

Global financial crisis: Which are the consequences for FX management by Central Banks in an Insurance Perspective?

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1. Introduction

A form of best practice has developed with regard to monetary policy with an inflation target. The monetary policies applied by several central banks, as well as academic research, have played a central role in this development.² When it comes to the central banks' management of financial assets, however, there is not the same clear consensus on what is meant by best practice.

With floating exchange rates it is important to stress that FX reserves are needed for several reasons: foreign exchange interventions, emergency liquidity assistance to banks in financial distress, and international commitments (IMF, G10). When there is a financial crisis, holding FX reserves for emergency liquidity assistance is probably the most important motive.

The traditional analysis model is based on the assumption that the central bank's own holdings of financial assets provide the only alternative when an acute need for foreign currency arises.

For a central bank with access to international financial markets and credit lines with other central banks and international organisations, this model is in some sense outdated and is in fact hardly used by modern central banks in practice.

The objective of this paper is to discuss the application of alternative models, based on contingent claims analysis, against the background of recent trends and the financial crisis.

Section 2 gives an outline of the system for the management of financial assets in industrial countries and emerging market countries with inflation targets, at the same time as developments in a number of other countries are also considered. Trends in recent years are

¹ I am grateful for the opportunity to draw on preliminary work by Dale Gray and Andrea Maechler on the FX Reserve Adequacy in Sweden. I am also grateful to Jaewoo Lee for providing Matlab code and to Peter Sellin for research assistance. The views expressed are my own responsibility and are not to be regarded as representing the view of the Executive Board of the Riksbank.

² See, for example, Svensson (2007) "Inflation Targeting," in The New Palgrave Dictionary of Economics, 2nd edition, edited by Larry Blum and Steven Durlauf.

discussed, as well as the conceivable effects of the current financial crisis on asset management. This is followed by an account of the factors that explain the size of the foreign currency reserve according to the academic literature.

Section 3 studies new models based on contingent claims analysis and modern insurance thinking, with applications to Swedish data. The first methodology, developed by Gray and Maechler (2008), uses risk adjusted balance sheets of the banks and the sovereign in order to study the potential for FX liquidity support to financial institutions in a crisis.³ The second methodology, developed by Lee (2008), bring forward the insurance motive for holding international reserves.⁴ In his model, the overall insurance level is affected by the central bank's commitments. The percentage of the overall insurance that needs to be retained as own financial assets or that can constitute external insurance is affected by the expected levels of return and risk for the foreign currency reserve, and is determined endogenously in the model. Section 4 draws some general conclusions.

2. An international review⁵

In this section, we first briefly review the foreign currency reserve management of the central banks. We go on to discuss the consequences of the current financial crisis, which began in 2007 and is still continuing. Finally, we draw a number of lessons for asset management from various international experience.

Foreign currency reserve management at the central banks

The tasks of the central banks with regard to price stability and the stability of the financial system are similar around the world. These tasks are the most important factors that the central banks take into account when they make decisions about their financial assets. Being ready and prepared to intervene if necessary is usually the most important requirement, which means that the assets must be highly liquid.

Although having access to liquidity in foreign currencies is the primary objective of the management of the foreign currency reserve, return requirements have increased in importance over the last 10 years. The definition of eligible asset types has been broadened in order to allow for a higher return than previously.⁶ It has also become more common to permit the use of derivatives in asset management. In addition, it has become increasingly common to divide up the foreign currency reserve into different portfolios with different objectives in terms of how liquid the assets must be in relation to the required return.

³ D. Gray and A. Maechler (2008), Technical Analysis of FX Reserve Adequacy, Including Banking Sector FX Related Risk, for Sweden Using Contingent Claims Analysis of the Banking Sector and Sovereign, Mimeo, Sveriges Riksbank.

⁴ Jaewoo Lee (2008), "Option pricing approach to international reserves", IMF, Research Department, Forthcoming, Review of International Economics.

⁵ This review is based on the annual surveys conducted by the Royal Bank of Scotland of a large number of central banks, the survey conducted by BIS at the end of 2006, and the survey the Riksbank has conducted of a number of central banks (the ECB and the central banks in Australia, Chile, Denmark, England, Canada, Norway, New Zealand, Switzerland and South Korea).

⁶ The Royal Bank of Scotland's survey in 2006 showed that three out of four central banks permit investments in government bonds with an AA rating, while one out of three central banks permit investments in government bonds with an A rating. The element of credit-related securities had also increased somewhat.

At some central banks the focus of asset management has turned towards *Asset Liability Management* (ALM). This means that commitments are matched with the properties of the assets. For a central bank this may mean that assets equivalent to the bank's own capital and notes are invested in the long term, while assets that are intended to be used for foreign currency interventions and emergency liquidity assistance are invested more in the short-term due to the high liquidity requirement. The central banks in Canada, New Zealand and the UK have, for example, all moved in this direction.

There are also examples of countries where asset management more explicitly aims to manage *Sovereign Wealth Funds*. In Norway, this aim has been clearly stated and a specific part of the asset management system has been organised to provide as high a return as possible. Other countries with a more explicit strategy for the management of national wealth based on the foreign currency reserve are China, Hong Kong, Singapore and South Korea.

A majority of the central banks in the Royal Bank of Scotland's survey stated that they have *outsourced* elements of asset management. Outsourcing was particularly common in the developing countries. On the other hand, less than a third of the central banks in the industrialised countries were involved in outsourcing. Outsourcing relates to only a small part of the total portfolios.

Increasing openness about the management of foreign currency reserves is also noted internationally, probably as an effect of the increasing independence of the central banks, and this has led to increasing demands for accountability.

The size of the foreign currency reserve

Since the Bretton Woods system collapsed in the early 1970s, the total foreign currency reserves in the world's central banks as a percentage of GDP have increased. This may seem surprising since the central banks should require less access to foreign currency with a floating exchange rate than with a fixed exchange rate. There are, however, major differences between different groups of countries. It is mainly in the developing countries that the foreign currency reserves have increased.

In developing countries with inflation targets, foreign currency reserves increased from approximately 9 to 20 per cent, as a percentage of GDP, between 1980 and 2004, while the increase in the industrialised countries with inflation targets was much more limited, from slightly less than 6 to 8 per cent, see table 1.

Table 1 FX reserves in 15 countries⁷

⁷ M. Obstfeld, J. Stambaugh & A. Taylor (2008), "Financial stability, the trilemma, and international reserves" CEPR 6693

FX reserves

(per cent of GDP)

	1980	2004
Australia	3,7	5,6
Brazil	3	8,7
Chile	15	17
Denmark	6	16
Israel	18	23
Japan	3,7	18
Canada	6	3,5
Mexico	2	9
Norway	11	17
New Zealand	1,6	7
Switzerland	6	21
Sweden	5	7
Rep. of Korea	5	29
Thailand	9	31
USA	6	1,6
Industrial countries with inflation targets	5,5	8,0
Emerging markets with inflation targets	8,7	19,6

Simple rules of thumb have often been used to determine the level of a central bank's financial assets. It may have been stated, for example, that the foreign currency holdings should cover three months of imports. Another common rule of thumb is the so-called Greenspan-Guidotti rule under which the foreign currency holdings should cover the total short-term foreign debt.

However, these rules of thumb are outdated for a central bank with access to financial markets. It has become apparent that the main reason for building up financial assets in the developing countries is the *precautionary motive*. Financial deregulation programmes and the crisis in Asia in 1997-1998, which entailed a dramatic decline in short-term capital inflows, have contributed to an increase in risk aversion and in foreign currency reserves. In recent years, the foreign currency reserves have also increased in developing countries in Asia as a result of foreign currency interventions designed to counteract strengthening tendencies for the domestic currency.

Financial transparency and the central banks' concern for financial stability play a particularly important role in the development of the foreign currency reserves.⁸ This means that the size of a country's banking system and the role of the central bank in providing emergency liquidity assistance affect the size of the reserve. All in all, there is support in the macro data for the notion that there is a tendency for the foreign currency reserves of the central banks to increase when:

- the country's financial openness to the outside world increases,

⁸ M. Obstfeld, J. Stambaugh & A. Taylor (2008), "Financial stability, the trilemma, and international reserves" CEPR 6693

- the size of the financial sector increases,
- the banking system has been disrupted.

Models that take financial variables into account are better at explaining the size of the foreign currency reserve in both developing and industrialised countries than models that do not, according to academic research.

At the same time, it is important to note that central banks in general have not developed an established method for assessing how the volume of the assets is affected by the primary tasks. There are very few examples of micro-based analyses that explain the size of the foreign currency reserves according to the Riksbank's survey of other central banks. One exception has been the Reserve Bank of New Zealand, where the foreign currency reserve is to some extent determined by the need to be prepared to act as a market-maker on the currency market for the country's own currency with the aim of coping with a short-term crisis of confidence in the national economy. Other central banks have noted that the need for emergency liquidity assistance affects the size and composition of the financial assets without more explicitly stating how this is calculated. Holding the major part of the foreign currency reserve in the form of liquid assets means that it can be used for both monetary policy interventions and as emergency liquidity assistance for banks in crisis. It is also important to note that the reserve can be complemented by other arrangements, for example swap agreements with other central banks, which we will discuss below.

The composition of the foreign currency reserve

Many central banks have chosen to handle the currency risk by choosing a currency composition in similar ways. This means that the share of the dollar in the reserves has declined, usually in favour of the euro. The relative weight of the dollar in asset management is, however, still very high. In the mid-1970s, the dollar's share of the total foreign currency reserves in the world was approximately 80 per cent. In 2005, the corresponding figure was 67 per cent, while the euro accounted for 24 per cent of the foreign currency reserves.

New Zealand has previously eliminated the currency risk by having the same currencies on the asset side of the balance sheet as on the liability side. In recent years, however, the Reserve Bank of New Zealand has chosen to maintain a certain degree of open exposure in its foreign currency reserve. The reason for this is that the bank in this way wants to reduce the risk that the value of the reserve will fall when it is needed most, i.e. when there is a risk that the New Zealand dollar will collapse.

Other countries that have chosen to neutralise their currency risk in the same way are Canada and the UK.

Examples of significant disruptions

There are many historical examples of significant disruptions to the foreign exchange markets that motivate having access to a foreign currency reserve. There is extensive literature on how fixed exchange rate systems can be subjected to speculative attacks. Significant disruptions can also occur on deregulated financial markets, for example as the result of terrorist attacks or a financial crisis.

11 September 2001

Following the terrorist attack on 11 September 2001, the US stock market closed for four days. Trading on the foreign exchange markets continued however, although turnover declined. Many foreign exchange traders in New York moved their operations to special emergency facilities or abroad. In addition, many foreign banks could not use their usual counterparties or correspondent banks. They therefore turned to their respective central banks to get assistance in acquiring liquidity in dollars.

The Federal Reserve also arranged swap facilities with the ECB (\$ 50 billion), the Bank of England (\$ 30 billion) and the Bank of Canada (\$ 10 billion). The ECB used this swap facility on 12, 13 and 14 September 2001 (in total \$ 23.4 billion) while the Bank of England and the Bank of Canada did not need to use it. The Executive Board of the Riksbank decided to make available up to \$ 1 billion to the Swedish banks who did not, however, need to use this loan facility.

Directly after the terrorist attacks, uncertainty on the foreign exchange markets for the dollar, euro and yen increased dramatically, but after a few days developments on the spot markets for these currencies were relatively calm. The demand for US government securities increased for liquidity reasons, which contributed to the recovery of the dollar. In smaller industrialised countries with a floating exchange rate, such as Australia, New Zealand and Sweden, the terrorist attacks contributed to a weakening of the exchange rates for a while.

The financial crisis 2007-2008

The financial crisis that began on the mortgage market in the USA in 2007 has affected the operations of the central banks in several ways. In this paper, we focus mainly on aspects relating to the supply of liquidity and the need to have access to foreign currency.

In the autumn of 2007, the banks' demand for secure and liquid investments increased as a result of the incipient crisis. The reason for this was partly a fear of being hit by liquidity problems and partly anxiety about increased credit risks when providing loans to other banks.

The banks' higher demands for liquidity reserves led to an increase in the demand for liquid risk-free investments, at the same time as the supply of interbank loans decreased. This meant that rates for government securities were squeezed downwards at the same times as the longer interbank rates increased due to a reluctance to tie up liquid capital with high-risk counterparties for a longer period of time. The spread between interbank rates and risk-free rates increased, especially for somewhat longer terms.

But even the shortest market rates increased when banks with a surplus at the beginning of the cash requirement period preferred to invest their money safely at the central bank rather than in the money market. The central banks responded by supplying more liquidity than usual in order to push the shortest interest rates down to the levels they were aiming for.

For market maintenance reasons, many central banks also tried to reduce the pressure on the somewhat longer interbank rates by increasing the supply of longer-term loans in order to reduce longer interbank market rates.

The central banks have thus taken several measures to ensure that financial institutions have access to liquidity. New liquidity facilities have been set up. The list of accepted securities

has been increased.⁹ Several central banks have also granted emergency liquidity assistance to financial institutions that have been taken over by Government authorities.

Emergency liquidity support in foreign currency

In the current crisis, the provision of emergency liquidity support has largely concerned support in domestic currencies. On several occasions, however, beginning in December 2007, the Federal Reserve, the ECB, and other central banks have coordinated a global supply of \$ liquidity.¹⁰ Interbank rates for slightly longer terms had risen, which made the pricing of currency swaps in dollars more difficult. This problem was reinforced by differences in time zones in that European banks needed dollars early in the morning at the same time as American banks waited until later in the day to loan dollars because they first wanted to guarantee that they could meet their own liquidity needs for the day. The ECB, the Swiss National Bank and a number of other central banks therefore set up facilities to supply their counterparties with liquidity in dollars. They signed currency swap agreements with the Federal Reserve so that they could offer loans in dollars to banks against collateral in euro and SFR. Between December 2007 and 10 September 2008, the Swiss National Bank conducted 15 auctions in which its own counterparties were able to purchase against collateral in domestic currency for a total sum of \$ 78 billion, while in the same period the ECB conducted 18 auctions where a total of \$ 320 billion was allocated to the counterparties.¹¹

The justification for these repurchase transactions was that they meant that the supply of liquidity in dollars could be provided in Europe during normal market hours and that the friction stemming from the different time zones on the global exchange markets could be limited. Another reason given for the swap agreements was that it would be advantageous for the central banks in the home countries to supply the banks with liquidity in dollars as these central banks have more knowledge about the needs of the borrowers.¹²

On 18 September 2008, the cooperation between the Federal Reserve and the other central banks was extended. The ECB's swap agreement was increased from \$ 55 billion to \$ 110 billion. The swap agreement with the Swiss National Bank was increased from \$ 12 billion to \$ 27 billion. In addition, new swap agreements were drawn up with the central banks in Japan (\$ 60 billion), the UK (\$ 40 billion) and Canada (\$ 10 billion).

In connection with these new agreements it was also announced that the central banks in Europe have begun to offer dollars on the O/N market. The ECB and the Bank of England would loan up to \$ 40 billion, while the Swiss National Bank would offer up to \$ 10 billion, overnight.

⁹ The Bank of England, which previously did not accept mortgage securities as collateral extended the list to cover these securities too. In March 2008, the Federal Reserve opened a new credit facility for its counterparties on the money market ((Primary Dealer Facility). In connection with the collapse of Lehman Brothers in September 2008, the central bank decided that, as collateral, the counterparties would be permitted to take out loans on assets other than those of "investment grade", e.g. shares.

¹⁰ The central banks in the USA, the euro area (ECB), England, Canada and Switzerland drew up an agreement on 12 December 2007 which was extended on 11 March 2008.

¹¹ In May 2008, a swap agreement was also signed between the Central Bank of Iceland and the central banks in Denmark, Norway and Sweden that entitles the Central Bank of Iceland to borrow a total of EUR 500 million.

¹² Central bank operations in response to the financial turmoil (2008), CGFS Papers No 31, BIS.

On 24 September 2008, temporary swap agreements were announced between the Federal Reserve and the Riksbank (\$ 10 billion), and the central banks in Australia (\$ 10 billion), Denmark (\$ 5 billion) and Norway (\$ 5 billion). These facilities, like the other swap agreements, were intended to improve liquidity conditions on the global financial markets.

On 26 September 2008, Danmarks Nationalbank implemented a 28-day repurchase agreement for \$ 5 billion and the Reserve Bank of Australia a 28-day repurchase agreement for \$ 10 billion, while the Bank of England implemented a repurchase agreement O/N for \$ 10 billion dollars and a one-week agreement for \$ 30 billion.

On 29 September 2008 Federal Reserve authorized a 330 \$ billion expansion of the temporary swap agreements with other central banks. These larger facilities will support the provision of dollar liquidity by the ECB (\$ 240 billion), Bank of Japan (\$ 120 billion), Bank of England (\$ 80 billion), Bank of Canada (\$ 30 billion), the Riksbank (\$ 30 billion), Reserve Bank of Australia (\$ 30 billion), Danmarks Nationalbank (\$ 15 billion) and Bank of Norway (\$ 15 billion).

On 1 October 2008, the Riksbank implemented a 28-day repurchase agreement for \$ 7 billion.

On 13 October 2008 it was announced that in order to provide broad access to liquidity and funding to financial institutions, the Bank of England (BoE), the European Central Bank (ECB), the Federal Reserve, the Bank of Japan, and the Swiss National Bank (SNB) were jointly announcing further measures to improve liquidity in short-term U.S. dollar funding markets.

The BoE, ECB, and SNB will conduct tenders of U.S. dollar funding at 7-day, 28-day, and 84-day maturities at fixed interest rates for full allotment. Funds will be provided at a fixed interest rate, set in advance of each operation. Counterparties in these operations will be able to borrow any amount they wish against the appropriate collateral in each jurisdiction. Accordingly, sizes of the reciprocal currency arrangements (swap lines) between the Federal Reserve and the BoE, the ECB, and the SNB will be increased to accommodate whatever quantity of U.S. dollar funding is demanded.

On 14 October 2008 it was announced that the size of the swap line between the Federal Reserve and the Bank of Japan will be increased to accommodate whatever quantity of U.S. dollar funding is demanded.

On 28 October 2008 the Federal Reserve and the Reserve Bank of New Zealand announced the establishment of a swap line to address ongoing, elevated pressures in U.S. dollar short-term funding markets. The facility will support the provision of U.S. dollar liquidity in amounts of up to \$ 15 billion.

On 29 October 2008 the Federal Reserve, the Banco Central do Brasil, the Banco de Mexico, the Bank of Korea, and the Monetary Authority of Singapore announced the establishment of swap lines. These facilities, like those already established with other central banks, were designed to help improve liquidity conditions in global financial markets and to mitigate the spread of difficulties in obtaining U.S. dollar funding in fundamentally sound and well managed economies. The facilities will support the provision of U.S. dollar liquidity in each country in amounts of up to \$ 30 billion.

Other consequences of the financial crisis

The survey conducted by the Riksbank, contains other examples of how the central banks have reacted to the crisis. Some central banks have decided to increase its foreign currency reserve as an emergency preparedness measure.

In the survey conducted by the Royal Bank of Scotland in the autumn of 2007, after the start of the financial crisis, it was noted that approximately half of the central banks believed that the traditional target for ensuring liquidity would be upgraded.

It was also noted that there was a clear trend towards low-risk securities with a high rating. More than 80 per cent of the central banks expected to increase the percentage of AA-rated bonds. Two-thirds of them expected to reduce their holdings of BBB-rated bonds. Between 80 to 90 per cent of the banks believed that they would reduce their holdings of MBS and ABS. On the other hand, more than half of the central banks expected that they would increase their use of financial derivatives.

The survey sent by the Riksbank to other central banks also reveals that stricter demands have been placed on the counterparties and that investments in less creditworthy securities have decreased on the margin.

Overall assessment

All in all, the international review indicates that the purpose of the foreign currency reserve has changed in recent decades. Previously, the central banks' foreign currency holdings have mainly been motivated by the need for interventions that may stem from a fixed exchange rate regime. Today, the supply of currency increasingly plays a role with regard to maintaining confidence in the functioning of the foreign exchange markets and ensuring that the central banks can maintain the stability of the financial system by supplying liquidity to financial institutions.

The developments on the financial markets and the financial crisis show that it is important for a central bank to take into account both its own foreign currency reserves and the access to foreign currency that swap agreements with other central banks provide. We have noted that the central banks on several occasions during the crisis have coordinated a global supply of liquidity. Several central banks have also signed swap agreements with the Federal Reserve in order to be able to offer loans in dollars to their counterparties against collateral in domestic currencies.

It is therefore important to consider that a central bank needs a form of overall insurance that consists of two main components: First, financial assets in foreign currency that constitute a kind of self-insurance and, second, other ways of meeting future needs for financial assets, for example swap agreements, that constitute a kind of external insurance.¹³

Any increase in the risk of a financial crisis can affect both of these components and may lead to a greater need for a central bank to have both its own foreign currency reserve and some

¹³ Jaewoo Lee (2008), "Option pricing approach to international reserves", IMF, Research Department, Forthcoming, Review of International Economics.

form of external insurance (swap agreements). The current crisis also shows, however, that access to swap agreements can reduce the need to increase the foreign currency reserve when anxiety increases on the financial markets. At the same time, it cannot be ruled out that a certain level for the foreign currency reserve has been necessary in order to be able to sign swap agreements with other central banks.

3. The FX reserves as an insurance policy

We have noted that the traditional academic model for calculating the size of the foreign currency reserve is not a particularly appropriate basis for a central bank with access to international financial markets and credit lines to other central banks and international organisations. The traditional analysis regards the financial assets of the central bank as the only insurance available in an emergency situation when the central bank needs access to foreign currency, which is no longer a realistic point of departure.

In recent years, a conceptual framework for how the balance sheet of a nation or a central bank can be analysed using modern insurance thinking has been developed. When the balance sheet for a nation's or a central bank's assets and liabilities is analysed, it is possible to use insurance thinking based on Robert Merton's theory of price contingent contracts.

The analysis is based on an essay that demonstrated how the value of deposit insurance can be calculated using the theory behind put options.¹⁴ The deposit insurance that the FDIC provides for bank deposits in the USA corresponds, for example, to a put option and can therefore be valued in the same way as such an option.

This framework has been applied by Dale Gray, Robert Merton and others to study several financial crisis, including the Asian Crisis, the Brazilian Crisis and the current subprime crisis.¹⁵

Such a model is more general than an analysis based on a traditional balance sheet. A traditional balance sheet does not address the fact that the costs for implicit or explicit insurance commitments between different sectors are affected by the volatility of underlying variables.

In the case with only two sectors, commercial banks and a consolidated public sector (including the central bank), there are several implicit option contracts.

The banks' asset side consists of loans to companies and other assets. In addition to this there is any deposit insurance and other guarantees from the State or the central bank that can be seen as a long position of an implicit put option. The banks' liabilities side consists of deposits and other liabilities. In addition to this there is the share capital, which can be seen as an implicit call option.

¹⁴ Robert Merton (1976), "An analytic derivation of the cost of deposit insurance and loan guarantees", *Journal of Banking and Finance*, 1, 3-11.

¹⁵ D. Gray and S. Malone (2008), *Macrofinancial riskanalysis*, Wiley Finance;

D. Gray, R. Merton and Z. Bodie "Contingent Claims Approach to Measuring and Managing Sovereign Credit Risk" *Journal of Investment Management*, 4, 2007, 5-28;

D. Gray, R. Merton and Z. Bodie, "A Contingent Claims Analysis of the Subprime Credit Crisis of 2007-2008, Mimeo.

The *consolidated public sector's* assets consist of the foreign currency reserve and the net total of other financial assets, both long positions. On the liabilities side there are any deposit insurance and other guarantees to the banks from the Government or the central bank that can be seen as a short position corresponding to the banks' implicit put option above. The liabilities side also includes the foreign debt, which can be seen as the total of a short position (the value of the debt excluding suspension of payments) and a long position in the event of suspension of payments that can be seen as an implicit put option. In addition there is the value of the banknotes and coins in circulation and liabilities in domestic currency.

The traditional balance sheet thus does not take into account the risks that the explicit or implicit commitments may entail when there are major variations in the value of the underlying assets. The advantage of an analysis based on an insurance model is that the transmission of risk between different sectors can be clarified. It is also possible to show that a traditional balance sheet can be seen as a special case of the insurance-based balance sheet where the volatility in the value of the assets is zero, which means that all implicit put and call options are without value.

Insurance thinking applied to the FX management of the central bank

There are many indications that this conceptual framework has several advantages when it is applied to the FX management of the central bank.

- It can be used to calculate the cost of the insurance level aimed at.
- Once the overall insurance level has been chosen, it can be used to decide how large a proportion of the overall insurance needs to be kept as financial assets by the central bank.
- It shows how the optimal reserve quota varies in line with the risks that the financial system is exposed to and can explain why countries that have suffered financial crises increase the reserve quota.

The point of departure is thus that a central bank needs a form of overall insurance that consists of two main components: First, financial assets in foreign currency that constitute a kind of self-insurance and, second, other ways of meeting future needs for financial assets that constitute a kind of external insurance.

We will present the preliminary results from applying two different models to Swedish data. The first is an application developed by Dale Gray and Andrea Maechler.¹⁶ The second is an application of a model developed by Jaewoo Lee.¹⁷

The Gray/Merton/Bodie Model

The application to the banking sector by Gray and Maechler (2008) use MKMV daily information on the four major banks in Sweden which uses market capitalization, volatility of market capitalization, the default point derived from liabilities to estimate implied assets,

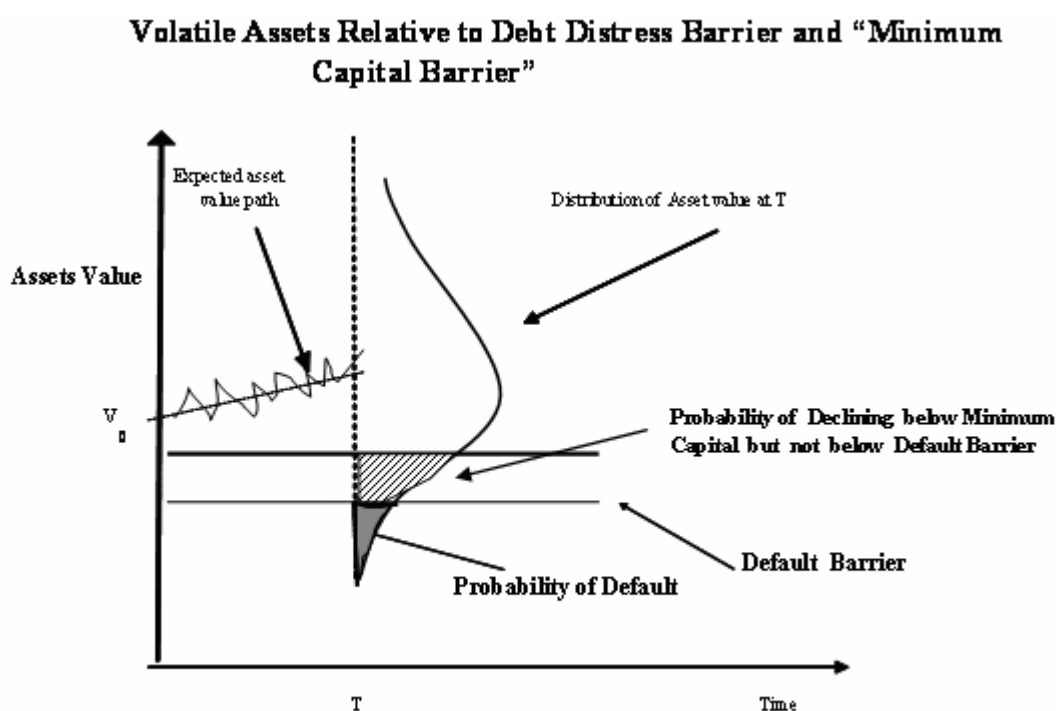
¹⁶ D. Gray and A. Maechler (2008), Technical Analysis of FX Reserve Adequacy, Including Banking Sector FX Related Risk, for Sweden Using Contingent Claims Analysis of the Banking Sector and Sovereign, Mimeo, Sveriges Riksbank.

¹⁷ Jaewoo Lee (2008), "Option pricing approach to international reserves", IMF, Research Department, Forthcoming, Review of International Economics.

implied asset volatility, expected default probability (EDF), as well as EDF implied CDS spreads daily for each bank. Data from MKMV on asset level and default point as well as base (calm period) volatility is used, plus additional information from equity options for each bank.

Financial support for liquidity and potential credit risk from the authorities is likely to be provided before “default” barrier is reached. A minimum capital barrier, or simply a capital barrier, is defined by Gray and Maechler (2008) in addition to the default barrier. The default barrier plus 8% of market value of assets is used as the “minimum 8% capital” barrier.¹⁸ Figure 1 shows the area between the minimum capital barrier and the default barrier. The area represents the probability of falling below minimum capital but not as far as default. The value of this area is calculated as the implicit put option below the minimum capital barrier minus the implicit default put option. Gray and Maechler (2008) call the value of the area as the “capital barrier put option” or “capital barrier expected loss.” This is particularly relevant to the central bank as it is a measure loss directly related to liquidity support/financial support which would be needed to get the bank asset level above the minimum capital level.

Figure 1 The Minimum capital barrier and the default barrier



Data on each bank’s foreign currency assets and liabilities is used to estimate the portion of the “capital barrier put option” (or “capital barrier expected loss”) of expected losses (put option) which is likely to be related to EUR or U.S. DOLLAR and the remainder (SEK and other). In this paper we only report the total in SEK in one scenario.

¹⁸ It is of course also possible to calculate other barriers, eg. a “minimum 4 % barrier”.

The basic assumption is that there is a 25, 50 or 100 per cent probability of a financial crisis, eg. related to a sudden credit deterioration in the Baltic countries, as Swedish banks have high exposure to the region. It may also be assumed that the crisis will reduce the value of the assets of the four largest banks by a certain amount.

In one scenario, with a 25 per cent chance of a financial shock the mean of the minimum capital expected losses is SEK 107 billion and the default loss is SEK 167 billion. But given the probability of a shock the losses may be higher as there is a probability distribution around the mean.

The Lee Model¹⁹

The model applied above was based on a thorough analysis of market capitalization and volatility of market capitalization of the banks. The focus was on central banks concerns for financial stability. Other restrictions, given by FX interventions for monetary policy reasons or international commitments, were not specified. External insurances, eg. swap lines with other central banks, were not included in the analysis, although that would be feasible. In this section we will turn to another model, which provides as possibility to determine the level of required external insurances endogenously. By estimating the Lee model on Swedish FX reserve data, both the desired overall insurance and the optimal mix between the central bank's own holdings of financial assets and other alternatives can be analysed.

The following terms will be used:

D = the central bank's total need for financial assets in foreign currency in an emergency situation in the future = the overall insurance requirement.

C = the central bank's own holdings of financial assets in foreign currency to be used in the event of an emergency situation in the future = the central bank's self-insurance = the foreign currency reserve.

C/D = the reserve quota = the percentage of self-insurance.

V_t = the value at the point in time t of the central bank's holdings of financial assets.

$I(C, V_t)$ = the market value of an option that provides the same insurance as V .

R = the return on V_t .

r = the risk-free interest rate.

σ = the standard deviation of the change in V_t .

The analysis assumes that at some point in the future the need for financial assets in foreign currency, D , will arise. This may relate to international commitments, emergency liquidity assistance for banks or currency interventions. The net cash flow for the central bank's own

¹⁹ Jaewoo Lee (2008), "Option pricing approach to international reserves", IMF, Research Department, Forthcoming, Review of International Economics.

currency holdings is $V_t - D$, which risks becoming negative if D is too large. This means that the central bank would need an insurance that pays $D - V_t$ when the value is negative.

This insurance is provided by a put option on the portfolio with the exercise price D which gives the central bank the right to sell the underlying asset V_t for D . If it is the case that the value of the portfolio, V_t , exceeds the exercise price, the central bank can pay out D without using the option. When, however, the value of the portfolio, V_t , is lower than the exercise price, D , the central bank triggers the option in order to meet the liquidity needs.

The alternative to acquiring the put option is for the central bank to create a sufficiently high level for its own holdings of financial assets so that V_t exceeds D at the point in time T . This means that the central bank's self-insurance, C , must be sufficiently high to meet the liquidity commitment, D .

When these two alternatives are compared, it is the value of the portfolio that acts as a kind of instrument of equilibrium so that both of the alternatives are equivalent, and that determines the market value of the insurance.

The insurance value for the central bank's own holdings of financial assets in foreign currency can thus be calculated as the market value of a put option that provides the same level of insurance as full self-insurance.

In order to find an analytical solution to the valuation problem, assumptions about how the value of V is expected to develop are needed.

The first possibility is to assume that the value of the central bank's own holdings of financial assets follows a log-normal process. This is a fairly reasonable assumption of how the development can be described under normal circumstances. Standard formulae can also be used in the calculations. The second possibility is to take into account the risk that a financial crisis can lead to sudden and major negative changes in the value of the portfolio. This risk can be taken into account by subtracting a special jump process from the log-normal process.

Let us begin with the more normal case. We thus assume that the value of V follows a geometric Brownian motion with drift with fixed parameter values for expected excess return (μ) and standard deviation (σ):

$$(1) \quad dV_t/V_t = \mu dt + \sigma d\phi(t)$$

We begin with a number of general factors that affect the size of the optimal reserve quota, i.e. how high a level of self-insurance may be appropriate. It is possible to show that the optimal reserve quota (C/D):²⁰

- depends on the quota D/V , irrespective of the level of V
- decreases with increasing excess return on the portfolio ($R - r$)
- increases with increasing volatility (standard deviation) in the changes in value (σ)

²⁰ Jaewoo Lee (2008), "Option pricing approach to international reserves", IMF, Research Department, Forthcoming, Review of International Economics.

However, the stochastic process is rather restrictive if we want to include the risk of a major financial risk.

Let us therefore continue with the second case. This entails complementing the model with a special jump process with the intention of including the risk that a financial crisis can lead to sudden and significant negative changes in the value of the portfolio. Such an analysis may be more realistic in certain situations, for example to describe the development of the reserve quota in several developing countries following the crisis in Asia. It may also be of value when a central bank analyses how a financial crisis may conceivably affect assessments of the optimal reserve quota.

A jump process is subtracted from the lognormal process. The jump process is a Poisson-process dq_t with jump risk (λ). When there is a jump the value of the jump is determined by another process, Y , and given $k = E(Y-1)$, the new process can be written as:

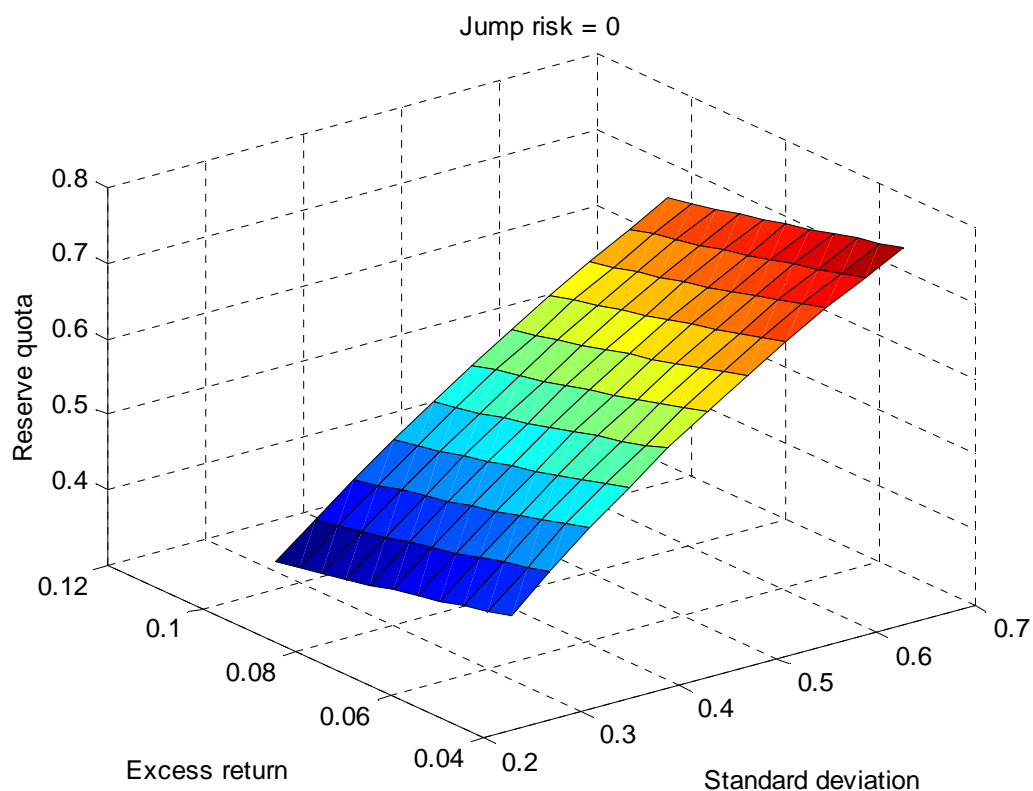
$$(2) \quad dV_t/V_t = (\mu - \lambda k)dt + \lambda d\phi(t) + dq_t$$

Traditional portfolio management theory suggest that FX reserves should be managed in order for return and risk being close to the efficient frontier, with the restriction that the need for liquidity should be the first priority and the return requirement the second priority. When the theory of contingent contracts is applied, however, it is possible to analyse how these motives affect each other.

For a central bank's asset management it is more appropriate to speak about an FX area rather than a frontier. The FX area shows the reserve quota as a function of excess return and volatility, for a certain assumption of the jump risk. This means that for every value of the jump risk an FX area can be constructed that shows the return, standard deviation and reserve quota.

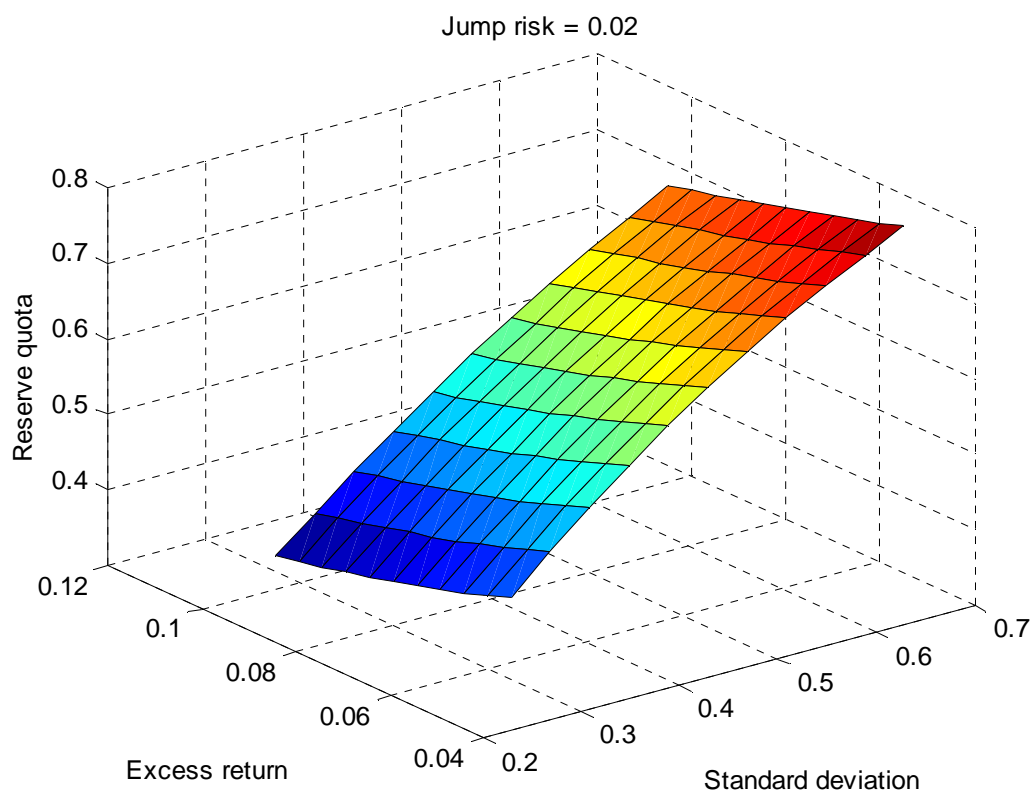
Let us begin with the simplest case. Assume that the jump risk is assessed to be zero. Figure 2 shows the corresponding FX area. We can see that the reserve quota decreases with increasing excess return. We can also see that the reserve quota increases with increasing volatility.

Figure 2 The FX area without jump risk



Let us continue by assuming that the jump risk is assessed to be 2 per cent. Figure 3 shows the corresponding FX area. We can see that the reserve quota has now increased compared to the case with zero jump risk. A very small increase in the risk of a crisis from 0 to 2 per cent means that the need for self-insurance increases. But the increase is not dramatic.

Figure 3 The FX area area with 2 per cent jump risk



Now we will consider the question of what jump risk may be assumed to be a reasonable starting point when an appropriate reserve quota is discussed. As we saw earlier, the insurance analysis is based on an assumption that the value changes in the foreign currency reserve follow a stochastic process that is a combination of a geometric Brownian motion and a Poisson process.

This means that the central parameters should be estimated simultaneously using econometric methods. Such an estimation on weekly data for the period January 1995 to August 2007 led to the assessment that the following data were reasonable as a starting point: Excess return = 8.8 per cent, standard deviation 70 per cent and jump risk 6 per cent.²¹ Figure 4 shows the FX area when jump risk is 6 per cent.

Figure 4 The FX area with 6 per cent jump risk

²¹ The estimate is $\mu = 12.9$ per cent, $\sigma = 70$ per cent and $\lambda = 5.95$ per cent. As the risk-free interest rate in the period averaged 4.1 per cent, I assume that the excess return was 8.8 per cent.

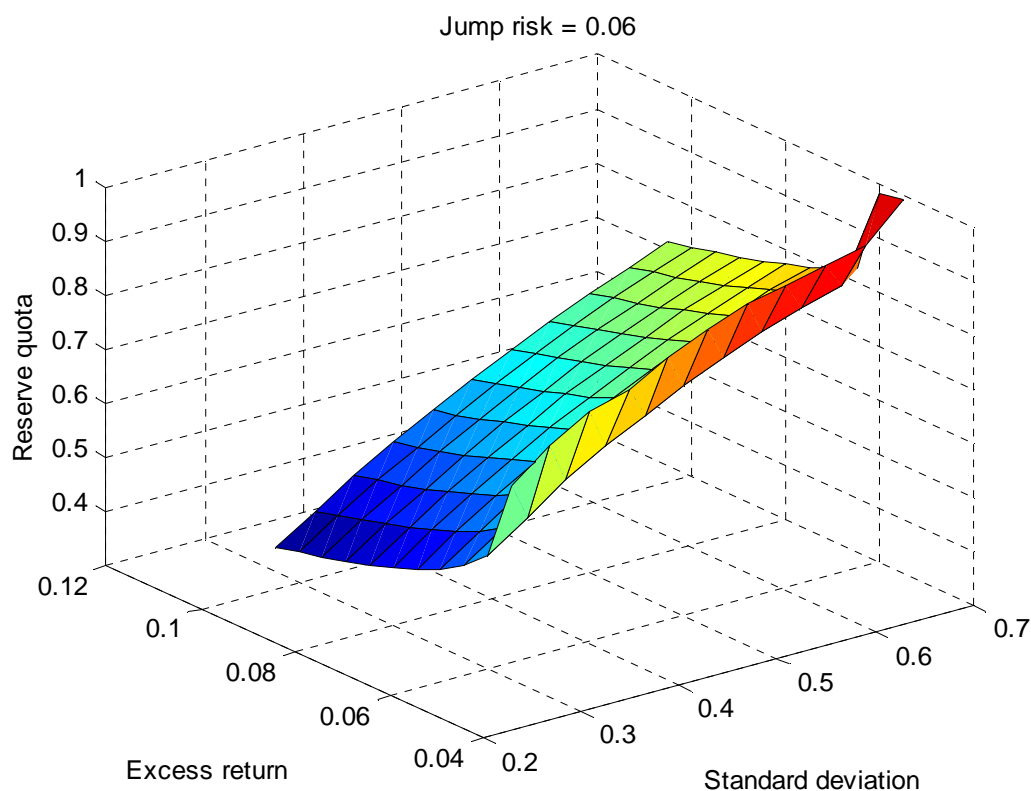
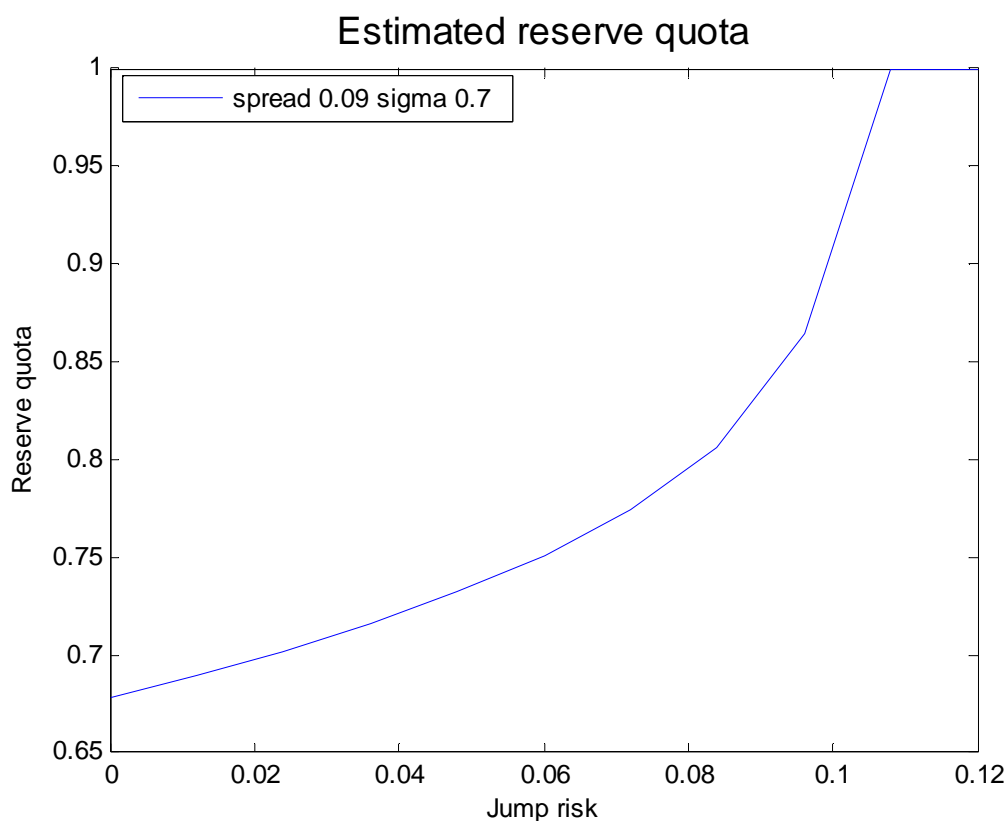


Figure 5 shows the reserve quota as a function of estimated values for excess return and standard deviation for different values of the jump risk. We can see that if the jump risk reaches 6 per cent then the appropriate reserve quota is 75 per cent. Note, however, that the estimation of the jump risk does not differentiate between positive and negative jumps. The estimated jump risk of 6 per cent can therefore be regarded as an upper limit. However, we can also see in Figure 5 that the curve for the reserve quota is rather flat for jump risk values below 6 per cent. This may indicate that the optimal reserve quota according to these estimates is in the region of 70 per cent.

The conclusion of this exercise is that when we take into account jump risk, the level of FX reserves increases. An increase in the risk of a financial crisis entails two things: first, a generally higher need for insurance and, second, a higher reserve quota. It increases the need for the central bank's self-insurance through a form of leverage effect that stems from option theory. The preliminary results indicate that the level of FX reserves should be 70 per cent of the overall insurance, whereas 30 per cent should be covered by external insurances, eg. swap lines with other central banks. More empirical research in this area is clearly warranted. One possibility is to estimate the model on longer data series, including earlier financial crises.

Figure 5 Estimated reserve quota with varying jump risk



4. Conclusions

After the break-down of the Bretton Woods system we have witnessed increased international reserves as a share of GDP in central banks around the world. This might be somewhat surprising as shift to more flexible exchange rates would suggest the opposite. However, the increased reserve ratios are most evident in emerging market economies. In developed countries the level of FX reserves has been relatively stable during recent decades. Nevertheless it is also surprising that there does not seem to exist well-established methods to calculate the level of FX-reserves in countries with market based financial systems and a floating exchange rate. The old rules suggesting that the international reserves should cover three months of imports or the total short term debt in foreign currency (the Greenspan-Guidotti-rule) are old-fashioned and belongs more to an era of fixed exchange rates.

With floating exchange rates it is probably the case that the FX reserves required are primarily related to financial deregulations and the risk of financial crisis. It is for example clear that several emerging market countries increased the level of international reserves after they have experienced financial crisis.

There is also evidence in the academic literature that concerns for financial stability is related to the level of FX reserves in both emerging markets and developed countries.

Which are the effects of the current financial crisis on central banks reserve management? We have witnessed an increased number of swap-agreements in foreign currency between central banks. It is also true that the traditional objective of providing liquidity is being upgraded by several central banks. Some central banks report that they have become more cautious regarding asset classes that might be under public scrutiny and have abandoned MBS and

ABS. There are also central banks reporting that they have reduced the exposure to less highly-rated institutions. Others have reported that counter-parties need to have an higher credit standing than earlier. Some central banks have increased the amount of international reserves.

Despite the fact that concerns for financial stability seems to be of increasing importance for keeping FX reserves there is normally no published formulas for central banks calculations related to this objective. Normally central banks only say that the amount of FX reserves is sufficient to meet both monetary policy objectives and financial stability objectives.

In order to calculate the FX reserves related to the financial stability objective, we reported ongoing work on applying methods based on contingent claims analysis.

A central bank needs a form of overall insurance that consists of two main components: FX reserves and other ways of meeting future needs for financial assets, for example swap agreements. The contingent claims models indicate that an increase in the risk of a financial crisis can affect both of these components. It may explain why the central bank may need to increase both its own FX reserves and the external insurance. However, in practice it is also true that access to swap agreements can reduce the need to increase the foreign currency reserve when anxiety increases on the financial markets. A certain level for the foreign currency reserve is, on the other hand, probably necessary in order to be able to sign swap agreements with other central banks.

The advantage of using CCA-analysis is that it will give central banks a possibility to analyse how a financial crisis may develop into a confidence crisis for the economy. Then the amount of FX reserves depends on the imbalances in the financial sector and the government sector. It may also take into account implicit or explicit guarantees extended by the government to the financial sector.

These valuation methods can hopefully be used to evaluate the effects of changes in FX reserves and swap-agreement with other central banks. It will probably be possible to estimate an appropriate target for reserve adequacy that minimizes distress by keeping risk indicators below a target threshold for a given confidence level.

