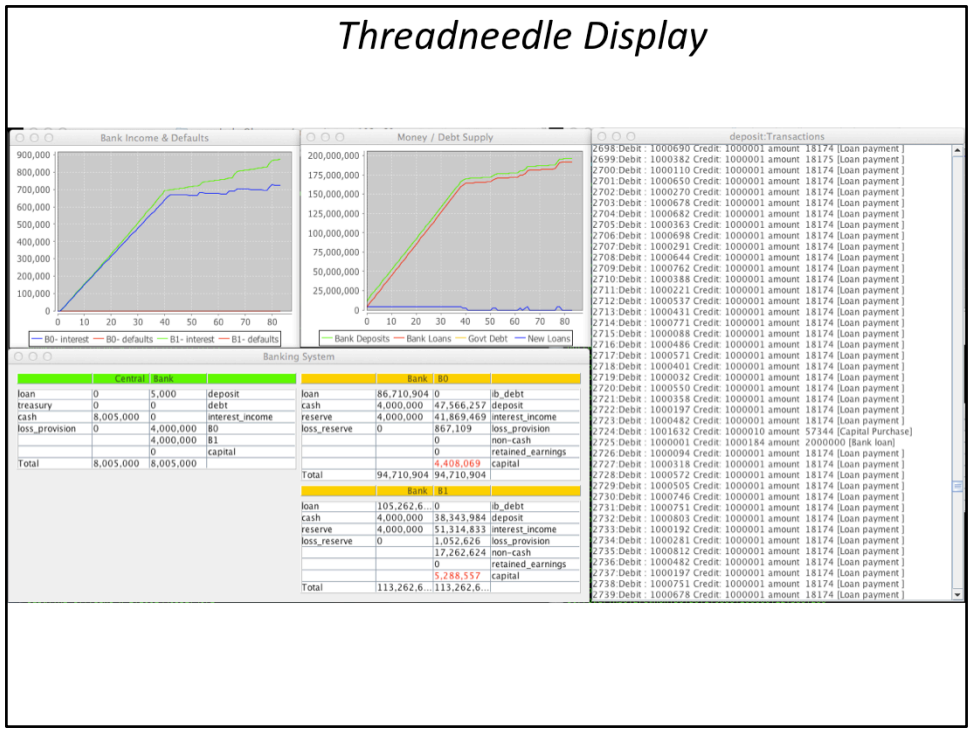
Current Simulation restrictions.

- Bank is restricted to one loan/step in order to provide an even demand for lending across loan period.
- To avoid demand shortfall:

  No. of borrowers > loan period * no of banks

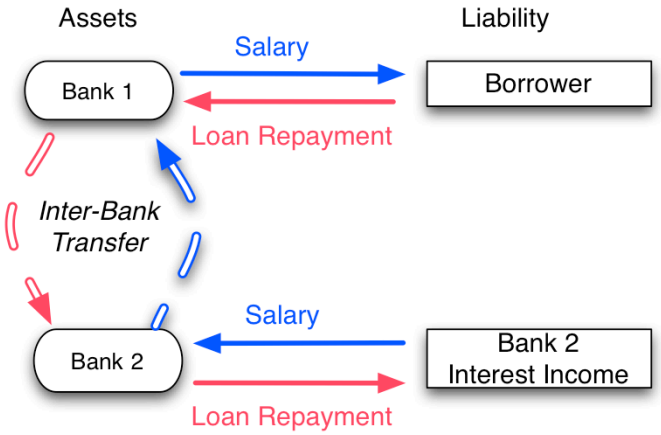
- All loans are currently made at the same interest rate, and are fixed for the duration of the loan.
- Interest rate can be changed during the simulation.

In order to create an even distribution of lending over time, each bank is restricted to making one loan/step. This can be relaxed for larger simulations.



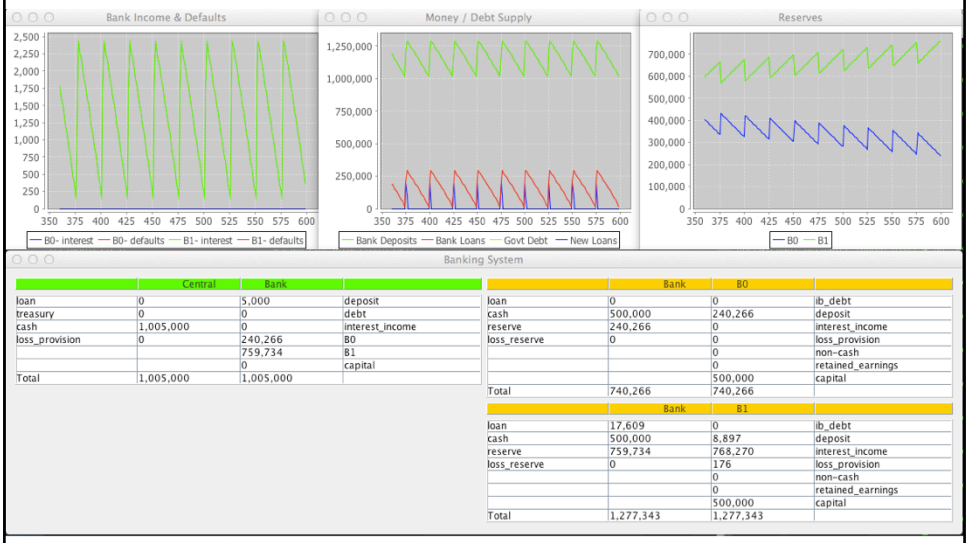
Example of complete display. Double entry book keeping transactions on each ledger can be individually displayed, and other graphs (e.g. reserve levels can also be displayed as required.)

What happens if we exercise inter-bank transfers – clearing mechanisms?



We can do this by having a borrower with a deposit at Bank 1, borrow from Bank 2.

Example of unbalanced reserve flows when lending to another bank's customers.



	Central	Bank	
loan	0	5,000	deposit
treasury	0	0	debt
cash	1,005,000	0	interest_income
loss_provision	0	240,266	B0
		759,734	B1
		0	capital
Total	1,005,000	1,005,000	

	Bank	B0	
loan	0	0	ib_debt
cash	500,000	240,266	deposit
reserve	240,266	0	interest_income
loss_reserve	0	0	loss_provision
		0	non-cash
		0	retained_earnings
		500,000	capital
Total	740,266	740,266	

	Bank	B1	
loan	17,609	0	ib_debt
cash	500,000	8,897	deposit
reserve	759,734	768,270	interest_income
loss_reserve	0	176	loss_provision
		0	non-cash
		0	retained_earnings
		500,000	capital
Total	1,277,343	1,277,343	

Compound Interest, Variable Rate 12 period loans, 2 Borrowers, Constant Capital Reserve, No loan defaults. No interest payments to depositors.

Simulation: singleloantest.csv [470]

Interestingly, part of this is a known problem. Keynes talks about this in the Macmillan report immediately after the deposit expansion example, explaining that because of the need to provide loan principal from asset money for money that is transferred to another bank, this will act to regulate bank's lending. However, while that is a correct description of the short term relationship, the long term relationship is exactly the opposite, the asymmetric flow of interest back to the loan originating bank will starve the other bank of asset money. This effect could be expected to be accentuated by inter-bank lending, and be directly linked to interest rates.

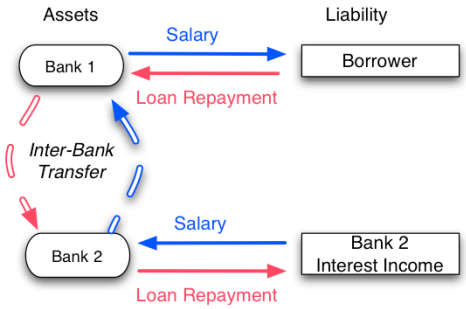
Two Bank System, 1 loan to borrower at other bank.

120 Borrowers, 1 year, fixed rate loans.

Central Bank Reserve Requirement:

Deposits <= 2% of Central Bank Reserve

No inter-bank borrowing.



Deliberately Created unbalanced flow:

- Bank making loan slowly (decades) drained the other bank's clearing funds.
- Interest rate dependency – faster @ higher interest rates
- Unpredictable effect – probably more significant for systems with larger numbers of small banks.
- Banks usually prefer to lend to their own customers because in the short term, the initial transfer of the loan capital can be problematic.

Note: this issue must be presumed to also be occurring in the tertiary structure of the Eurozone between countries.

Basel Capital Controls

Two Banks

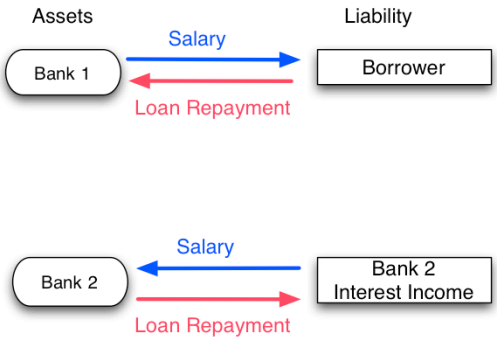
600 Borrowers, 25 year, fixed rate loans.

Central Bank Reserve Requirement:

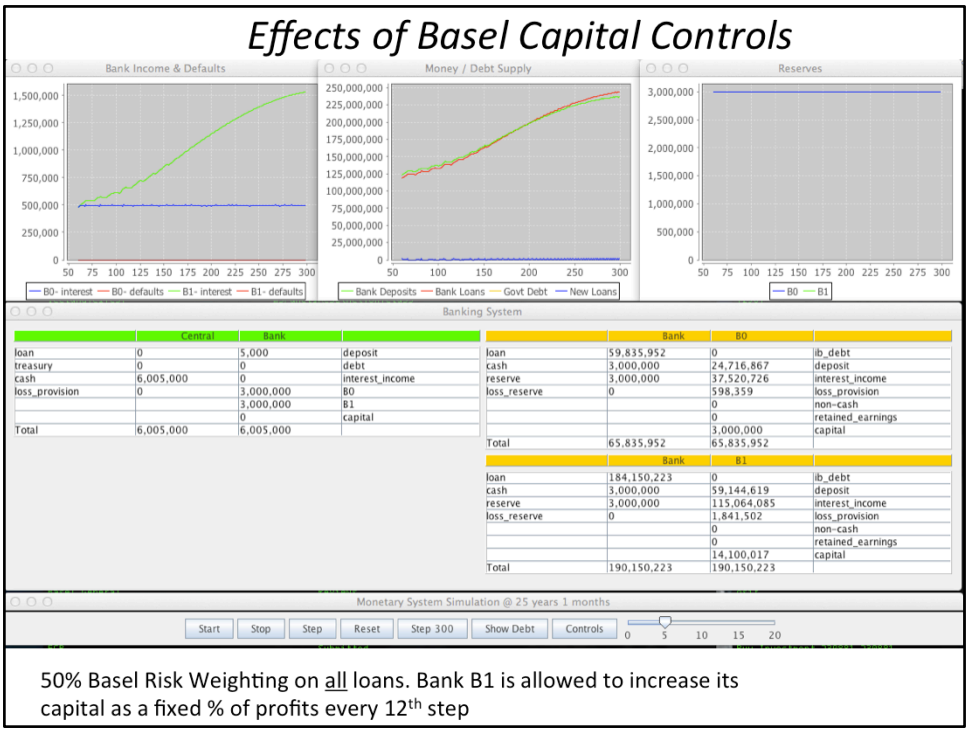
- Deposits <= 2% of Central Bank Reserve

Basel Capital Reserve Requirement:

- 50% Risk Weighted Capital on ***all*** loans



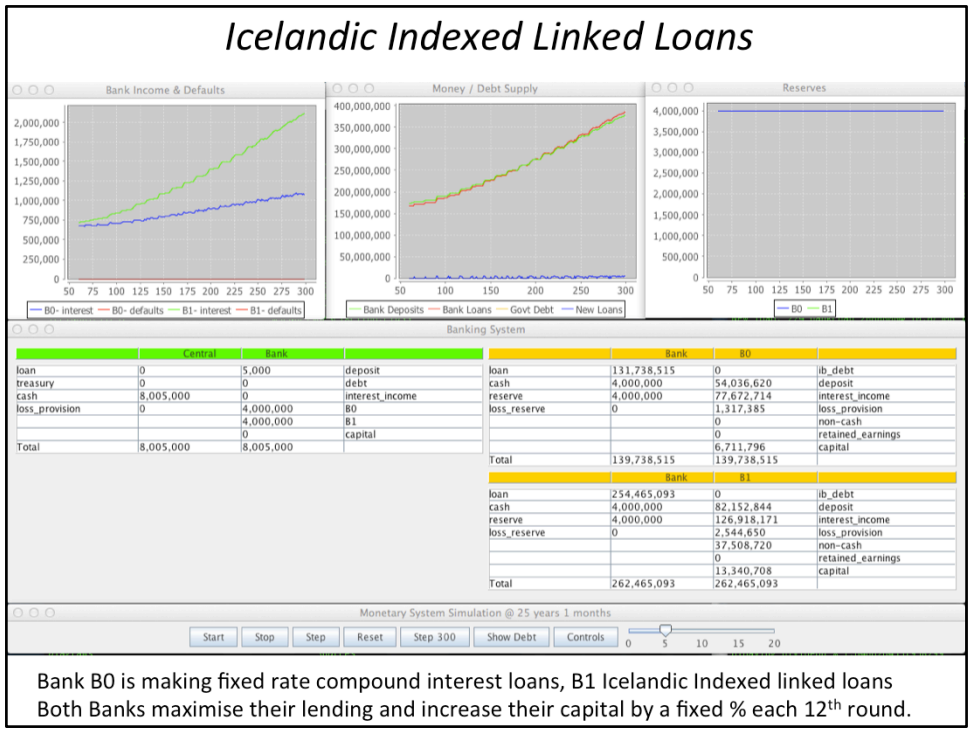
Threadneedle has a full implementation of the Basel risk weighting model, and different percentages can be set on each type of loan if desired.



50% Basel Risk Weighting on all loans. Bank B1 is allowed to increase its capital as a fixed % of profits every 12th step

Simulation: ecb_basel_1.csv

Somewhat ironically, it appears that the basel capital controls could work as a more effective control on system wide lending and borrowing than the old style central bank reserve controls, if the banks were not allowed to arbitrarily increase their capital holdings, or have 0% weighting categories. However, since they are, and since most countries no longer have central bank reserve requirements on all liability deposits (not that this worked when they did), the only constraint on the lending (and consequent money creation) of modern banking systems appears to be the rate at which banks can increase their capital holdings. This approach to regulation would also require a mechanism to control capital holdings across the entire banking system, rather than individual banks. Nb. We have not yet examined if or how such a regulatory mechanism could be circumvented, but it should be noted there have been signficant issues with existing mechanism ref: Hybrid capital.



Bank B0 is making fixed rate compound interest loans, B1 Icelandic Indexed linked loans
Both Banks maximise their lending and increase their capital by a fixed % each 12th round.

Simulation: icelandic.csv With 0.02%of profits annual capital increase.

This simulation demonstrates a local peculiarity in Iceland, by showing the results from two banks, each with identical starting conditions, one bank is making fixed rate compound interest loans, and the other is making Icelandic indexed linked loans. Both banks are allowed to increase their capital as a fixed percentage of their profits every 12 steps. The simulation shows that the Icelandic bank expands faster due to a positive feedback loop within the banking system created by the indexed linked loans. This demonstrates that differences inherent in the micro-structure of individual country's banking systems can have macro-economic influence, in this case on the money and credit supply for Iceland.

Threadneedle

Banking System Simulation Framework

- Supports:
  - Simplified Basel Risk weighted capital model
  - Central Bank Reserves
  - Compound loans (fixed and variable rate)
  - Simple interest loans (unit testing)
  - Verðtrgg Lán (Negatively amortized indexed linked loans)
  - Loan default and write-off against loss provisions and capital
  - Treasuries

- Full Double Entry Book keeping model
  - General Ledger, Individual Ledgers maintained separately for each bank
  - Each transaction recorded as [Debit, Credit] to specific ledger
  - Central Bank, Individual Banks, Government taxation (flat rate)

- Technical
  - Fully object-orientated, written in Java
  - Runs on OSX, Linux, Windows 7, 8
  - GUI, command line, and batch mode support.

Next Steps

- Open Source Release
  - Target Spring 2014

- Complete Banking Simulation
  - Include securitized lending, government treasuries, and extend to be able to simulate multiple countries.
  - Visualisation of debt flows within banking network
  - Visualisation of monetary flows, especially showing differences between asset and liability money

- Add Economic simulation elements
  - Markets, Production, Employees, and Ownership
  - Consumable and non-consumable goods (e.g. shares)
  - Taxation

- Research
  - Continue focus on controlled experiments, with small changes between simulations.
  - Explore dynamics created by interbank lending
  - Build up a set of experiments exploring behaviour of banking system within the larger economy of monetary flows.
  - Examine behaviour of pricing and monetary transmission mechanisms

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