Northern Rock plc: A case study in banking policy during times of duress

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Abstract: This paper explores the events that engulfed Northern Rock plc, a UK publicly listed company, during the latter part of 2007. The background to those events that took place is illustrated together with their consequences for Northern Rock. A model of the Northern Rock liquidity situation is produced and tested using the System Dynamics paradigm and methodology. The resultant model is verified and validated with reference to known behaviour and data. Hypotheses are constructed resulting in conclusions which centred on the need for co-operation between the Tripartite Authorities and Northern Rock together with a need for active, coordinated management action. Within the limitations of the model different means of coping with banking credit problems are illustrated and remedies postulated.

The model presented could be further developed to produce recommendations for automatic triggering of interventions. A variant of the model could be adapted to model contagion risk. These, together with others, are areas for further work.

Methodological conclusions are that the model correctly exhibits linear behaviour if not actively managed, that the model contains both continuous and discrete elements, that there is scope within the model to adapt it for use as a teaching/study aid in finance and/or System Dynamics.

Keywords: Northern Rock, System Dynamics, Systems Thinking, Finance, Banking, Simulation

Introduction and background

International and UK national environments

There has been increased turbulence in financial markets around the world for the past year and more. From a previously favourable environment for international financial trading the early part of 2007 revealed, with hindsight, the precursors of a less benign financial climate (FSA, 2008, pp9-12). Figure 1 illustrates this change and emphasises the rapid turnaround in available liquidity through the liquidity index. With the lens of hindsight it has been observed that the ripple effect that emanated from decreasing confidence in and default rates for US sub-prime lending (Figure 2) led to a global tightening in money markets which then trickled down to UK housing markets in the middle and latter parts of 2007 and this effect continues into 2008 (FSA, 2007).

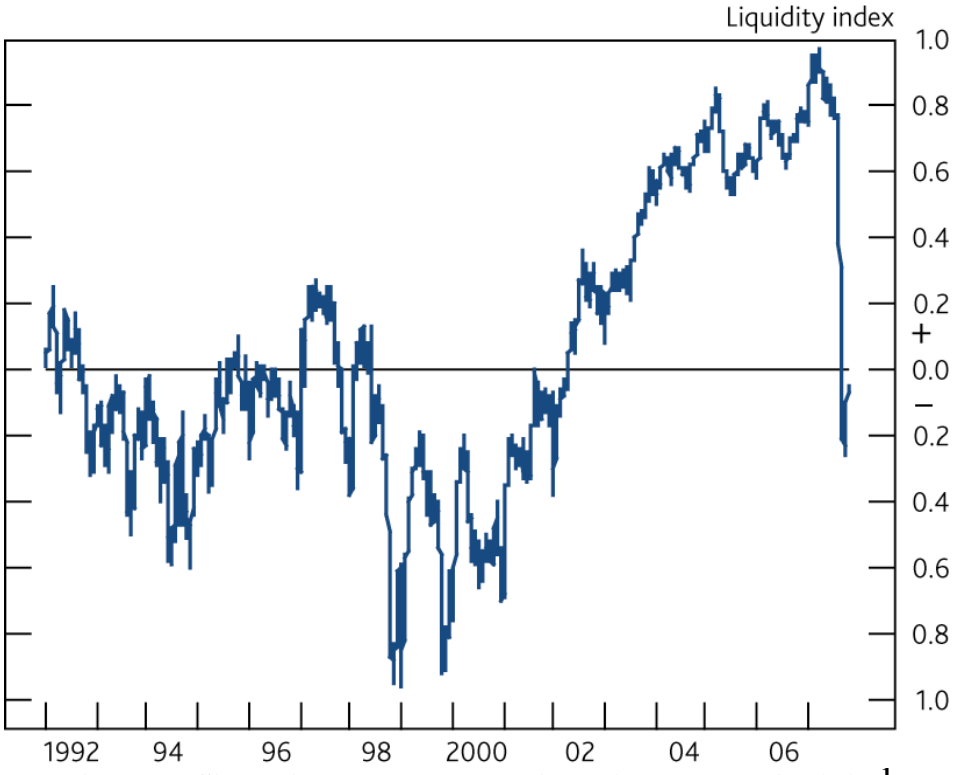

Figure 1: Signalling the crunch – Financial Market liquidity[1]

Sources: Bank of England, Bloomberg, Chicago Board Options Exchange, Debt Management Office, London Stock Exchange, Merrill Lynch, Thomson Datastream and Bank calculations.

In effect we had a US consumer derived phenomenon having an effect on UK consumers in the same market segment; US home buyers had an indirect but definite effect on UK homebuyers; through their lenders (figure 2).

[1] "The liquidity index shows the number of standard deviations from the mean. It is a simple unweighted average of nine liquidity measures, normalised on the period 1999–2004. Data shown are an exponentially weighted moving average. The indicator is more reliable after 1997 as it is based on a greater number of underlying measures. Data have been revised following methodological changes. See April 2007 Report, Box 2: Financial market liquidity, page 18. "(Bank of England, 2007)

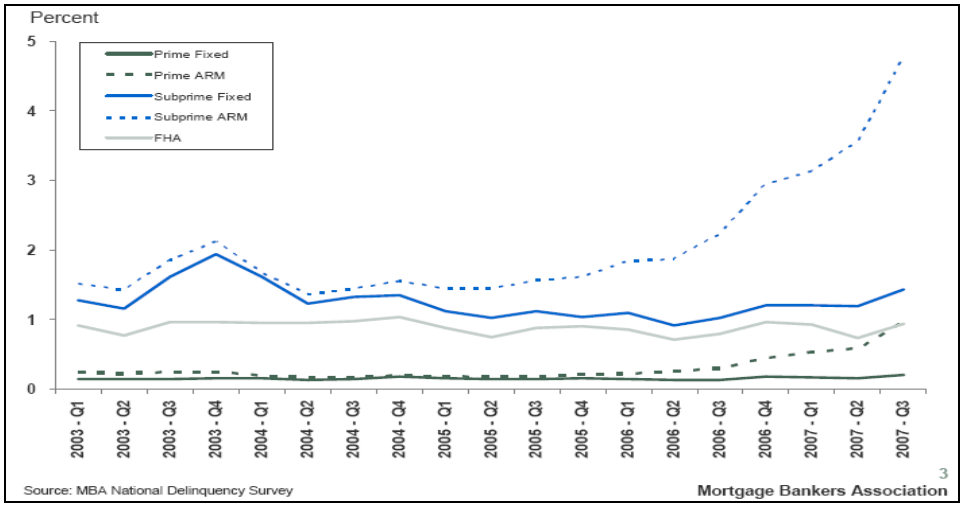

Figure 2: The crunch on consumption - US foreclosures started by loan type

	2004	2005	2006	2007	2008
House price growth, Q4, year on year % change	15	5	10	7 (7)	1 (5)
Property sales, England and Wales (Land Registry), millions	1.29	1.07	1.25	1.17 (1.19)	1.01 (1.13)
Gross advances, £bn	291	288	345	360 (360)	340 (360)
Net lending, £bn	101	91	111	105 (120)	90 (115)
Arrears, over 3 months, number at end period	103,400	124,900	120,500	145,000	170,000
Arrears, over 3 months, % of all mortgages at end period	0.90	1.08	1.03	1.22	1.42
Possessions, number in period	8,000	15,100	22,700	30,000	45,000
Possessions in period, % of all mortgages	0.07	0.13	0.19	0.25	0.38
GDP, %	3.3	1.9	2.7	3.0 (3.0)	2.25 (2.8)
Bank rate, end year, %	4.75	4.5	5.0	5.5 (5.25)	5.0 (5.0)

Source: Bank of England, National Statistics, HM Land Registry, HBOS, CML
Notes: (1) Figures for arrears and possessions are estimates and relate only to first charge lenders who are members of the CML. They do not include arrears and possessions relating to other secured lending or to firms that are not CML members. (2) December 2006 forecast shown in brackets. December 2006 arrears and possessions forecasts are no longer comparable due to changes in methodology.

Figure 3: The picture in the UK – forecast summary statistics – CML

The statistics and forecasts from figure 3 reveal that some sources look upon the UK market as heading for a clear downturn with consequent rises in arrears and repossessions. Though if we take figure 3 as our guide then it looks more like an orderly retreat than any kind of full scale rout.

Having set the national and international scene we can now focus in on the main subject matter of this paper; Northern Rock (formerly plc) a UK bank.

Historical and current background of Northern Rock

The Northern Rock Building Society was formed on 1st July 1965 but can trace its origins back to 1850 when the Northern Counties Permanent Building Society (established in 1850) and Rock Building Society (established in 1865) merged.

Northern Rock Building Society then went on to merge with a number of small local building societies and, prior to its conversion to a public limited company in October 1997, was an amalgamation of 53 societies (Northern Rock, 2008), (Datamonitor, 2008).

A building society is the approximate UK equivalent of the US savings and loan association, building societies are described as mutual societies which exist to further the interests of their members; usually in the form of arranging loans (mortgages) to purchase land or property with any surplus directed back to the members. Building societies do not have shareholders they are owned by their members.

"A significant development in the recent history of Northern Rock was its conversion on 1 October 1997 from a building society to a public limited company, listed on the London Stock Exchange and authorised under the Banking Act 1987. The conversion also resulted in the establishment of The Northern Rock Foundation, a charitable body which is entitled to receive approximately 5% of the annual consolidated profit before tax of Northern Rock plc" (Northern Rock, 2008).

Northern Rock is a substantial banking institution within the UK having been a member of the FTSE 100, which "comprises the 100 most highly capitalised blue chip companies, representing approximately 81% of the UK market"(FTSE International, 2008), since September 2001 until its removal to the FTSE 250 in December of 2007.

Recent events have again altered the nature of the bank which is now a nationalised banking institution, since 17th February 2008, and whilst this is described as a short term measure there is no way of knowing how long public ownership will last or in what form Northern Rock will emerge from that public ownership.

Northern Rock though now a bank and not a building society still has its roots in the same market segments – on the lending side at least - see figure 4 for a breakdown.

£ millions	Residential	Buy to Let	Total Residential	Commercial	Unsecured	Total
2007 1st Half						
Gross	15,979	1,455	17,434	188	1,704	19,326
Net	9,170	899	10,069	91	554	10,714
Closing balances	81,212	6,181	87,393	818	7,829	96,040
2006 1st Half						
Gross	11,515	1,196	12,711	259	1,837	14,807
Net	5,427	924	6,351	72	853	7,276
Closing balances	63,912	4,704	68,616	1,594	6,638	76,848

Note: Net flows represent net cashflows excluding fair value adjustments and excluding asset disposals. Closing balances are stated including fair value adjustments.

Figure 4: Northern Rock lending profile (Northern Rock, 2007)

Whilst the lending profile may have remained similar in that it is still based primarily on lending for purchase of property with a small component relating to unsecured loans (8.15% of the closing balance in June 2007 down from 8.64% at the comparable point in 2006) the borrowing profile has undergone some changes. Instead of funding lending from retail deposits it now, as at June 2007, relies much more heavily on borrowing from sources other than retail depositors to finance its lending activities.

£ millions	Retail	Non-Retail	Securitisation	Covered Bonds
2007 1st Half				
Net flow	1,734	2,509	5,632	2,194
Closing balances	24,350	26,710	45,698	8,105
2006 1st Half				
Net flow	1,666	(2,329)	5,834	1,382
Closing balances	21,773	19,570	36,334	4,965

Note: Net flows represent net cashflows excluding fair value adjustments. Closing balances are stated including fair value adjustments.

Figure 5: Northern Rock funding profile (Northern Rock, 2007)

The retail deposit funding amounted to some 23.1% of total funding in June 2007 and 26.3% at the comparable point in 2006.

A chronology of events is outlined in (BBC News, 2008).

At the end of 2007 Northern Rock was being supported by the Bank of England to the tune of several billion pounds, estimates vary between £44bn and £55bn, and had become a candidate for either nationalisation or takeover.

Research framework

It is the aim of this paper to present a brief analysis of the issues that faced Northern Rock during the latter half of 2007. The analysis is comprised of a review of the overall background, see above, resulting in a lack of funds in the wholesale credit markets, 'the credit crunch', and the effects of the reduction in retail confidence in Northern Rock which in turn led to a highly publicised run on that bank (BBC, 2007).

The approach to the analysis is centred on the use of System Dynamics (SD) and a current methodology within that discipline which was outlined by Sterman (Sterman, 2000). A description of that methodology is presented in Annex C to this paper. It is customary to apply SD to continuous simulations, simulations that flow in an analogue manner with little or no examination of single cases or events, however it should be noted that this simulation contains various discrete elements both as events modelled and in the treatment of individual variables; see (Richmond, 2004) (Sterman, 2000) (Pidd, 2004) for a discussion of continuous/discrete simulation.

Within the framework set out in the preceding paragraph and the methodology given in Annex C the design philosophy can be summarised as follows:

- Keep the simulation simple and where factors could be removed without compromise to the viability of the overall simulation this was done. There are good reasons for keeping things simple; principal among these is the tendency to chaotic behaviour of larger systems. Every variable removed reduces the complexity and therefore the tendency to chaos. It is therefore accepted that this simulation will be a compromise based on the need to produce both a simplification of reality and the need to include as much detail as is required to maintain empirical integrity.

- Where possible all data is grounded in empirical research and theory would only ever flow from this – rather than guide the simulation design. This is therefore a fundamentally interpretive research work as is most if not all simulation modelling (Gummesson, 2003) and the progression of thought is inductive in nature; "observations/findings >> theory" (Bryman & Bell, 2007, pp.14). Both quantitative and qualitative techniques are used, quantitative techniques driving the simulation model and qualitative judgement being used to construct and manipulate the model.

- The management simulator or interface (Annex E) was kept as simple as possible to enable this model to be used as a teaching aid both for SD and in financial systems (Größler, 2004), (Heat, 2007). Previous personal experience also suggests that it is very difficult to interpret complex simulation models and this is reflected in the literature (Howie et. al., 2000).

The remainder of this section focuses on the process of applying the research framework.

Phase 1

The problem scenario is to devise a model that incorporates the major factors which influenced the state of liquidity of the UK based Northern Rock bank (Foley, 2007), (Griffiths, 2007). Initial analysis of the problem scenario led to the conclusion that the liquidity crisis, which had developed in the wider wholesale credit market (see figure 1), was the key variable in determining the survival or otherwise, of Northern Rock as a commercial concern.

From the initial research process two particular aspects of the problem are identified; the lack of wholesale credit 'the credit crunch' and the loss of retail investor confidence. Possible levers which may affect a solution to either or both of these factors are examined. These levers have been identified as being of two broad types.

The first set are the internal levers that are available to the bank and its management without recourse to outside bodies and are the ability of the bank to 'shut up shop' closing its branches, shutting down its ATM network, taking the internet banking site off line and disabling access to their call centre the second internal lever is the ability of management to stop issuing new loans to its lender base thereby hoarding that liquidity rather than investing it (Croft, 2007b). Though there is some evidence that mortgage lending is dropping anyway as a result of general unease about the state of the bank (Croft, 2007a). The exact cause of this reduction in mortgage lending is not yet clear and could be internally driven; see model description for how this could be achieved. A third lever has also been identified which is the ability of Northern Rock to pay or cancel the proposed £59m dividend signalled in (Northern Rock, 2007) and due for payment in October 2007. The dividend has a minimal effect on performance and is retained only because it may have an effect on investor confidence and could perhaps have been used as a signal by Northern Rock to counter adverse publicity. For a discussion on dividends as signals see (Allen and Morris, 1998). The dividend payment is treated as a discrete event and as such raises some methodological issues see 'Research Framework' above.

The second set are the external levers available to those who have a stake in the business for purposes beyond that of just maintaining Northern Rock as a going concern. These could be labelled the regulators who wish both to stop the loss of confidence in the economy on a wider scale that could result from a banking failure and to forestall the possibility of contaminating the remainder of the UK banking sector; the so called 'contagion risk'. The regulators in this case are composed of Her Majesty's Treasury, the Bank of England which is the UK's central bank and 'lender of last resort' and finally the Financial Services Authority who are given responsibility for regulating the UK financial services industry. A description of the roles of each of these players, who are collectively referred to as the tripartite authority, is given in the Memorandum of Understanding between HM Treasury, the Bank of England and the Financial Services Authority (HM Treasury, 2006). There are two levers that have been identified as being available to the tripartite authorities; they are the issuance of guarantees to Northern Rock depositors to back their deposits with Northern Rock by government funds (a practical nationalisation of retail deposit accounts) and secondly a loan facility to enable Northern Rock to continue to fund its borrowing requirements.

This paper is centred on the financial environment surrounding Northern Rock plc, the tools it has to cope with that environment and the tools available to the tripartite authorities to influence the financial environment of Northern Rock. It is beyond the scope of this paper to model the structure or behaviour of the 'credit crunch' in any detail, see following paragraph, the internal machinations or philosophical determinants of why it might be worth saving a failing business or the internal details and processes of the tripartite authorities. The overall view of the tripartite authorities can be summed up by their position statement that it "must be noted, however, that it is neither possible nor desirable to design a regulatory system that removes the possibility of a bank ever failing" (HM Treasury, 2008) together with the steps they have taken to remove the possibility of Northern Rock failing.

A further constraint on scope for this paper was the lack of available reference sources. Much of the analysis for this work has been done from media sources rather than the more usual academic ones. This is in part due to the nature of the situation which is commercially sensitive and possibly embarrassing for the regulatory authorities as well as the lack of available academic papers on the subject. There is also the issue of confidence; would the regulators or other Northern Rock stakeholders release information that might suggest the bank's situation was very bad? There may also be a fear of contagion risk from releasing information that would lead other UK banks to further limit their lending.

The 'credit crunch' is widely reported as being rooted in the rise of sub-prime mortgages in the US; see glossary for definition. Sub-prime lending by Northern Rock is not seen as a significant factor in their performance, as at the reference date of June 2007, with figures for residential sub-prime lending being reported as 0.47% of total loans which is significantly below the industry average. Though there is some acknowledgement that this position is likely to worsen even a doubling in substantial arrears would still only have moved Northern Rock up to the UK average (Northern Rock, 2007). However this situation may be worth monitoring in the medium to long term, 2-10 years, and including in any longer term analysis.

There has been widespread reporting of the Northern Rock business model, lend long term, borrow short term, as being a significant factor in their 'failure' (Hill, 2007), (Hill and Betts, 2007), (Wolf, 2007). The simulation needs to cope with this business model and does so partly by the use of data to determine the flow of funds that are sourced either through the wholesale credit markets or, where this is not available, to those measures taken by the tripartite authorities to replace that lack of commercial funding with state backed funding (Farrell, 2007).

The role of interest rates in general and their effect on Northern Rock policy was examined. When short term rates differed from longer term rates this did have an effect on Northern Rock but not a significant one. Interest rates variations were not therefore considered relevant to this model. A sample of historic rates is included in Annex B for information.

The possibility of an equity related fundraising was not considered as a viable option for Northern Rock as they had largely kept the liquidity crisis under wraps until it manifested itself of its own accord. Any early attempt by Northern Rock to raise cash through equity issue would have raised eyebrows not to mention suspicions and any later attempt would have been unlikely to have met with much success as the truth about the financial position of the bank would have reduced the value of the release. Having said that, Societe General a French bank, did attempt to rescue itself, via its shareholders, with a substantial rights issue to cover a funding gap albeit from an entirely different root cause; this issue is not without its difficulties (Hollinger, 2008).

The time frame for this analysis is the six month period commencing July 2007 and within that overall time frame to allow analysis at both daily and monthly intervals. Choosing this time frame allows the modelling of events that occurred rapidly, over a period of days, 'the run on the bank', those that took place over a slightly longer period, 'liquidity drain', policy formation within the bank and tripartite authorities, and finally understanding the effects of applied policy in the slightly longer term.

Typical behaviour, reference mode, for this scenario is defined here as that which existed in the six month period leading up to end June 2007 (Northern Rock plc, 2007), (FSA, 2007 and 2008).

Phase 2

Given the results of phase 1 it has been possible to devise an overall causal map of the scenario described therein. Figure 6 illustrates the overall result of this analysis. Beginning with the hypothesis that the key to understanding the effects that the credit crunch had on Northern Rock rests on a liquidity crisis within the bank this becomes central to the initial modelling process. This hypothesis is motivated by the assertion that liquidity is necessary for survival and other business objectives can only be realised if the business survives.

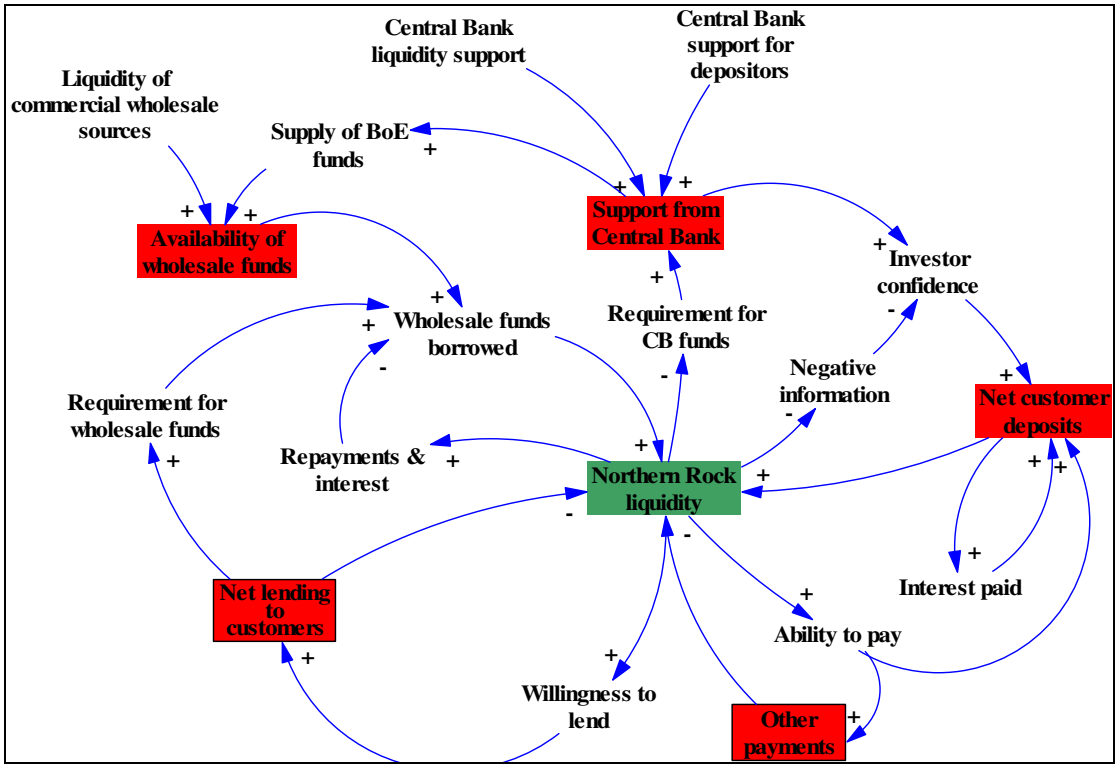

Figure 6: Causal map of Northern Rock situation

From the literature it has become obvious that although there is a loop between Northern Rock and the 'credit crunch' (availability of wholesale credit in figure 6) in general the effect that Northern Rock has on the wider lack of credit is not significant this effect is acknowledged here but removed from the causal map. If this paper were to examine the effect of the UK banking sector as a whole then this would have a significant effect on wholesale credit and would be a viable loop on that causal model.

Business model risk (or policy) within Northern Rock has a direct influence on that banks liquidity and it has been determined that this needs to be included in the overall structural view of the system; this is indicated in figure 6 as 'willingness to lend', 'wholesale funds borrowed' and within the modelling of 'Availability of wholesale funds'.

Net retail deposits have an effect on bank liquidity and in particular the lack of confidence which spread rapidly within Northern Rock's customer base leading to a run on the bank (Walsh, 2007). This process becomes a reinforcing loop with lower confidence leading to decreasing net deposits (withdrawals) leading to decreased liquidity. As with the previous two factors this aspect of the model is accounted for in figure 6.

The fourth major factor to play a role in the Northern Rock scenario is support from the tripartite authorities – represented as the 'Central Bank' in figure 6. The reason why the authorities are represented as a bank is that it is the Bank of England that implements many of the policies that are agreed between the other members of the triumvirate and given that the workings of the tripartite authority are beyond the scope of this paper the Central Bank seems the most appropriate representation. There has

been some criticism of the authorities handling of their regulatory responsibilities (Brown, 2008).

Distilling the four aspects above it is possible to determine that from the point of view of maintaining Northern Rock's liquidity the 'credit crunch' is to be a given and not explained further other than that its existence or otherwise is a prime motivator for the entire crisis. See (BBC News, November 2007) for a straightforward explanation.

In addition to these dynamic flows there is one further flow which represents the 'other expenses' of the bank, these are pretty straightforward and represent the semi-fixed costs such as heating, lighting and shareholder dividends. The latter was due for payment but cancelled by Northern Rock in October 2007.

Apart from the 'credit crunch' in order to explain the dynamic behaviour of the system and its potential solutions it emerged that the motivating factors and those offering a potential solution are; Internal management policy, Central Bank policy and Depositor confidence. If we treat these as the hypothetical keys to the solution box then these are the aspects which it is necessary to turn to in order to provide solutions. Much of the dynamic behaviour of the system is governed by the application of policy inputs and in the absence of these the liquidity levels of Northern Rock would be expected to continue growing, as was the case up until June 2007. Additionally as much of the reference mode behaviour is defined using actual data at a point in time then it would be assumed that growth would be linear.

All phases of this project have been iterative in nature and within those iterations several variables were considered but not included, at least not directly, a sample of those considered but rejected is given in the list below.

- The effect of interest rates which due to the short time-scale of the simulation (6 months) rates were not considered relevant. Additionally lending rates (new and variable rate loans to customers) could be adjusted to reflect wholesale market rates.
- The extent and effect of negative publicity which is a driver for the retail run on the bank was rejected primarily due to resource constraints and lack of information. The run on the bank is modelled through a fall in investor confidence which manifests itself as a reluctance to deposit and a tendency to withdraw funds.
- Lack of information amongst depositors about existing deposit guarantee schemes, depositors were guaranteed 100% of their first £2,000 and 90% of the following £33,000. Manipulation of a lever that increased/decreased awareness of existing deposit guarantee schemes might have shed some light on how communication facilitated the retail run on the bank.
- Reconstruction of the NR business model which could not have been achieved within the timescale of the simulation
- Fixed costs such as staff costs, buildings, etc…Were included but no substantial change in these costs was available within the time scale of the simulation. Though notably this appears to be on the agenda for restructuring the nationalised Northern Rock.

- Equity release through rights issue or other means – rejected because it would have been unlikely to have been successful due to the state of the underlying business

If actual data were not used for net flows then a generic causal loop of a net flow would look something like figure 7 below.

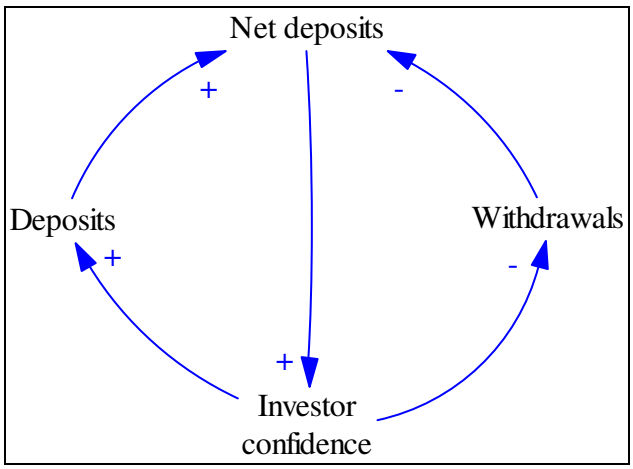

Figure 7: Causal map of net deposits

Phase 3

It is a founding principle of System Dynamics that delays may be present in any system which will in turn produce behaviour that is complex and at times confounding in nature (Howie et. al., 2000), having said that there are no delays hard-wired into this simulation model. However as this model was designed to be used as a management flight simulator there are places other than within the SD model that delays can be incorporated. Figure 8 below shows the structure of a Management flight simulator and the points at which delays can occur.

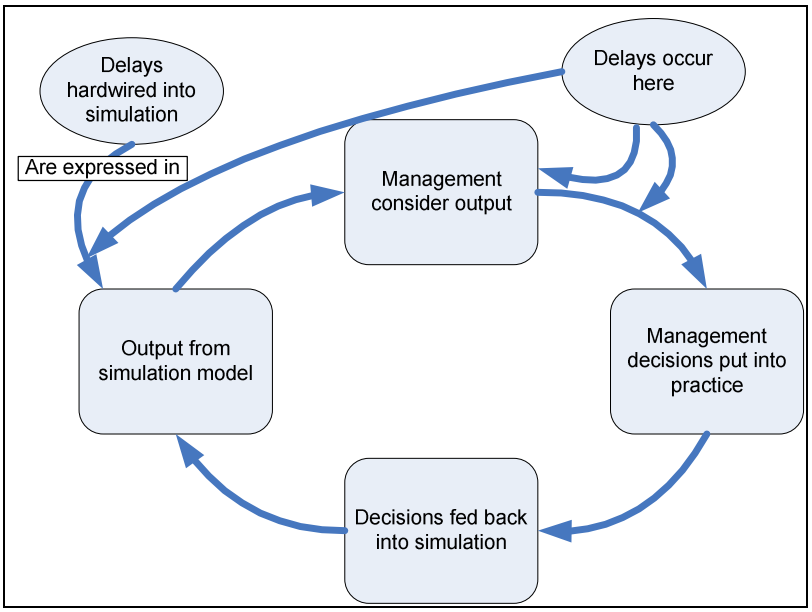

Figure 8: Delays in management simulators outside the SD model

The points at which delays are present in a management flight simulator are: within the model, between model running and output production, time for management to make a decision and finally time to implement that decision. In short a management flight simulator will most likely have delays built into its structure even if these are not present in the SD model

In parallel with the modelling of delays in management flight simulators feedback structures also exist within the flight simulation system that are outside of the hard wired model. Referring to figure 8 above it can be seen that the entire structure of the flight simulator is a feedback loop.

Phase 3 involves the construction of stock and flow models which are in line with the previous analysis. The graphical representation of the computer model is illustrated in figures 9, 9a below.

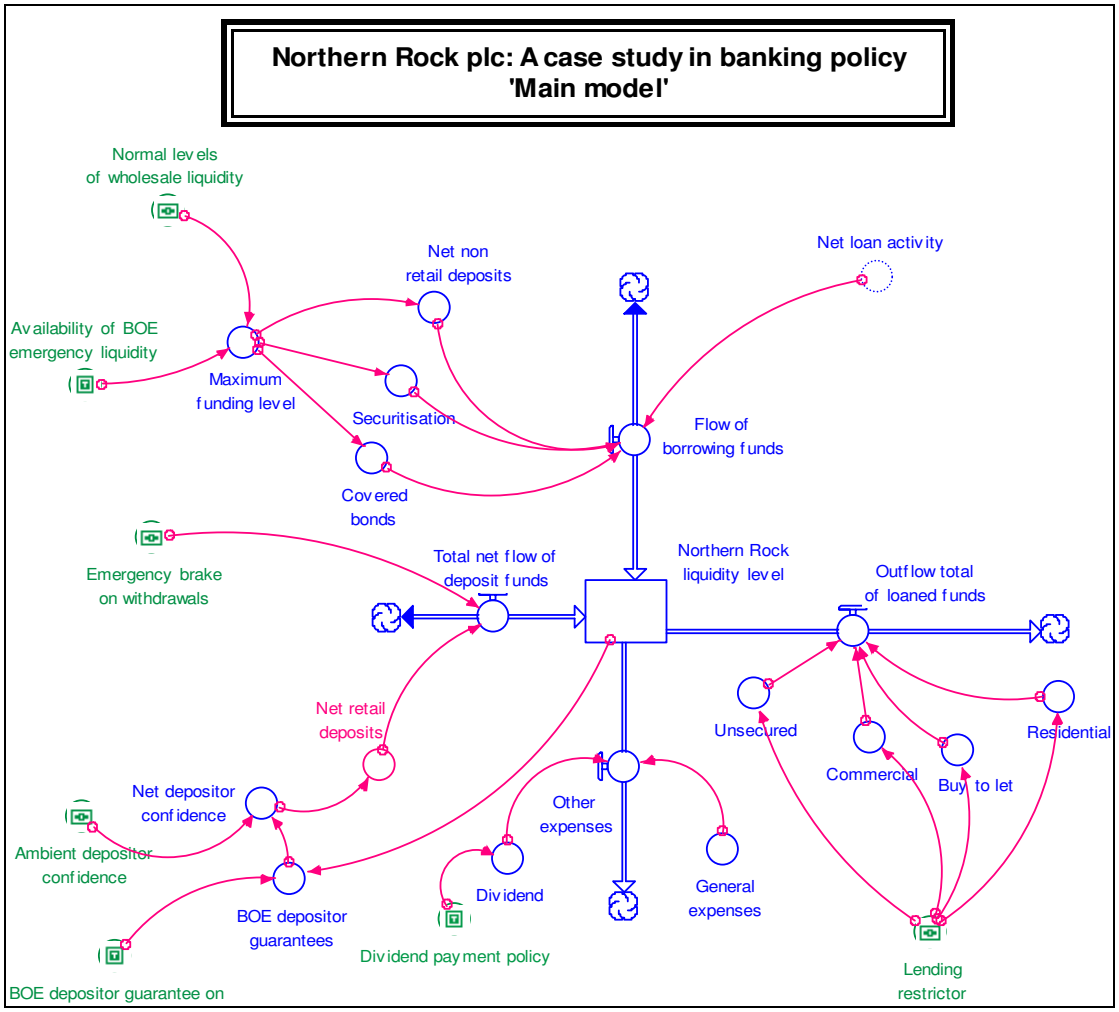

Figure 9: Stock and flow model of Northern Rock liquidity influences

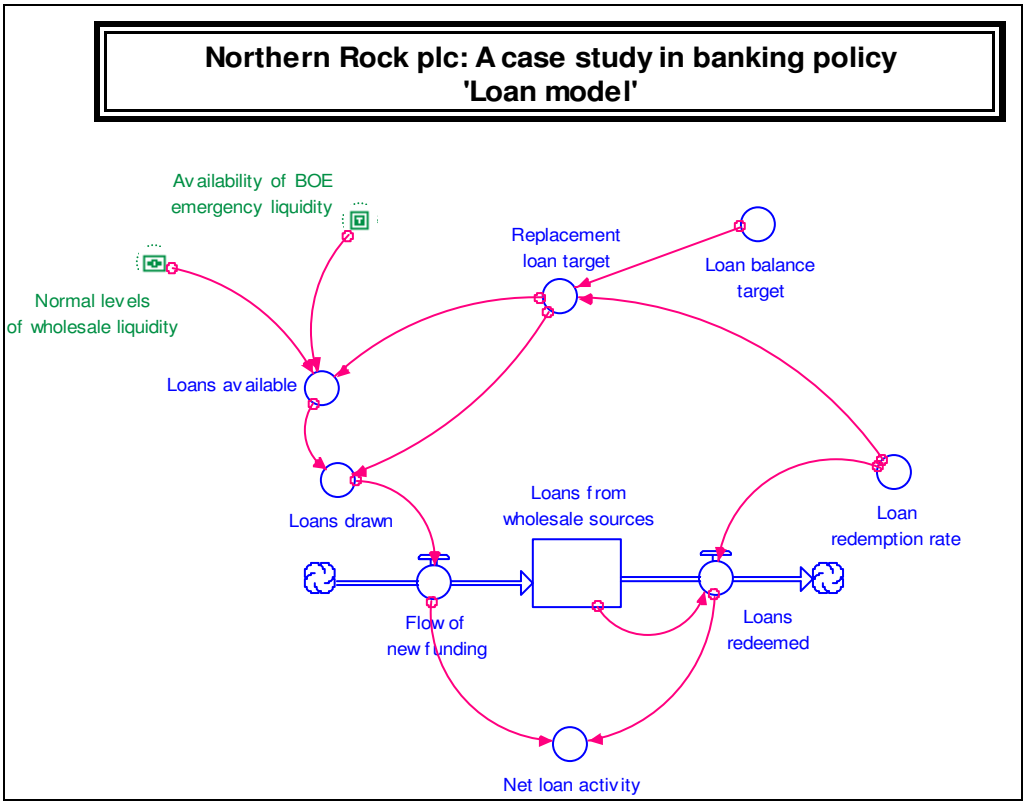

Figure 9a: Stock and flow model of Northern Rock lending behaviour

The equations for this model are reproduced in Annex D and the interface level in Annex E, the causal model for this paper (figure 6) was developed in Vensim PLE and the Stock and Flow model (figures 9,9a, Annex D and E) in Stella 8.1.1.

Parameter values have been calibrated from existing data where possible (Northern Rock, 2006, 2007) and where unavailable were estimated from other sources (Bank of England, 2007), (FSA 2007, 2008).

The interface is reproduced at Annex E and takes due regard of those factors identified in (Howie et. al., 2000). It is also noted that the application being developed is created in an off-the-shelf System Dynamics software package and scope for development of the interface is limited to those features supplied by the software.

The model has been tested using sensitivity analysis, via the interface at annex E, and has been found capable of generating results close to those occurring in the real world. Although it is true that any model is a simplification of reality and constraints of time and resource do not enable a full description of all possible variables or their relationships; no significant factor appears to be absent.

Phase 4

The model conforms with the reference mode and produces a good approximation of what would have occurred had the reference mode continued to be the systemic behaviour over the period modelled. Figure 10 below illustrates this.

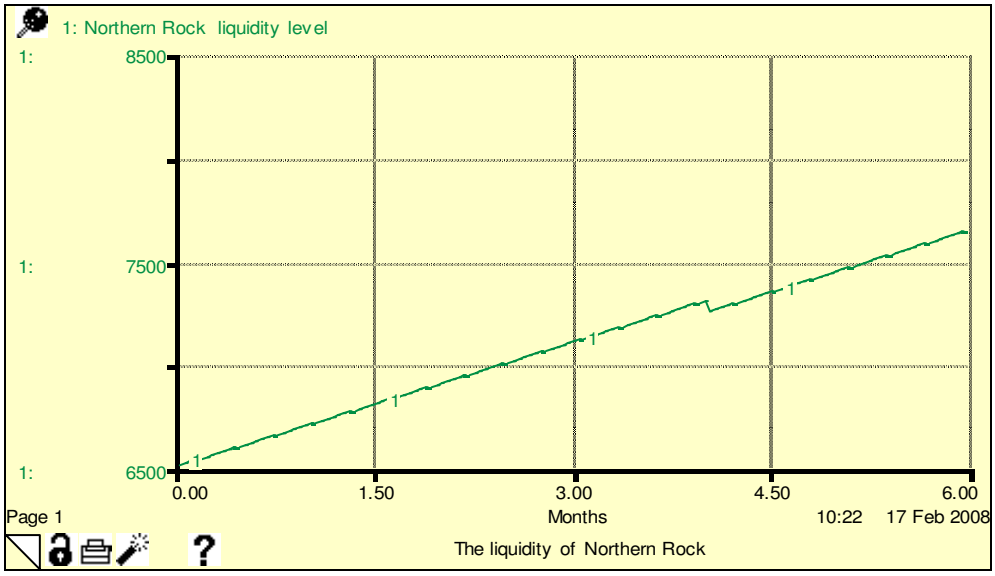

Figure 10: Reference mode modelled over the period

Figure 11 below illustrates the effect of a wholesale market 'credit crunch' with no attempt to correct for it over the six months being modelled. Northern Rock is effectively insolvent at simulation time 0.83 (approximately 3 weeks).

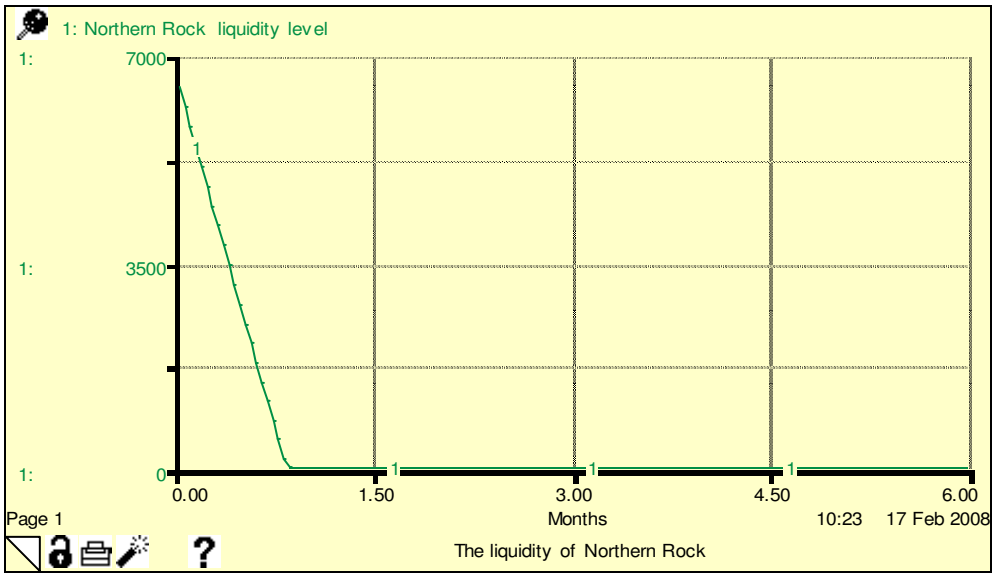

Figure 11: Performance of Northern Rock in an unmitigated 'credit crunch'

Figure 12 below illustrates the effect of a credit crunch and a complete collapse in investor confidence leading to a run on the retail bank; Northern Rock becomes entirely insolvent at simulation time 0.79 (again about 3 weeks into the simulation).

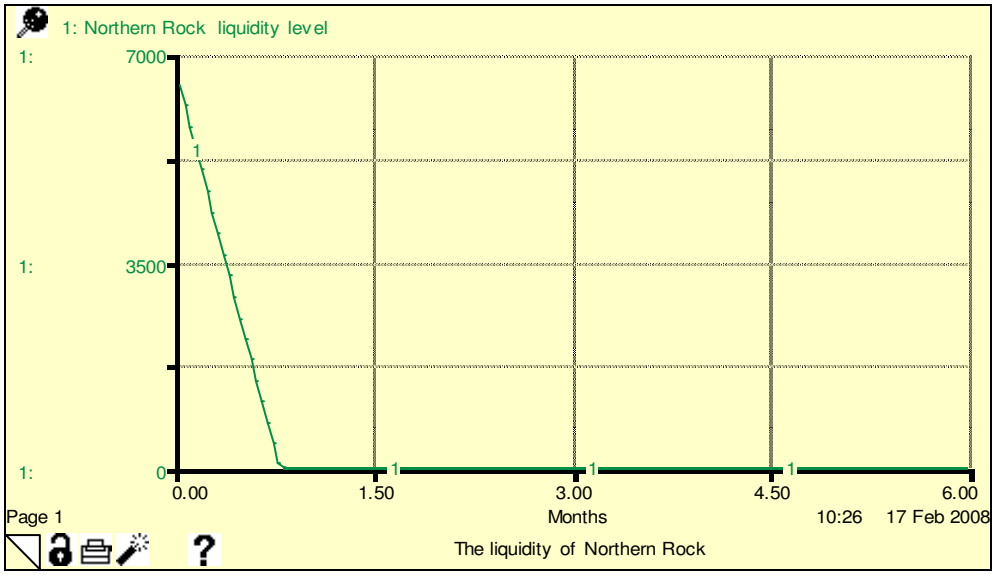

Figure 12: Performance of Northern Rock in an unmitigated 'credit crunch' and with an unaddressed collapse of consumer confidence

From the two scenarios presented immediately above (figures 11 and 12) it can be seen that the model produces realistic results in the case of unaddressed problems.

Figure 13 below illustrates the effect of a removal of wholesale credit and the total loss of depositor confidence with in addition all possible Bank of England measures taken. The bank remains fairly liquid though it is in a state that could be termed operational nationalisation with the Bank of England supplying its wholesale credit needs and backing all retail deposits with state funds.

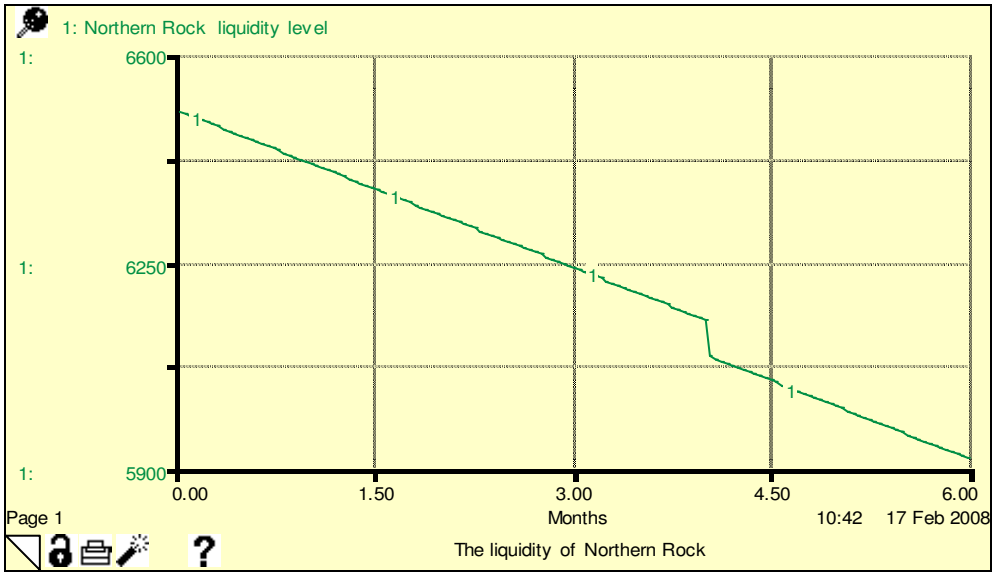

Figure 13: Performance of Northern Rock in a 'credit crunch' with a 'run on the bank' and all Bank of England mitigating measures in place

It can be seen from figures 10, 11, 12 and 13 that the model, though straightforward, is sensitive to parameters and amenable to a wide range of behavioural simulation.

Phase 5

The model was tested to evaluate several specific hypotheses, these are:

H0: That in the absence of any policy or external changes Northern Rock would continue to behave as it had in the six months to June 2007.

H1: That in the presence of a 'credit crunch' Northern Rock would become insolvent if no correcting actions are taken.

H2: That in the presence of a 'credit crunch' Northern Rock could maintain solvency through the use of the internal levers available to it.

H3: That in the presence of a 'credit crunch' and total absence of investor confidence Northern Rock would become insolvent if no correcting actions are taken.

H4: That in the presence of a 'credit crunch' Northern Rock could maintain solvency through the use Bank of England emergency liquidity funding.

Definitions and scope:
For the purposes of testing insolvency means that liquidity falls below 50% of the level available at the start of the simulation (£6504.9m at end June 2007 (Northern Rock, 2007, p.20)) and all hypotheses are time limited to the simulation period; start July to end December 2007.

Testing of these hypotheses was carried out and the results are shown below or where applicable referred to in the text.

Testing H0

Testing under H0 was carried out and could be defined as reference mode an illustration of the effect on liquidity at Northern Rock is given in figure 10 above Northern Rock continued to grow in a linear fashion, as would be expected, given no change in conditions from those in existence at end June 2007. The conclusion is that H0 is in accord with simulated results.

Testing H1

Testing under conditions of H1 was carried out and an illustration of their effect on liquidity is given in figure 11 above. As can be seen from figure 11 Northern Rock showed a linear decline in its liquidity into insolvency and although not actually entirely without liquidity, a £12m residual balance remains due to depositor and lending flows, it was insolvent according to the assumptions given in the definitions and scope, above, at the end of the simulation. The conclusion is that H1 is in accord with simulated results.

Testing H2

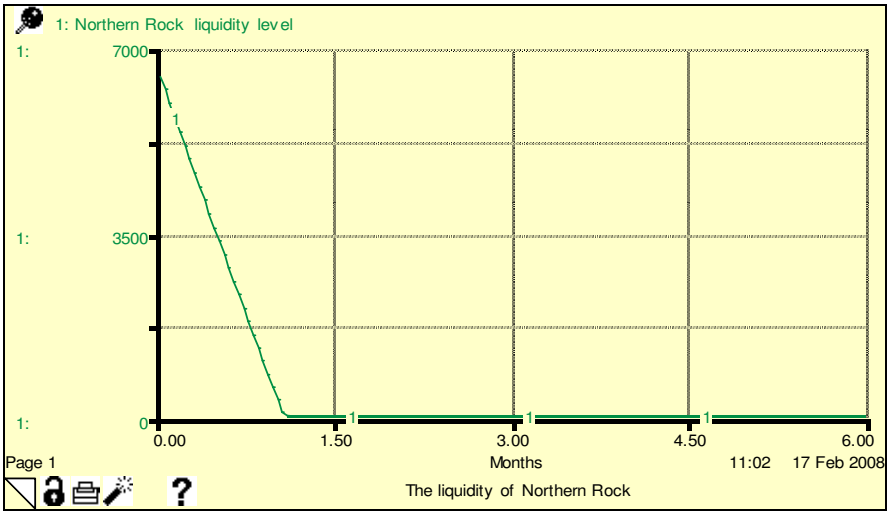

Figure 14: Results of testing under conditions of H2

Figure 14 illustrates the output from a simulation where the 'Lending restrictor' was applied at the 0% level, the emergency brake on withdrawals was fully applied and the credit crunch was in operation. Application of the emergency brake on withdrawals reduces the amount of net retail deposits by a proportionate amount; in this case nil. The application of the 'Lending restrictor' simulated an effective halt to the amount lent to customers and amounted to a hoarding of liquidity. This latter point could be an important indicator of how retail credit contagion would propagate i.e. if all banks did this it would cause a credit crunch for retail customers (Haycock, 2008).Northern Rock had nil liquidity at simulation time 1.04 (approximately one month and one day into the simulation). The conclusion is that H2 is not in accord with the simulated results.

Testing H3:

Results of testing under conditions of H3 are illustrated in figure 12. They illustrate the complete absence of liquidity within Northern Rock. The conclusion is that H3 is in accordance with the modelled results.

Testing H4:

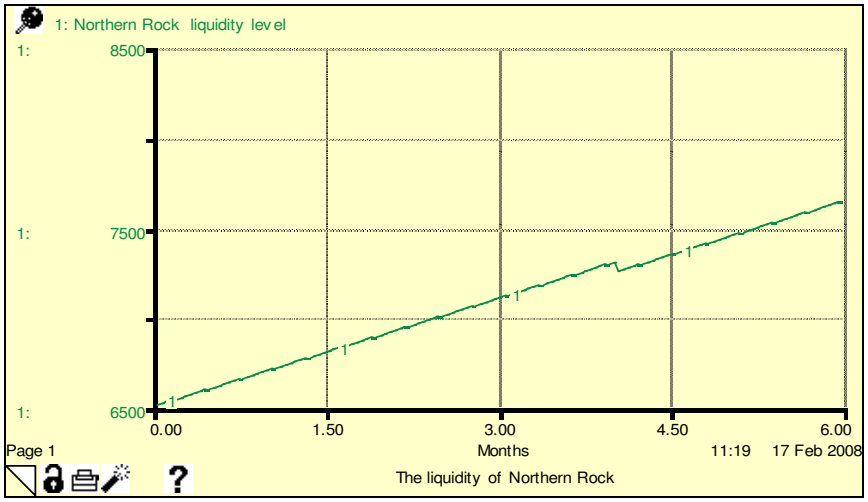

Figure 15: Results of testing under conditions of H4

Figure 15 illustrates the output graph from testing under hypothesis 4. This demonstrates the effect of the introduction of Bank of England emergency liquidity funding. In effect this scenario simulates the replacement of commercial funding with Bank of England funding. Liquidity grows as per the reference mode. The conclusion is that H4 is in accord with the model results.

Supplementary scenario

In the hypothesis testing carried out above management and regulators have been fairly docile; setting policy at the simulation outset and letting that continue until simulation end. This supplementary scenario shows the results of a more active management approach. At the outset of the simulation the wholesale 'credit crunch' is active, set to 50%, and the investor confidence level is set to zero. All other parameters are as per reference mode any changes are made at the end of each month. The first month is run with the set up as described above and the subsequent series of actions is taken:

Month 2:
Lending restrictor is set to 0%
Month 3:
Bank of England depositor guarantee is set to on
Month 4:
Bank of England emergency liquidity is set to on
Month 5:
Lending restrictor is set to 50%
Month 6:
Lending restrictor is set to 80%

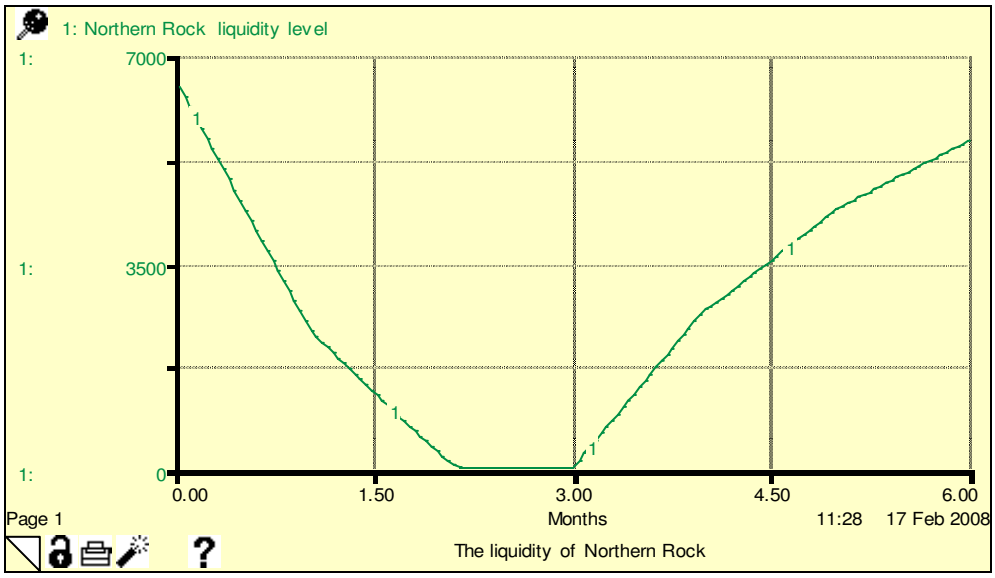

Figure 16: Results of testing under conditions supplementary scenario

Looking at the results of the actions taken in the supplementary scenario and shown in figure 16 it can be seen that we have a much more dynamic (and realistic) progression of events. This shows a manipulation of various levers at various points, implying a degree of co-operative action, by both Northern Rock and the Bank of England to

return the bank to a 'business as usual' stance. The turning point for this scenario is at the start of month 4 when the Bank of England steps in.

Conclusions

General

From an analysis of the hypotheses presented in Phase 5 above it is clear that an amalgam of both internal and external levers are best used together to maintain both Northern Rock as a going concern and remove the need to restructure the entire business. Teamwork amongst the tripartite authorities and Northern Rock is desirable as the most effective solutions were achieved using co-ordinated application of both internal and external levers. Neither internal nor external levers were effective on their own for maintaining Northern Rock plc as a going concern this rests on the assumption that Bank of England emergency liquidity cannot remain in perpetuity.

An active approach as outlined in the supplementary hypothesis is recommended as this approach achieved the most responsive and solution oriented means of dealing with the problems facing Northern Rock.

Contagion risk is addressed in phase 5, H2 and a tentative explanation for its existence, individual institutions hoarding liquidity, is put forward.

That this model is one interpretation of the system which results in the dynamic variation in Northern Rock liquidity and does not purport to be 'the' correct solution or description of that system.

Automatic triggering of state guarantees or funding could be developed within a variant of this model, here they are activated via the interface as policy decisions, which could define an overall response framework for particular scenarios. To define these as automatic within this model would have resulted in an unrealistic simulation. This is identified as an area for possible further work.

It is concluded that a variant of this model could be used to model the UK, or another national, banking system with a minimum of further work.

It is concluded that areas of detail within the model such as the 'credit crunch' and the operation of the credit loss propagation risk could be given a more detailed treatment to effect a more comprehensive model; again with minimum extra work

Methodological

Methodological conclusions drawn here are:

1. That this model is largely linear in functionality due to the presence of data informing the results, for example when defining monthly receipts and payments as a function of the flows from the previous six months. It only exhibits dynamic complexity when actively managed as illustrated by the supplementary model and graphed in figure 16; which is simple and realistic.

2. There is the conclusion based purely on the construction of the stock and flow model that this simulation in neither wholly continuous in nature nor is it wholly discrete in nature. It contains discrete events such as the dividend payment and discrete behaviour as in the construction of various system components using 'If…THEN..ELSE…' logic. It is also worth noting that as the simulation was run on a digital computer and no truly continuous simulation can be created on same this is a best attempt to model a continuous simulation given the available hardware (Pidd, 2004, pp. 26).

3. That this simulation is quite basic with just a few controls but seems to be broadly capable of representing the actual situation of Northern Rock in the latter part of 2007, the intrinsic behaviour and inputs to its system that determine its liquidity status.

4. That the model produced could be a useful teaching/learning tool for those involved in the teaching or study of finance and for those involved in the teaching/study of System Dynamics. There are some reservations and limitations to this conclusion and these are accurately summarised in (Größler, 2004), (Heat, 2007).

Glossary

ABS – Asset Backed Security

Basis Points – Hundredths of a percent; usually applied to interest rates changes

CDO – Collateralised Debt Obligations

CMBS – Commercial Mortgage Backed Security

CML – Council of Mortgage Lenders

Contagion risk – The risk that a particular set of circumstance will spread within the community in which it arose. In this case a risk that the credit crunch and loss of investor confidence would spread from one bank to the UK banking sector.

Libor – London InterBank Offered Rate

RMBS – Residential Mortgage Backed Security

Sub-prime – "Less than first"; for example a sub-prime borrower in the UK is often accepted as those in 'adverse credit' i.e. previously had significant arrears and/or have had County Court Judgements, been bankrupt or have entered into an IVA. In the US the definition of a sub-prime borrower is wider including those with high loan to value and loan to income multiples. (Bank of England, October 2007)

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Annex A

Abridged financial history of Northern Rock

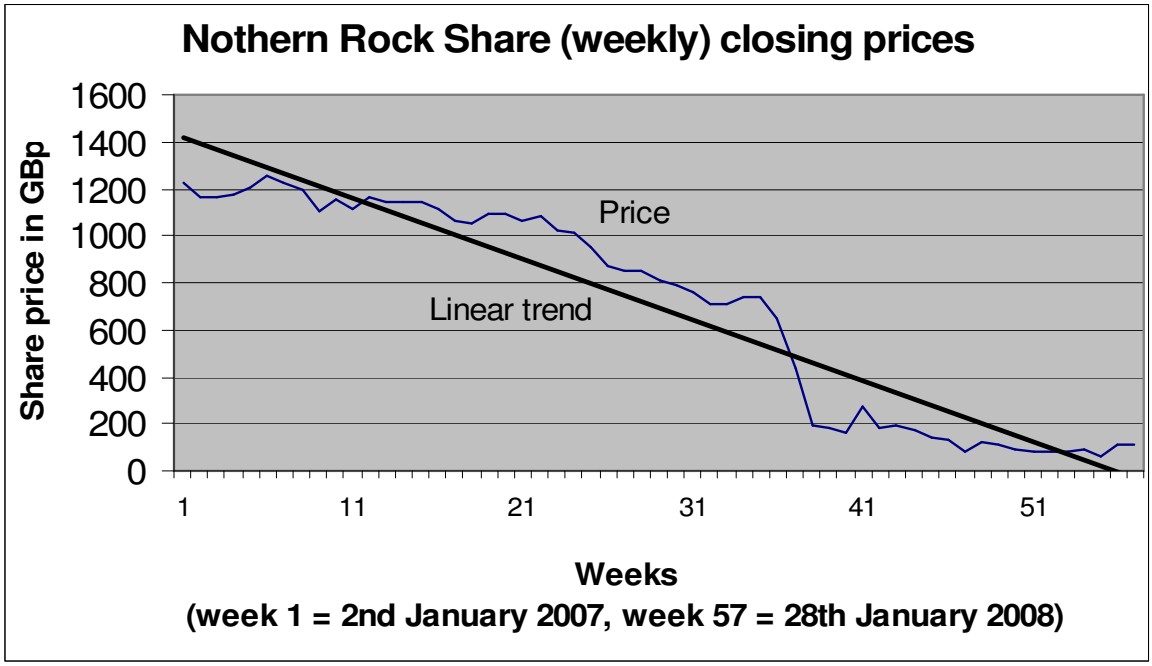
		2002	2003	2004	2005	2006
Net interest income	£m	391.2	450.7	466.9	752.3	849.1
Other income and charges	£m	169.8	209.0	252.3	129.0	152.8
Net hedge ineffectiveness and other unrealised fair value gains and losses	£m	–	–	–	(56.4)	14.9
Total income	£m	561.0	659.7	719.2	824.9	1,016.8
Operating expenses – ongoing	£m	169.8	194.5	218.3	249.4	277.5
Operating expenses – non-recurring[1]	£m	2.3	5.6	–	–	–
Operating expenses – amortisation of goodwill	£m	1.5	3.6	–	–	–
Covenant to The Northern Rock Foundation	£m	16.3	19.3	21.6	24.7	31.4
Impairment losses on loans and advances	£m	43.1	48.7	48.5	56.6	81.2
Amounts written off fixed asset investments	£m	2.6	1.4	(4.5)	–	–
Profit before taxation	£m	325.4	386.6	435.3	494.2	626.7
Income tax expense	£m	96.5	112.2	125.8	144.9	183.7
Profit for the year	£m	228.9	274.4	309.5	349.3	443.0
Attributable to:						
Appropriations	£m	–	–	–	48.6	48.5
Profit attributable to equity shareholders	£m	228.9	274.4	309.5	300.7	394.5
Total assets[2]	£m	41,875	51,944	64,881	82,709	101,011
Growth in total assets	%	35	24	25	28	22
Average interest earning assets	£m	36,036	46,435	57,071	72,730	88,788
Mean assets	£m	36,482	46,909	58,415	73,710	91,860
Retail deposits	£m	15,336	16,343	17,290	20,104	22,631
Equity shareholders' funds	£m	1,165	1,340	1,538	1,576	2,175
Total capital ratio	%	15.5	14.3	14.0	12.3	11.6
Tier 1 ratio	%	9.1	9.0	8.7	7.7	8.5
Gross lending	£m	12,584	17,315	23,342	26,879	32,989
Net lending	£m	6,697	8,514	12,932	14,555	16,621
Loan balances acquired	£m	1,544	–	–	–	–
Increase in retail balances	£m	773	1,007	896	2,809	2,527
Retail balances acquired	£m	1,193	–	–	–	–
Increase in profit after tax[3]	%	18	20	n\a	11	31
Net interest margin	%	1.09	0.97	0.82	1.03	0.96
Total income : mean assets	%	1.54	1.41	1.23	1.12	1.11
Operating expenses[3]: total income[4]	%	30.3	29.8	30.4	30.2	27.3
Operating expenses[3]: mean assets	%	0.47	0.41	0.37	0.34	0.30
Impairment charge as % of mean advances to customers	%	0.19	0.19	0.10	0.09	0.10
Post-tax return on mean equity[5]	%	20.8	21.9	21.6	20.3	23.5
Post-tax return on mean risk weighted assets[5]	%	1.43	1.49	1.45	1.23	1.38
Earnings per Ordinary Share	p	55.4	66.6	74.9	72.5	94.6

1. Non-recurring costs represent
   2002 – non-recurring costs incurred in relation to the acquisition of the banking subsidiaries of Legal & General
   2003 – non-recurring costs incurred in relation to the closure of certain branches
2. Total assets for 2002 and 2003 represent assets under management, which comprised total balance sheet assets plus non-recourse finance. There is no difference between total assets and assets under management from 2004
3. Before non-recurring costs
4. Before surplus on sale of credit card portfolio of £7.3 million in 2003
5. Post-tax returns are calculated by reference to profit attributable to equity shareholders

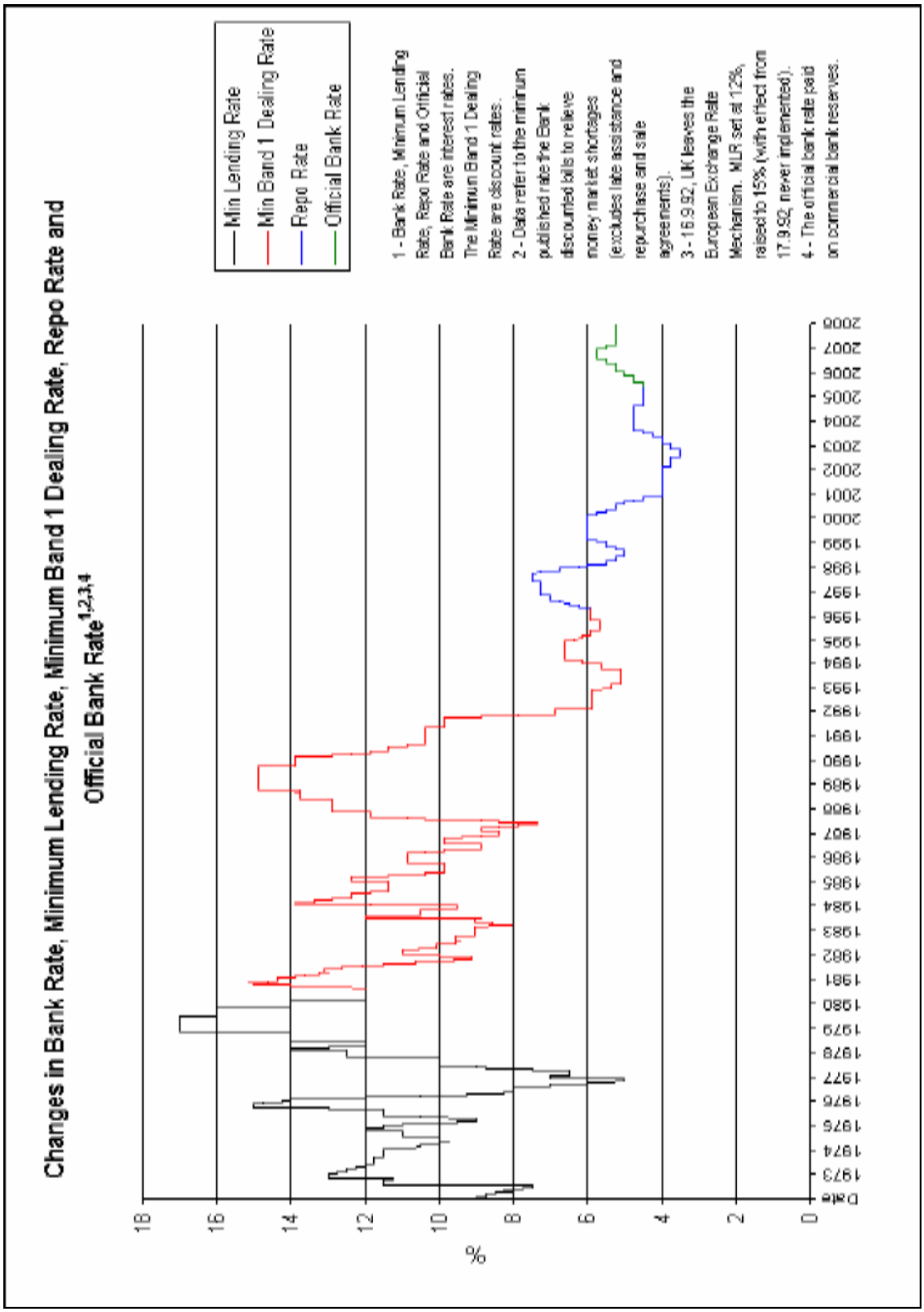
Source: Northern Rock Annual Report and Accounts 2006

Annex B

Share price data



Northern Rock share price January 2007 to January 2008



Historic interest rates, source Bank of England,
http://www.bankofengland.co.uk/statistics/rates/baserate.pdf

Annex C

Methodology

An adapted version of Sterman's description of the Systems Dynamics modelling process is shown in the table below, this is the methodology used in this analysis.

Phase 1 - Problem Articulation	Structuring the problem; determining the main variables, bounding the scope; specifying the time frame; defining the reference mode – 'typical' behaviour.
Phase 2 - Formulation of dynamic hypothesis	Develop maps/causal loop/influence diagrams of the relations between the factors; identify the main feedback structures; generate hypotheses explaining the behaviour in terms of the feedback processes.
Phase 3 - Formulation of simulation model	Generate a representation in terms of stocks and flows; estimate all necessary relationships and parameter values; develop a computer model and test for consistency.
Phase 4 – Testing and validation	Comparison with reference mode; robustness under extreme conditions; sensitivity to parameters; initial conditions.
Phase 5 – Using the model – Policy design and evaluation	Specify possible scenarios; develop alternative strategies and policies; do what-if analyses; check sensitivity and interaction of policies.

Outline of a System Dynamics methodology (Sterman, 2000)

Annex D

Equations for the stock and flow model

accumulated__net_lending(t) = accumulated__net_lending(t - dt) +
(Accumulated__lending) * dt
INIT accumulated__net_lending = 0

INFLOWS:
Accumulated__lending = Net_loan_activity
Loans_from__wholesale_sources(t) = Loans_from__wholesale_sources(t - dt) +
(Flow_of__new_funding - Loans__redeemed) * dt
INIT Loans_from__wholesale_sources = 80513

INFLOWS:
Flow_of__new_funding = Loans_drawn
OUTFLOWS:
Loans__redeemed = Loans_from__wholesale_sources/Loan__redemption_rate
New_loan__accumulator(t) = New_loan__accumulator(t - dt) + (acquired) * dt
INIT New_loan__accumulator = 0

INFLOWS:
acquired = Flow_of__new_funding
Northern_Rock__liquidity_level(t) = Northern_Rock__liquidity_level(t - dt) +
(Total_net_flow_of__deposit_funds + Flow_of__borrowing_funds -
Outflow_total__of_loaned_funds - Other__expenses) * dt
INIT Northern_Rock__liquidity_level = 6505

INFLOWS:
Total_net_flow_of__deposit_funds = if Emergency_brake__on_withdrawals > 0
then
Emergency_brake__on_withdrawals*Net_retail__deposits
else
Net_retail__deposits
Flow_of__borrowing_funds =
Covered__bonds+Securitisation+Net_non__retail_deposits+Net_loan_activity
OUTFLOWS:
Outflow_total__of_loaned_funds = Buy_to_let+Commercial+Residential+Unsecured
Other__expenses = Dividend+General__expenses
Total_deposits(t) = Total_deposits(t - dt) + (Deposited) * dt
INIT Total_deposits = 0

INFLOWS:
Deposited = Total_net_flow_of__deposit_funds
Total_lending(t) = Total_lending(t - dt) + (Loaned) * dt
INIT Total_lending = 0

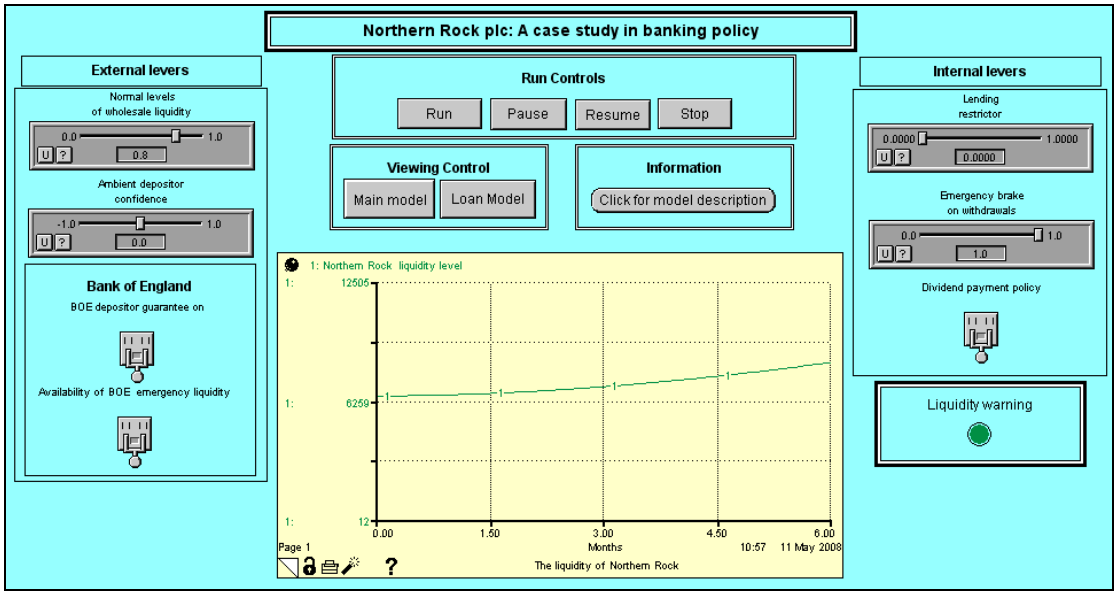
INFLOWS:
Loaned = Outflow_total__of_loaned_funds
Total_market__borrowing(t) = Total_market__borrowing(t - dt) + (Borrowed) * dt
INIT Total_market__borrowing = 0

INFLOWS:
Borrowed = Flow_of__borrowing_funds
Total_other_expenses(t) = Total_other_expenses(t - dt) + (Expenditure) * dt
INIT Total_other_expenses = 0

INFLOWS:
Expenditure = Other__expenses
Ambient_depositor__confidence = 1
Availability_of_BOE__emergency_liquidity = 1
BOE_depositor_guarantee_on = 1
BOE_depositor__guarantees = if Northern_Rock__liquidity_level < (6505/0.5) and
BOE_depositor_guarantee_on
then 1
else 0
Buy_to_let = (899/6)*Lending__restrictor
Commercial = (91/6)*Lending__restrictor
Covered__bonds = (2194/6)*Maximum__funding_level
Dividend = if (Dividend_payment_policy)
then pulse(59,4,0)
else 0
Dividend_payment_policy = 1
Emergency_brake__on_withdrawals = 0
General__expenses = (153.2/6)
Lending__restrictor = 1
Loans_available = Replacement__loan_target*
min(Availability_of_BOE__emergency_liquidity+Normal_levels__of_wholesale_liq
uidity,1)
Loans_drawn = min(Loans_available,Replacement__loan_target)
Loan_balance__target = 80513
Loan__redemption_rate = 12
Maximum__funding_level =
min(Availability_of_BOE__emergency_liquidity+Normal_levels__of_wholesale_liq
uidity,1)
Net_depositor__confidence =
min(BOE_depositor__guarantees+Ambient_depositor__confidence,1)
Net_loan_activity = Flow_of__new_funding-Loans__redeemed
Net_non__retail_deposits = ((2509/6)*Maximum__funding_level)
Net_retail__deposits = (Net_depositor__confidence*(1734/6))
Normal_levels__of_wholesale_liquidity = 1
Replacement__loan_target = Loan_balance__target/Loan__redemption_rate
Residential = (9170/6)*Lending__restrictor
Securitisation = (5632/6)*Maximum__funding_level
Unsecured = (554/6)*Lending__restrictor

Annex E

Interface to the model



Interface in Stella 8.1.1