Sveriges Riksbank
Economic Review

2013:1

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Dear readers,

In this edition of the Riksbank's journal you will find three articles dealing with different aspects of developments on the financial markets in recent years:

- Karolina Ekholm describes how the international integration of the financial markets around the world has developed since the global financial crisis. The process of internationalisation that began in the early 1980s appears to have come to a halt after 2008. This is reflected, for instance, in the fact that European banks have reduced their lending on foreign markets and that activity on the interbank market has declined. The author discusses what advantages and risks can be found in financial integration, as well as how they may be affected by the international regulations emerging in the wake of the crisis. In particular, she focuses on developments at EU level, where the endeavour to maintain financial stability on an integrated market appears to require a higher degree of joint supervision and regulation. Her conclusion is that a reinforced European banking sector, with a smoothly-functioning bank union, could have beneficial effects on the Swedish economy, regardless of whether or not Sweden takes part in the bank union.

- Maria Bergsten and Johannes Forss Sandahl survey algorithmic trading on the foreign exchange market and discuss its advantages and disadvantages. Using interviews with a number of participants in the foreign exchange market as a base, the authors assess that this type of automated trading, where orders are given and executed by computers, is used for trading currency pairs that include the Swedish krona, and to an even larger extent for trading other currency pairs. The purposes of algorithmic trading are to execute orders, set prices, manage risks and make use of opportunities for arbitrage. Some of these functions are fulfilled by the algorithms referred to as high frequency trading. The authors also note that the practice that has developed on the foreign exchange market largely functions well as self-regulation for managing risk that algorithmic trading can give rise to.

- Tor Johansson and Fredrik Bonthron present the Riksbank's new index for financial stress in Sweden. Unlike the previous index, which the Riksbank has used since 2011, the new index contains several indications for each sub-market. The degree of stress on the stock market, bond market, money market and foreign exchange market is now measured by means of three indicators for each respective market. Each indicator receives a value by being given an order of rank in relation to all of the previous observations since 1995. The index is then calculated as a squared mean value of the indicators, adjusted for correlations between them. This adjustment is made to emphasize periods when there is stress on several sub-markets at the same time. The authors consider that the new index provides a better measure of financial stress than the previous one, as it takes more information into account, is less sensitive to individual sub-markets and more clearly emphasizes period of widespread stress.

Read and enjoy!

Claes Berg, Joanna Gerwin and Per Sonnerby

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The global financial crisis seems to have led to a break in the trend in recent
decades toward a closer international integration of financial markets. To a
certain extent, this relates to the effects of the ongoing euro crisis, which
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probably also have a role to play and these may have a more lasting effect.
Greater fragmentation of the financial markets would result in costs in the
form of poorer capital allocation, risk diversification and competition on the
banking market. At European level, a properly structured banking union could
help to prevent such outcomes. The Swedish banks currently enjoy a favourable
competitive situation, partly because they are seen as safe counterparties
compared with many other European banks. Nevertheless, stronger European
banks outside Sweden are also preferable from a Swedish perspective, since
they improve competition and reduce the risk of pressure on the financial
markets.

The foreign exchange market is an important part of the financial system and
performs important functions for the real economy. Recently, trading in this
market has become increasingly automated as the use of electronic foreign
exchange trading and algorithms has increased. In this article, we analyse how
and why algorithmic trading is used on the market for Swedish krona. We also
analyse how this trading affects the functioning of the market. From interviews
with market participants, we reach the conclusion that algorithmic trading is a
component of competition-driven technological development. On the whole, it
should therefore contribute towards a more efficient foreign exchange market
with lower transaction costs. At the same time, it may entail certain risks for
both individual market participants and the financial system as a whole. Finally,
we observe that the market itself has worked out a practice for the functioning
of algorithmic trading in the foreign exchange market.

■ Further development of the index for financial stress for Sweden **46**

Tor Johansson and Fredrik Bonthron

This article describes the Riksbank's new index for financial stress for Sweden. The index is a tool for analysing the development of the financial markets and financial stability. The index aims to provide an aggregate measure of the financial stress in the various sub-markets. One improvement compared with the previous stress index is that the stress on each sub-market is measured using several indicators. It is also important that the levels assessed as normal for these indicators can vary over time. Consequently, in the new stress index, the indicators are systematically ranked at the same time as the comparison period is extended. A further improvement is that the weighting of stress on the various sub-markets more clearly draws attention to periods in which financial stress is widespread. In this article, we show how the new stress index describes the degree of financial stress in Sweden between 1995 and 2013.

The globalisation of the financial markets following the global financial crisis

Karolina Ekholm*

Professor, Deputy Governor.

The global financial crisis seems to have led to a break in the trend in recent decades toward a closer international integration of financial markets. To a certain extent, this relates to the effects of the ongoing euro crisis, which can be expected to diminish as the crisis subsides. However, new regulations probably also have a role to play and these may have a more lasting effect. Greater fragmentation of the financial markets would result in costs in the form of poorer capital allocation, risk diversification and competition on the banking market. At European level, a properly structured banking union could help to prevent such outcomes. The Swedish banks currently enjoy a favourable competitive situation, partly because they are seen as safe counterparties compared with many other European banks. Nevertheless, stronger European banks outside Sweden are also preferable from a Swedish perspective, since they improve competition and reduce the risk of pressure on the financial markets.

Introduction

When Lehman Brothers filed for bankruptcy protection on 15 September 2008, the international financial markets had already been showing signs of strain for over a year. The spreads on the interbank markets had been increased since summer 2007, not just in the United States, but also in the eurozone and the UK. Spreads also began to increase in Sweden in summer 2007. During this period, it was still unclear to most people just how much impact problems on the financial markets would have on the global real economy.

However, the fall of Lehman Brothers triggered an exceptionally rapid reduction in economic activity in large parts of the world. The financial disruption had its origins in problems on the US housing market, but it quickly affected the real economy around the world as a result of the strong globalisation of the financial markets. Globalisation had been underway for several decades, driven by a combination of political decisions to facilitate trading in financial assets and technical progress within information and communications.

The fact that the shock spread so rapidly and had such major consequences for the real economy, has led to the globalisation of the financial markets being viewed to some extent in a new light. The efficiency gains of more integrated markets have come to be weighed against possible risks in terms of maintaining the stability of the financial system. Policy-makers have become considerably more sceptical about financial integration. Particularly in countries with large financial sectors, the positive view of their own banks' international competitiveness has been tempered with concern about what a banking crisis can do to the economy. The experiences of countries such as Iceland and Ireland are alarming, where a collapse of the banking system wreaked havoc on public finances.

This article discusses how the pros and cons of financial integration can be viewed in light of the financial crisis and how the crisis has affected the integration process. The article also considers what changes new regulations for financial institutions may bring. Sweden is a country with a large financial sector relative to the economy as a whole. The Swedish authorities have therefore actively sought to tighten up requirements on the banks. The Swedish banks have also been quick to meet these requirements, even where they have only been issued in the form of recommendations. Their good level of compliance also seems to provide some competitive advantages, which improve the banks' ability to expand abroad and thus grow even larger.

The article begins with a discussion of the pros and cons of the international integration of the financial markets. This is followed by a section on how the financial crisis has affected the level of international integration on these markets. In some areas, integration seems to have declined but it is difficult to know whether this is a temporary or more lasting effect. Following this section, there is a discussion of new regulations and frameworks which have been introduced or are about to be introduced. Finally, I discuss what the consequences of the changed conditions on the financial markets can be expected to involve for Sweden.

Pros and cons of financial integration

EFFICIENCY GAINS AND IMPROVED RISK DIVERSIFICATION

The globalisation of the financial markets involves several aspects of financial integration:[1]

- opportunities for companies to invest abroad and to finance domestic investments using share capital or loans from abroad,

- opportunities for individual and institutional investors to trade in foreign securities, such as shares and bonds, and

- opportunities for banks to expand abroad and lend on international interbank markets.

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1   Alsén (2009) provides a comprehensive review of the globalisation of the financial market.

According to the theoretical literature, there are potentially major benefits from internationally integrated financial markets. Two main benefits are usually assumed:

- a better international allocation of capital, and
- a better diversification of risk.

A better allocation of capital can be obtained because savings in countries where the real return on capital is relatively low can be used to finance investments in countries where the real return on capital is relatively high. This generates potential gains as the limited investments which can be financed using total global savings are made where they provide the best return. The international trading of financial assets therefore enables the separation of national savings and national investments. The savings generated in developed countries with high income levels, such as Sweden, can be used to finance investments in rapidly growing developing countries, for example, where there is a great deal of scope for investments to increase productivity. The expected return on Swedish savings would be higher in this case, while at the same time, the financing of investments in emerging economies would be expected to help income levels in these economies move more quickly towards those of Sweden.

Whenever researchers have attempted to quantify this type of gain, however, they have found no evidence to suggest that it would be particularly large. An often cited study by Gourinchas and Jeanne (2006), for example, has concluded that the welfare benefits of going from a situation without any capital mobility to a situation with completely free movement of capital is roughly equivalent to a one per cent increase in consumption for a typical emerging economy.[2] One reason for the comparatively small estimated gains is that the low level of labour productivity associated with a low income level seems not to be primarily the result of a lack of capital, but is dependent on other factors, such as poorly functioning institutions.

The ability of financial integration to enable the better diversification of risk is due to the fact that the volatility in a country's income may be reduced as households own foreign assets, provided that macroeconomic developments differ between countries. Households are thus able to avoid reducing their consumption should the country experience a negative shock by holding assets with a return that is instead dependent on developments abroad. The results of empirical studies of the gains financial integration may bring as a consequence of better risk diversification are mixed – there are studies which indicate significant gains, but also studies which do not find any gains at all.[3]

Despite strong theoretical arguments for significant economic gains, the empirical literature as a whole therefore does not strongly support the idea that the globalisation of financial markets really has resulted in such gains. It is hard to say, however, whether this is because of the difficulty in measuring the gains which have nevertheless been made, or whether the gains are in fact small.

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2   There are studies which identify more significant effects, however, such as Hoxha, Kalemli-Ozcan and Vollrath (2009).
3   See, for example, Kose, Prasad and Terrones (2009).

GLOBAL IMBALANCES

A key observation is that the pattern for countries' net flows of capital does not follow what is theoretically expected in a situation where the capital markets are fully integrated. One way of studying the net flows is to follow the current account, which shows the difference between what is produced and what is absorbed during a given time period. If the value of what is absorbed exceeds the value of what is produced, there is a deficit which must be covered through an inflow of capital – a loan – from abroad. The loan must be repaid with interest in the future, however. When that day comes, the value of what is produced must exceed the value of what is absorbed, for example by exports of goods and services exceeding imports of goods and services. Countries with a current account deficit import capital, while countries with a current account surplus export capital. Those countries which import capital have a lower level of savings than is required to finance their own investments. Countries which export capital have a higher level of savings than is required to finance their own investments.

With fully integrated capital markets, we would expect that capital-rich high-income countries would tend to have a current account surplus and low-income countries with a shortage of capital would have a current account deficit. As can be seen from Chart 1, China and the emerging economies in Asia have had a surplus since the late 1990s, while the United States has had a large deficit for a long period. The United States is actually the country that imports the most capital in the world. China's capital markets are of course not particularly integrated with the rest of the world – the Chinese currency, renminbi, is not fully convertible to other currencies, for example. It is therefore not particularly surprising that China's capital flows cannot be explained by what would be expected in fully integrated capital markets. However, the phenomenon as such – that a relatively poor but rapidly growing country exports capital to a rich country with considerably less growth potential – appears to be the wrong way round and is often referred to in terms of global imbalances.

Chart 1. Current account of countries and regions, percentage of total global GDP
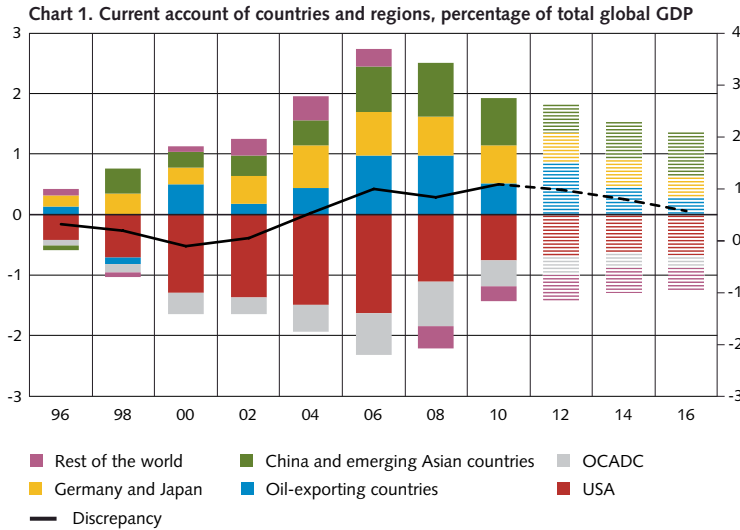
Note. OCADC comprise Bulgaria, Croatia, the Czech Republic, Romania, Hungary, Ireland, Lithuania, Poland, Portugal, Estonia, Greece, Spain, Turkey and the United Kingdom. The discrepancy arises because the total deficit does not exactly correspond to the total surplus.

Source: IMF WEO April 2012

These imbalances are often quoted as a contributory factor to the global financial crisis of 2008-2009. The widespread access to credit in the United States was partly the result of the rest of the world's willingness to invest in US assets and is considered to have contributed to the rapid increase in debt and thereby to greater vulnerability. As Table 1 shows, global savings increased between 2001 and 2008 from around 21 per cent to around 24 per cent of global GDP. In contrast, savings in the United States fell significantly during this period, from around 16 per cent to around 12 per cent. Savings increased primarily in China, the emerging economies in Asia, Germany and oil-exporting countries.

Table 1. Savings (S), investments (I) and the difference (S-I) as a proportion of GDP in each country or group of countries (percentage)

	2001			2008			2011		
	S	I	S-I	S	I	S-I	S	I	S-I
USA	16.5	19.1	-2.6	13.4	18.1	-4.7	12.2	15.5	-3.3
China	37.6	36.3	1.3	53.2	44	9.2	51.3	48.6	2.7
Emerging economies in Asia	27.6	24.2	3.4	32.6	27.6	5	32.6	25.9	6.7
Germany	19.5	19.5	0	25.5	19.3	6.2	23.9	18.3	5.6
Oil-exporting countries	33.3	24.8	8.5	38.9	25.6	13.3	36.4	24.7	11.7
World	21.4	21.5	-0.1	24.2	23.8	0.4	23.9	23.4	0.5

Note. Savings and investments for the world as a whole are the same size by definition. The fact that they are slightly different in the table is the result of measurement errors.

Sources: Berg (2012, table 17.3, page 365) and IMF (2012a, 2012b)

There are several potential explanations for this development. The low level of savings in the United States is partially the result of negative savings in the public sector; in other words a large, persistent budget deficit. According to the twin deficit hypothesis, there is a strong positive correlation between a budget deficit and a current account deficit.[4] However, US household savings were also low throughout the first decade of this century and a large proportion of the growth in consumption in the US has been driven by credit. In China, the lack of publicly provided social security systems has created a need for high levels of saving among households. So, although investment has been very high in China, savings have been even higher. Cabellero, Fahri and Gourinchas (2009) suggest that the lack of traded financial instruments in China results in savings being channelled, to a great extent, through capital flows to a country such as the United States, with well-developed financial markets. According to their analysis, this may continue for as long as this difference in financial development exists.[5]

Table 1 also shows that US savings as a proportion of GDP fell further between 2008 and 2011 by more than one percentage point. At the same time, investments as a proportion of GDP fell by over 2.5 percentage points. The reduced difference between savings and investments is reflected in a reduced current account deficit (see Chart 1). If the proportion of investments returns to the levels seen in the United States prior to the financial crisis, the current account deficit can be expected to increase again.

Countries with persistently large current account deficits often run into problems. The deficit in itself means that an initially negative net asset position vis-à-vis the rest of the world increasingly becomes larger, and sooner or later this debt must be repaid. If the creditors lose confidence in the country's economic prospects, they may not be willing to refinance the loans, which risks triggering a crisis where the country must move quickly from a deficit to a surplus.

Many developing and emerging economies with large, persistent current account deficits have been affected by a sudden dramatic reduction in or complete evaporation of the willingness of the rest of the world to finance further deficits. This affected many countries in Asia, for example, during the so-called Asian crisis.[6] The only ways of moving from a deficit to a surplus are either by obtaining more income from abroad – for example through increased exports – or by reducing expenditure on payments going abroad – for example through reduced imports. It is rarely possible to increase exports in the short term, so in practice it is imports that must be reduced through lower consumption and less investment. This takes place through a general downturn in the economy, where production and incomes may fall significantly – a process which can lead to social unrest and political instability.

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4   See Normandin (1999), for example.
5   The idea that the US could have a current account deficit for the foreseeable future is also supported by an analysis by Gourinchas and Rey (2007), which shows that the US nevertheless has a net inflow in terms of return on assets and liabilities compared with the rest of the world.
6   See, for example, Corsetti, Pesenti and Roubini (1999).

Before the financial crisis, there were many who expected something like this to happen to the United States. What triggered the global financial crisis in 2008-2009, however, was in many ways a different process. It was not about a sudden reduction in the world's willingness to invest in US assets, but was more a crisis of confidence within the US financial sector, which was heavily indebted and exposed to bad mortgage loans through complex financial products. When the problems on the US financial market spread and developed into a global financial crisis, the world's interest in investing its assets in US securities actually increased, which among other things resulted in an appreciation of the dollar and falling interest rates for US government securities.

RISKS ASSOCIATED WITH LARGE GROSS FLOWS

Behind the net flows of capital which are reflected in the current accounts, there are very large gross flows. These gross flows can affect the stability of the system over and above the global imbalances caused by the net flows. Some even believe that any stability problems caused by the net flows are dwarfed by those caused by the gross flows.[7] The net flows which a current account surplus or deficit entails, result in a change in the wealth position vis-à-vis other countries, as a surplus increases net assets and a deficit net liabilities vis-à-vis the rest of the world. However, these changes in the wealth position can be almost negligible relative to the changes which result from capital gains and losses on the stock of assets and liabilities which the country has in relation to the rest of the world. These gains and losses arise partly because the value of various types of assets changes and partly because the exchange rate moves, changing the value in domestic currency of assets and liabilities denominated in foreign currency.

It would appear that the large gross flows derive to a great extent from various types of debt instruments, particularly short-term loans within the banking sector (Obstfeld, 2012). Chart 2 shows the outstanding stocks of interest-bearing securities which are traded on the international money and bond markets. These stocks increased strongly until the financial crisis hit, but since then they have remained quite stable at just over the USD 20 trillion mark. As the chart shows, a large proportion of international trading in interest-bearing securities takes place in securities denominated in EUR. The majority of these securities are issued by banks and other financial institutions.[8]

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7   See, for example, Borio and Disyatat (2011).
8   In September 2012, financial companies were the issuers of around 75 per cent of the outstanding stock of international interest-bearing securities (BIS, 2012).

Chart 2. International trading in interest-bearing securities by currency, value of stocks, USD billion
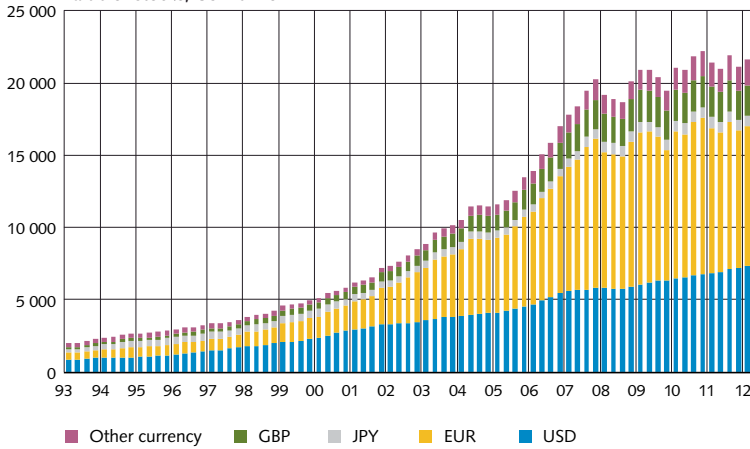
Note. Before 1999 the category EUR consists of interest-bearing securities in the currencies of the initial euro area countries and the European Currency Unit (ECU).

Source: BIS (2012)

Trading in debt instruments involving large volumes may create risks for financial stability. This is because short-term loans tend to increase the refinancing risk and thereby the risk of liquidity problems spreading rapidly through the system, affecting more financial institutions. The gross flows create problems because the foreign assets acquired by certain players in the market cannot be used to cover the liabilities generated by others in a situation where the latter experience liquidity problems.
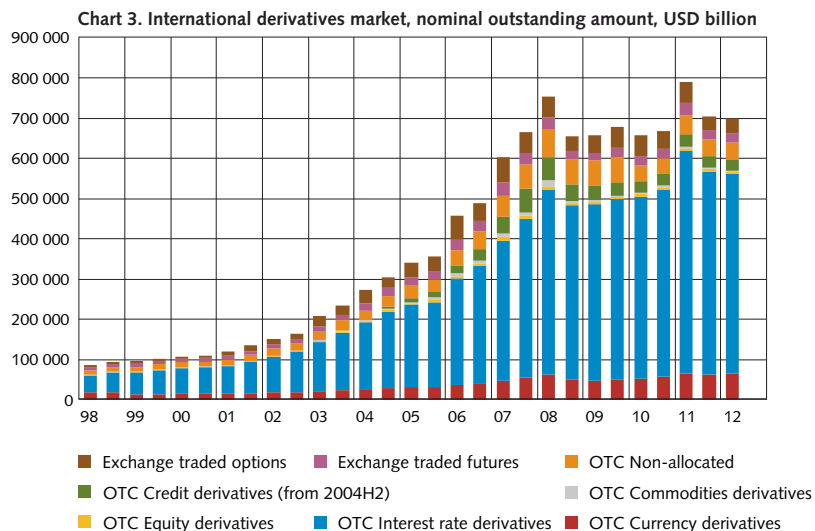
This is therefore one way in which the globalisation of the financial markets can have a negative impact on financial stability. Large gross flows of capital bring a risk of major knock-on effects between different markets, where problems in one country spread to other countries and there is a snowball effect where the problems get bigger and bigger, as do the costs of handling them.

RISKS ASSOCIATED WITH DERIVATIVES TRADING

One segment of the financial market that has come under scrutiny in connection with the financial crisis is the market for financial derivatives. Derivatives are securities which are linked to the value of an underlying asset, such as shares, bonds, commodities or currencies. They are used, among other things, to hedge against a fall in value of the underlying assets and can therefore improve risk management. However, there are also obvious speculative elements to derivatives trading. It enables bets that the value of the underlying asset will move in a certain direction. The wrong bet can result in very heavy losses. Derivatives are also often complex, which may have contributed to the difficulty of both the supervisory authorities and the management of the institutions trading in derivatives to grasp the risks involved. The major insurance corporation AIG (American

International Group), for example, made such large losses on credit derivatives in 2008 that the company would have gone bankrupt without the support of the US government.

International trade in derivatives grew very strongly during the years leading up to the financial crisis. Chart 3 shows that the outstanding value of derivatives traded on international markets amounted to around USD 750 trillion in 2008. Since then, this value has remained comparatively stable at around USD 700 trillion.

Chart 3. International derivatives market, nominal outstanding amount, USD billion

- Exchange traded options
- Exchange traded futures
- OTC Non-allocated
- OTC Credit derivatives (from 2004H2)
- OTC Commodities derivatives
- OTC Equity derivatives
- OTC Interest rate derivatives
- OTC Currency derivatives

Sources: BIS "OTC derivatives statistics" and "Exchange traded derivatives"

Most derivatives trading takes place on the OTC market, that is outside organised exchanges, and the underlying assets are primarily interest-bearing instruments. The fact that such a large proportion of trading takes place without a central counterparty makes it difficult for the authorities to obtain adequate information about the trade in order to see the risks involved. In recent years, efforts have been made at an international level to get more of the trading in derivatives onto exchanges or other kinds of central counterparty.

CROSS-BORDER BANKING ACTIVITIES

Another aspect of financial integration is the increased significance of cross-border activities for banks. The experiences of the past few years have shown that it can be very difficult and costly to deal with banks beset by problems in a cross-border context. This is partly because there are many stakeholders involved in the process and partly because the rules for winding up a financial institution are even more inadequate internationally than they are nationally. Since governments are accountable to their respective parliaments, and ultimately the voters, there is also a strong tendency to favour national solutions. During

the financial crisis there were also several poorly coordinated crisis solutions implemented, which resulted in extensive government support being given to banks.[9]

Nevertheless, there are some who maintain that cross-border banking as a whole strengthens rather than weakens financial stability.[10] Foreign banks are generally not as susceptible to government pressure to lend to "prioritised borrowers" as domestic banks, particularly if the latter are partially state-owned. Foreign banks can therefore help to increase the overall quality of loan portfolios. Since foreign banks are active on more than one market, they also usually have a more geographically diversified credit portfolio. This means that they run less of a risk of being affected by any pressures which may be brought to bear on the local market. They also generally have better conditions for obtaining international financing and may therefore find it easier to deal with any liquidity problems that may arise.

The financial crisis and the degree of integration

Globalised financial markets are usually considered to be a modern phenomenon. However, much of the internationalisation that has taken place since the early 1980s is in some respects a return to the situation that prevailed before the outbreak of the First World War. At that time, the financial markets around the world were highly developed and there were large movements of capital between countries.[11] In contrast, during the period from the depression of the 1930s to the end of the 1970s, the financial markets were regulated and opportunities to buy foreign assets were limited. During the 1980s, most restrictions were gradually lifted in Western countries and Japan, and the economies were once again opened up to capital flows. During the 1990s, developments in information and communication technology contributed to even greater financial integration and new financial instruments were created and launched on the market.

FINANCIAL OPENNESS

One way of studying developments in relation to the regulation of cross-border financial transactions is to gauge the so-called financial openness of countries. A measurement of this is shown in Chart 4. According to this, financial openness for the world as a whole has gradually increased since the 1980s. The increase has been especially noticeable in Europe.

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9   The handling of Fortis and the default of the Icelandic banks are clear examples of this.
10 See, for example, Barba Navaretti, Calzolari, Pozzolo and Levi (2010), Goldberg (2002, 2004, 2008).
11 See, for example, Obstfeld and Taylor (2004).

Chart 4. Financial openness of countries, Chinn-Ito index
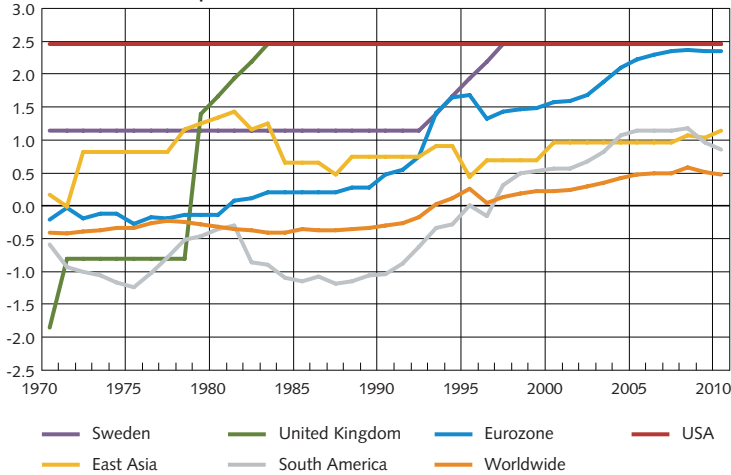
Note. The index is based on binary dummy variables which codify the tabulation of restrictions for cross-border financial transactions as reported in the IMF *Annual Report on Exchange Arrangements and Exchange Restrictions* (AREAER). The data used for the various geographical areas is unweighted averages. For further information, see Chinn and Ito (2008).

Sources: http://web.pdx.edu/~ito/Chinn-Ito_website.htm and the Riksbank

It is difficult to say with any degree of certainty what effect the financial crisis has had on this trend, as it is only a relatively short time since the crisis hit and the world has still not returned to normality. What was originally a global financial crisis has now turned into a European debt crisis, which continues to create pressure on the financial markets. Chart 4 nevertheless shows that the increase in financial openness for the world as a whole has tailed off in recent years.[12] The underlying trends here are for less openness in South America and slightly increased openness in Asian countries. As the chart shows, South America has a history of a lack of financial openness and it was actually only towards the end of the 1990s that financial openness in South American countries, as measured here, exceeded the average for the world as a whole.

One consequence of the financial crisis has been very low monetary policy rates in those countries whose real economy has been hit especially hard. This applies to the United States, the eurozone and the United Kingdom. Many emerging economies have experienced a strong inflow of capital during this period, which to a certain extent originates from the investors' strategy of generating arbitrage profits by borrowing at low interest rates in the United States, Europe and Japan and then investing at higher interest rates in the emerging economies, so-called "carry trade". In countries that are subject to such capital inflows, the inflows may be considered a destabilising force, as they create upwards pressure on asset prices and the value of the currency. Many countries have also taken steps to limit such inflows, such as Brazil, South Korea, Peru and Thailand. In Brazil, in particular, there have been a lot of strains with regard to capital inflows from countries

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12 The index measures a country's openness based on its capital account. It was introduced by Chinn and Ito (2006).

with low policy rates and representatives of the Brazilian government have even spoken of a "currency war".[13] The fact that the central banks of many countries are also attempting to keep long-term interest rates low through the purchase of assets and other unconventional methods, has further fuelled the debate about a currency war.

Whether the measures to restrict the inflow of capital have had any positive effect is currently the subject of widespread discussion, without any consensus having been reached.[14] However, a lot of attention has been directed towards the fact that an organisation such as the International Monetary Fund (IMF), which previously has advocated free capital movements, has revised its position and is now stressing the problems that capital flows may bring (IMF, 2012c). The IMF also considers that the decision-makers in the countries which generate capital outflows have a responsibility and should bear in mind how their decisions affect the economic and financial stability of other countries.

REDUCED BANK LENDING

The emerging economies may be affected by other indirect effects of the handling of the financial crisis, however. As a result of the more stringent capital requirements imposed on the banks both by the authorities and by potential investors in the wake of the financial crisis, many banks have had to reduce their balance sheets. Banks with cross-border activities often cut back on their lending abroad first. This can create problems in countries where the banking sector is dominated by foreign-owned banks – which is often the case in emerging economies – as there is a risk of a reduction in the supply of credit, which in turn can dampen economic activity. To a certain extent, a reduced supply of bank credit can be expected to have the opposite effect on the economy compared with capital inflows. The effect on a particular emerging economy of the expansionary monetary policy of the United States, Japan and Europe and the more stringent requirements on the banks therefore depends on which effect dominates.

The Bank for International Settlements (BIS) collects data on the foreign assets and exposures of banks. Chart 5 shows the foreign exposure of banks since 2005 according to data from the BIS. This is not a perfect measurement of the banks' lending abroad, but it gives an idea of how their foreign assets evolve. For the world as a whole, we can see a clear increase in these exposures in the years leading up to the financial crisis, followed by a marked fall in 2008. Since then, exposures have remained at a more or less constant level. We can see that there are no signs of reduced exposure for UK and US banks – in the latter case quite the reverse, as exposures increased slightly in 2008-2009. In contrast, the foreign exposures of banks in the rest of Europe have clearly declined.

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13 Brazilian finance minister Guido Mantega warned of a currency war in September 2010.
14 A study by Klein (2012) finds these measures to have little effect, for example.

**Chart 5. Foreign exposure of banks, USD billion**

Note. Banks in all reporting countries include those countries whose banks (at least 90 per cent of the banking system in the respective country) report to the BIS. There are 30 of these countries in total. Banks in the rest of Europe include banks in all European countries which report to the BIS, excluding the United Kingdom.

Source: BIS

The IMF has highlighted the risk that the reduction of European banks' activities in Asia may create problems in terms of access to trade credits and financing of major investment projects there (IMF, 2012d, chapter 2). European banks have typically dominated within these market segments. To a certain extent, this creates opportunities for banks from other countries to increase their market shares. However, financing major investment projects, in particular, is a highly specialised activity and it can be difficult for other banks to fully compensate the reduced supply of credit from European banks, since this often requires syndicated loans with long maturity.

With regard to trade credits, on the other hand, it appears that banks from other regions have taken over some of the market shares of the European banks in Asia. There are indications of this in particular with regard to Australian and Japanese banks. Chart 6 shows the exposures of banks to countries in Asia divided into European, Japanese and Australian banks. It can clearly be seen that the exposures of the European banks to countries in Asia fell significantly in 2008 but then started to increase again. However, the chart suggests that these exposures then fell during 2011. It appears that the exposures of Japanese and Australian banks to countries in Asia have increased somewhat, although overall they are at a considerably lower level than those of the European banks.

Chart 6. Bank exposures to countries in Asia, USD billion

— Banks in Europe — Banks in Australia — Banks in Japan
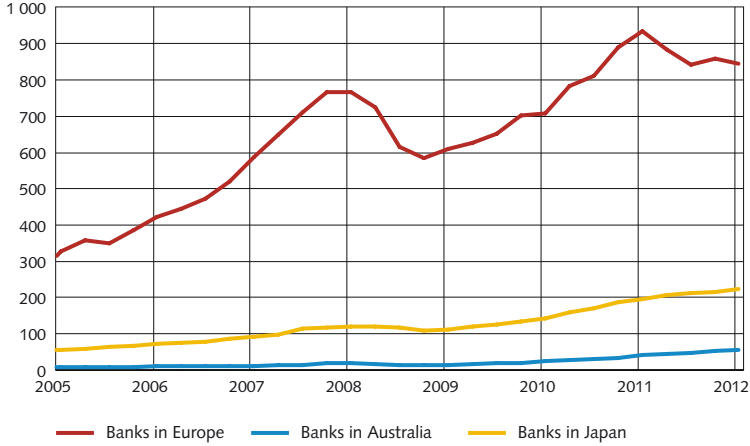
Note. The data in the chart refers to banks which report to the BIS. Japan is excluded from countries in Asia.

Source: BIS

The foreign exposures of Swedish banks have generally not declined. This can be seen in Chart 7. Exposures in the Nordic countries have continued to increase, while exposures in the Baltic States have fallen off. Exposures in the rest of Europe have remained relatively constant since 2005.

Chart 7. Foreign exposures of Swedish banks, USD billion

— The Nordic Region — The Baltic States
— Eastern Europe — Other EU countries
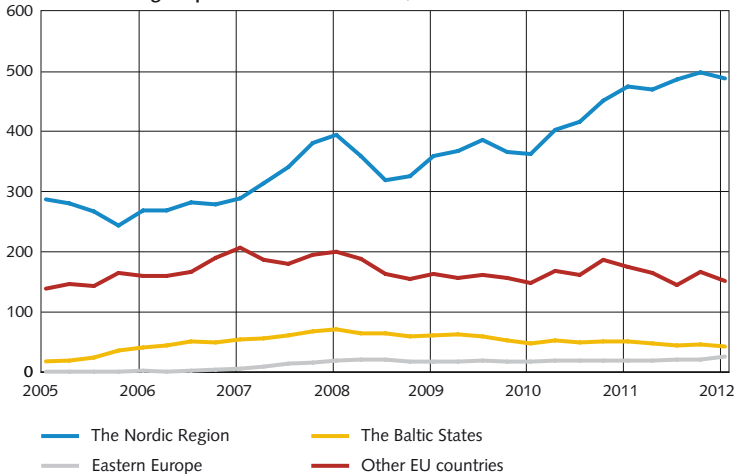
Note. The data for other EU countries excludes the Baltic States and Poland. Eastern Europe comprises Poland, Ukraine and Russia.

Source: BIS

The picture is a little different, however, if we focus on the Swedish banks' lending in the Baltic States, which can be seen in Chart 8.[15] The Swedish banks have clearly reduced their lending there as a result of the financial crisis. This is particularly true of Latvia and Lithuania, while the reduction is less pronounced in Estonia.

Chart 8. Swedish banks' lending in the Baltic States, EUR million

Estonia   Latvia   Lithuania
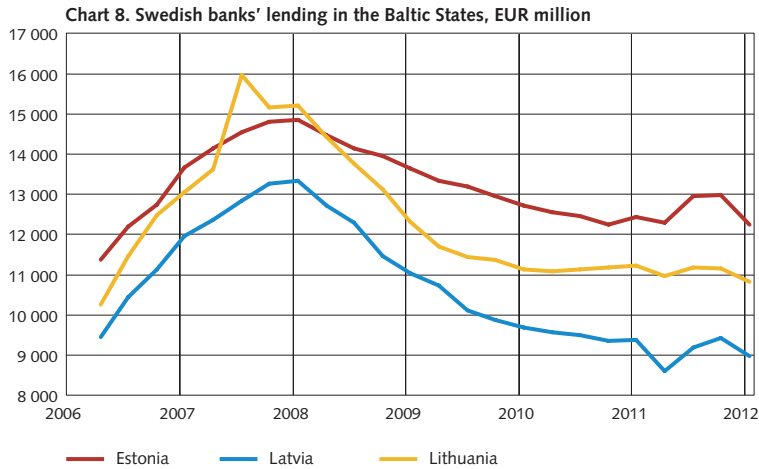
Sources: The banks' annual reports and the Riksbank

On the whole, it appears that countries in Eastern and Central Europe have been hit the hardest by the reduction in banks' lending abroad. The reduction in bank lending in emerging economies is largely driven by the problems the banks are experiencing. Since banks experiencing problems are primarily banks from the eurozone and as it is mostly these banks that have foreign operations in eastern and central Europe, the cutbacks there have been particularly severe.[16] Whether this constitutes an economic problem for these countries is not easy to determine, however. In some respects, the development in eastern and central Europe has been reminiscent of that in southern Europe and Ireland before the crisis, with large current account deficits combined with rapidly rising unit labour costs, indicating a deterioration in competitiveness. This development was probably not sustainable in the long run. More restrictive lending should therefore at least partially represent an adjustment to the underlying growth conditions, which may not have fully justified the growth in credit observed before the crisis.

15 The exposures shown in Chart 7 are reported on the basis of the country which ultimately bears the risk, which is not always the same as the country where the lending takes place. Therefore, the exposures shown in Chart 7 differ from those shown in Chart 8.

16 For an empirical analysis of the factors behind the reduction in lending in emerging economies, see Avdjiev, Kuti and Takáts (2012).

THE INTERBANK MARKET

According to the latest statistics from the BIS, activity on the international banking markets has recently declined considerably (BIS, 2012, 2013). Cross-border claims between banks have contracted every quarter since Q4 2011 (the latest provisional statistics relate to Q3 2012). During the second quarter of 2012, cross-border claims between banks in developed economies reduced by USD 344 billion. Most of this reduction can be attributed to reduced claims on banks in the UK and the United States. A smaller portion can be attributed to reduced lending to banks in the eurozone, primarily in Germany, Spain and the Netherlands. The reduction in cross-border claims was mainly driven by a reduction in loans between various parts of international banking groups.

The Swedish banks appear to have remained relatively unaffected by the reduced activity on the interbank market, however. They continue to enjoy good access to funding, not least short-term funding in USD. Chart 9 shows how the US money market funds' exposures to European banks have developed since the financial crisis. These funds have reduced their total exposures to European banks by over half, from around USD 1 100 billion during autumn 2009 to around USD 500 billion during autumn 2012. Their exposures to the Nordic banks have remained more or less constant during this period, however.

Chart 9. US money market funds' exposures, USD billion
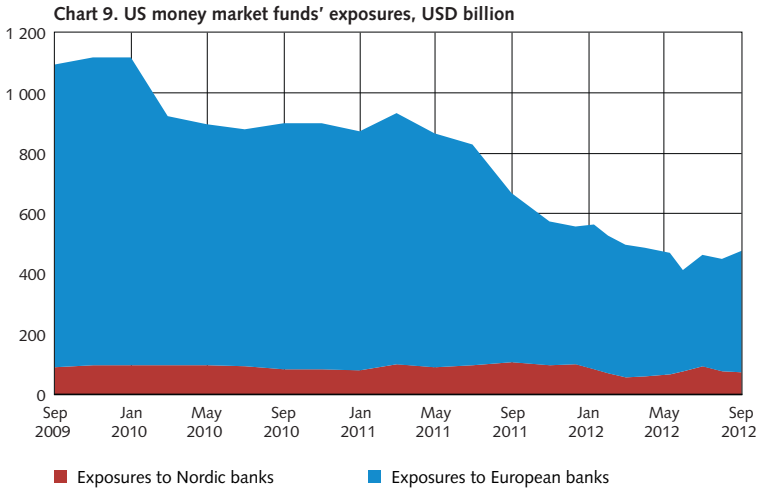
Sources: Fitch Ratings and the Riksbank

Thus, overall there is a clear indication that the financial crisis has set globalisation back somewhat. Some countries have reintroduced restrictions on capital inflows. Some cross-border banks have focused their activities more on their home countries, thereby becoming more national in nature. It is too early to tell whether this development is temporary – something which in the future will appear as a kink in the curves – or a new trend.

New rules create new challenges

New regulations for the activities of financial institutions are being drawn up and introduced around the world. This may result in more lasting changes of the global financial markets. The new regulations are more stringent and are being designed on the basis of the deficiencies revealed during the financial crisis. Extensive efforts have been made internationally in recent years to implement new regulations. The aim has been to dramatically reduce the likelihood of a global financial crisis happening again and to ensure that the costs of future global crises will be significantly lower should they nevertheless arise.

Some believe that the recent regulation brings a risk of returning to the world as it was before the days of deregulation, with financial markets performing their basic functions poorly: that is processing payments, turning savings into financing, and managing risks. This was also a world with significantly less internationally integrated financial markets than in recent decades. Others believe, in contrast, that the new rules are not strict enough and are far too close to the situation before the financial crisis. It is difficult to determine exactly what the right approach is in this area, so the discussions about how the regulations should be designed are in all certainty set to continue.

BASEL III ACCORD

For Sweden, the regulations agreed upon within the EU are of major importance, since these can be expected to be binding. The EU reforms are affected in turn by the negotiations underway at international level to agree on which rules all countries should introduce. The Basel Committee, which is an international committee that makes recommendations on banking regulations, has been working since the financial crisis to provide new recommendations in precisely this area. The new recommendations are known as the Basel III Accord (Basel Committee on Banking Supervision, 2010a, 2010b). The basic principles of the new regulations are that the banks will be required to hold more and better-quality capital and to have liquidity buffers.

Work is currently underway to implement the Basel III Accord in many parts of the world. At EU level, the new requirements for how much and what kind of capital the banks must hold will be implemented in a new Directive and a new Regulation (usually referred to together as the CRD IV Package or CRD IV/CRR). The European Commission has submitted a proposal, on which there has not yet been a final decision. The Swedish government has been critical of some elements of this proposal. One such element is that the capital requirements imposed on banks within the EU should be completely harmonised. That is, they will not just be set on the basis of a specified minimum level, but will also have an upper limit, so-called maximum harmonisation. This is problematic from a Swedish perspective, since both the government and authorities such as Finansinspektionen (the Swedish financial supervisory authority) and the Riksbank want higher capital requirements than the minimum levels recommended by the Basel III Accord, which risk

also becoming maximum levels. The argument for having higher capital requirements in Sweden is that the Swedish banks represent a greater risk than banks in other countries simply because of their size relative to the economy as a whole. The experiences of countries with small economies and a large banking sector – such as Ireland and Iceland – show that the consequences of a banking crisis can be disastrous. There is therefore good reason for the Swedish authorities to impose stricter requirements so as to make the Swedish banks less vulnerable.

However, so far this argument does not seem to have met with much sympathy in the negotiations on the CRD IV Package. The Commission's analysis has been based on the idea that capital requirements that are higher in one country than in other countries would risk giving a competitive advantage to that country's banks, as they would appear to be better and therefore able to obtain cheaper funding. The underlying justification for this approach is the desire to create rules which mean that all banks within the EU compete on the same terms, in other words, the desire to create a level playing field. If the authorities in one country impose stricter requirements than in the other countries, they would be guilty of so-called gold-plating, where a country gives its own banks a seal of approval which says they are better than the banks of other countries.

A EUROPEAN BANKING UNION

The CRD IV Package is part of a much larger package – launched by the Commission – which aims to create a European banking union. In early autumn 2012, a proposal was submitted for a single supervisory mechanism for banks within the eurozone, with the European Central Bank (ECB) as the responsible authority. The single supervisory mechanism is intended to represent the first step on the road to a banking union. The other steps involve a common deposit guarantee scheme and common rules for preventing bank failures and for intervening when a bank gets into financial trouble. In December 2012, the Council of the European Union agreed that from 1 March 2014, the ECB should assume responsibility for the supervision of larger banks in the eurozone. The other elements of the banking union proposal will be discussed during 2013.

It is widely recognised that an integrated European financial market is poorly suited to today's regulatory framework and institutional structures, where regulation, supervision, deposit guarantee schemes and crisis management are at national level. This has also been the subject of discussion for many years. The complexity of the problem has been appropriately described as the European financial trilemma. This refers to the impossibility of achieving the three goals of financial stability, financial integration and national financial independence at the same time (Schoenmaker, 2011).

Thus far, EU Member States have chosen to prioritise financial integration and their national decision-making powers. The financial crisis, however, has clearly shown that financial stability and financial integration cannot be achieved at the same time as pursuing a strict national policy. The initiative to raise not just banking regulation, but

also supervision, the deposit guarantee system and the framework for handling financial institutions in crisis to a supranational level should therefore be welcomed.

However, as is often the case with new large-scale regulations, the devil is in the details. At present, there is only a detailed proposal for the first stage: establishing a single supervisory mechanism. Detailed proposals for the other two stages – a common deposit guarantee scheme and a common framework for bank resolution – will be submitted at a later date. However, a single supervisory mechanism without the other two elements in a banking union may result in a system that is at least as fragile as the previous entirely national regulations. It is difficult, for example, to foresee what would happen in a situation where the ECB decides to revoke a bank's permission to operate. Such a situation could be costly for the taxpayers in the bank's home country where the government is compelled to take over the bank or otherwise support it in order to avoid a banking crisis.

The single supervisory mechanism applies initially to the eurozone countries, although EU Member States outside the eurozone are allowed to participate on a voluntary basis. An important question for Sweden in the future is whether we should remain outside or join the banking union. The Swedish government has been critical of the proposal and declared that, at least initially, Sweden will not join. The government has stressed the need to be able to impose higher capital requirements on the banks and also to be able to influence the decisions made, something which was not possible for countries outside the eurozone in the Commission's original proposal. The government has also emphasised that it wants to ensure that Swedish tax revenues are not used to rescue banks in countries which have not taken adequate responsibility for ensuring that the banks are stable.

The government nevertheless appears willing to work towards a single mechanism for bank supervision that is designed in such a way that it will be possible for Sweden to join at a later date. In order for the government to want to join in the future, however, there probably has to be greater clarity with regard to how the other elements of a European banking union will be designed, as well as guarantees that Swedish taxpayers will not be forced to pay for failing banks in other countries.

The desire to create common frameworks can nevertheless be seen as something positive, as it would be a concern if the European banking market were to become more fragmented and national. One general problem with the banking sector is that it is highly concentrated and there is therefore a tendency towards anticompetitive behaviour. One reason for this high level of concentration is without doubt the relatively strict regulation compared with many other sectors. Regulations tend to create barriers to market entry and exit. At the same time, however, it seems that the dynamics of banking crises are such that the banking sector tends to become more concentrated after a crisis than it was before. A common solution when banks get into difficulty is to get a competitor to buy them. Sweden is a good example of this. The Swedish banking crisis in the early 1990s led the number of major banks to shrink from seven to four through acquisitions.

One of the few things that may reduce anticompetitive behaviour on a concentrated market is external competition. When new players enter local banking markets, this can result in increased competition and efficiency gains, which are passed on to consumers in the form of a wider range of financial services and lower prices.[17]

It is therefore important to safeguard the common banking market within the EU. This is far from easy, however, at a time when some countries are experiencing problems with their banking sectors. It would require these countries to deal with unrealised losses on the banks' balance sheets and to restructure the banking sector. But the stakes are high and powerful special interests may complicate the political process required to carry out restructuring.

MACROPRUDENTIAL SUPERVISION

There is a closely related and partially overlapping area where new regulations are being drawn up: macroprudential supervision. This is a policy area which aims to reduce the level of risk in the financial system as a whole, not just at individual institutions. Some of the tools used for this purpose include countercyclical capital buffers, lending ceilings, risk weights and liquidity requirements.

At European level, the European Systemic Risk Board (ESRB) has been formed. The ESRB is the body responsible for the overall macroprudential supervision of the financial system in the EU. Its tasks include collecting and analysing relevant information as well as identifying and assessing systemic risk. The ESRB does not have any direct regulatory powers of its own, however, but has to rely on the national authorities taking action when the Board issues warnings and recommendations.

Macroprudential supervision may also have effects on the degree of international integration of the financial markets. It is easy to imagine a conflict of objectives when countries are to carry out macroprudential supervision of what are fundamentally highly globalised markets. Increasing a countercyclical buffer in a country in order to reduce the vulnerability of the banks, for example, may have a negative impact on lending in other countries where the country's banks are established. The effect of introducing a mortgage ceiling in order to reduce household debt may be small if branches of foreign banks which are not covered by the mortgage ceiling increase their lending. Such cross-border externalities may create friction between countries and encourage a negative view of the high degree of integration from which the externalities ultimately derive. The ESRB is intended to be a forum where the EU Member States can inform other Member States of their macroprudential supervision and resolve any conflicts which arise from undesirable side effects in other countries. This will remain an important task of the ESRB, despite the fact that its role as the European macroprudential supervision body has become somewhat

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17 On the other hand, increased competition can have a negative impact on financial stability. Goodhart (2012) has maintained that the lack of competition was a major reason for the stability of the UK financial system between 1930 and 1970. He believes that bank managers take fewer risks if they can generate large profits without too much effort.

unclear in light of the ECB's new role as having ultimate responsibility for banking supervision within the eurozone.

CENTRAL COUNTERPARTY CLEARING OF FINANCIAL DERIVATIVES

As previously mentioned, work is currently underway at international level to steer some of the OTC trading in financial derivatives towards central counterparties. This work is being led by the Financial Stability Board (FSB), which is an international group primarily made up of representatives of the G20 countries. It wants all standardised derivative contracts to be traded through central counterparties and for OTC trading in derivatives to be linked to higher capital requirements.[18] If more derivative trading takes place with central counterparties, these counterparties can be expected to become key players on the financial markets. They may even become systemically important in the same way as a lot of banks are systemically important today. The authorities therefore need to ensure here that these parties have sufficient capital and properly functioning risk management, and that they can be wound down in an orderly manner if required.

Many central counterparties clear transactions in multiple currencies. In London, for example, LCH.Clearnet clears transactions in several currencies, including the euro. Similarly, in Stockholm NASDAQ OMX clears some transactions in euros. According to the ECB's location policy, however, significant amounts in euros should only be cleared by central counterparties in the eurozone, which may present a further obstacle to the continued globalisation of the financial markets.[19] The ECB's position is based on the view that supervisory bodies in the eurozone should exercise complete operational control over parties which influence the financial stability of the eurozone. However, if everyone adopts this view, central counterparties will inevitably become national in nature and some of the benefits of trading in multiple currencies will be lost. It is difficult to assess the size of these benefits, but it nevertheless appears to be an ineffecient solution for the global economy as a whole to have relatively small central counterparties clearing trade in derivatives in each individual currency area. A better solution would probably be to develop international cooperation in this area so that central banks and supervisory authorities support one another with the information necessary to ensure financial stability at home.

Conclusions and consequences for Sweden

International integration of financial markets is expected to bring economic gains, although it is not without risk. The risk relates to global imbalances reflected in large and persistent current account surpluses and deficits. If a deficit is no longer sustainable, countries may have problems adapting to a new situation. The risk also relates to large gross flows of

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18 See G20 communiqué from the summit in Pittsburgh in September 2009 (G20, 2009).
19 This policy resulted in the UK government taking the ECB to the Court of Justice of the European Union in September 2011 for contravention of European Union law and of the internal market.

capital between countries. These create risk as the foreign liabilities that some parties have amassed cannot be covered by foreign assets amassed by other parties.

Very recently, however, it appears that the globalisation of the financial markets has come to something of a standstill and on some segments even started to reverse. It seems that this is largely the result of problems in the eurozone, as it mostly relates to reduced lending by and to European banks. It is entirely possible that globalisation will pick up again once the problems in the eurozone begin to subside. However, new regulations also probably play a role and their impact may be of a more lasting nature.

Greater fragmentation of the financial markets would result in costs in terms of poorer capital allocation, risk diversification, and competition on the banking market. At European level, however, a properly structured banking union could help to prevent such outcomes.

For Sweden, the plans for a European banking union are something which policy-makers need to deal with, whether or not Sweden participates. If Sweden does not participate, the ECB will nevertheless form part of the supervisory colleges that exist in order to enable authorities in different countries to work together on the supervision of cross-border banks. The ECB will be the supervisory authority for the eurozone countries and other EU Member States who choose to participate in the single supervisory mechanism. This means that even if Finansinspektionen holds the chairmanship of the colleges established for the Swedish banks, the ECB will probably have a major influence on the decisions made.[20] If Sweden were to join subsequently, the decisions on the supervision of Swedish banks would be made by the ECB, and Finansinspektionen would become a kind of branch office performing some of the day-to-day tasks of supervision. In both cases Swedish decision-makers would lose some of their control over the Swedish banks.

The Swedish banks currently enjoy a favourable competitive situation. The confidence in them on the international markets seems high and they are able to obtain comparatively cheap funding. They are relatively well-capitalised and have a good liquidity position. This makes them attractive counterparties. However, to a certain extent their favourable funding situation may be a consequence of the Swedish authorities imposing more stringent requirements regarding capital and liquidity than in many other EU Member States. From this perspective, the argument of "gold-plating" may have a certain bearing on the development of the Swedish banks. A side effect of the more stringent requirements may be that the Swedish banks are favoured in international competition and therefore are able to increase their market shares and grow even larger. This would be something of an irony, as the size of the banks is precisely the reason why Swedish authorities have been tougher than those in other countries.

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20 In the original proposal there was also a risk that the ECB's opinion would always prevail if supervisory authorities were in disagreement and the European Banking Authority (EBA) was called in to mediate. This was because in the initial proposal, the eurozone countries would always have a majority at the EBA in so-called binding mediation. This part of the proposal has been modified, however, and the voting rules are now intended to guarantee that countries outside the single supervisory mechanism will also be able to exercise influence over decisions.

The Swedish banks' good access to short-term funding in US dollars brings some risks from a stability perspective, as it may be difficult for the Riksbank to provide liquidity support in US dollars in a crisis situation. The Riksbank did provide such support during 2008 and 2009, but at that time the Riksbank, like many other central banks, had a swap agreement with the Federal Reserve which facilitated this support. The realisation that a liquidity crisis may involve currencies other than Swedish kronor is the reason why the Riksbank has recommended that the banks fulfil liquidity requirements in both US dollars and euros, which is something that the four major banks now do (Sveriges Riksbank, 2012, p. 18).

The most important reason for the favourable funding situation of the Swedish banks, however, is probably the euro crisis. This has resulted in Swedish banks appearing to be safer counterparties than many other European banks. As the euro crisis subsides, it can therefore be expected that the Swedish banks will lose some of the favourable competitive position they currently occupy. Although this would mean Swedish banks losing market shares, it would nevertheless be a very welcome development. Stronger European banks outside Sweden are preferable, even from a purely Swedish perspective. Sweden benefits from a well-functioning financial sector in the eurozone, as this not only promotes competition but also reduces the risk of pressure on the financial markets escalating in such a way that it also affects fundamentally sound banks.

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Algorithmic trading in the foreign exchange market

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The foreign exchange market is an important part of the financial system and performs important functions for the real economy. Recently, trading in this market has become increasingly automated as the use of electronic foreign exchange trading and algorithms has increased. In this article, we analyse how and why algorithmic trading is used on the market for Swedish krona. We also analyse how this trading affects the functioning of the market. From interviews with market participants, we reach the conclusion that algorithmic trading is a component of competition-driven technological development. On the whole, it should therefore contribute towards a more efficient foreign exchange market with lower transaction costs. At the same time, it may entail certain risks for both individual market participants and the financial system as a whole. Finally, we observe that the market itself has worked out a practice for the functioning of algorithmic trading in the foreign exchange market.

1. A WELL-FUNCTIONING FOREIGN EXCHANGE MARKET IS IMPORTANT FOR THE ECONOMY IN GENERAL

The foreign exchange market plays an important role for the basic functions of the financial system: mediating payments, converting savings into funding and managing risks (Sveriges Riksbank, 2013). For foreign exchange trading to function smoothly, it is important that the various risks in the transaction chain are managed as securely and efficiently as possible, from the moment of trade until the transaction is settled. In addition, there must be many buyers and sellers, so that currencies can be sold and bought rapidly, which is to say that market liquidity is good.

A further condition for an efficient market is that those trading on it have confidence in its way of working. However, it does happen on the financial markets that information on both market participants and financial instruments is deficient and unevenly allocated, which can have a negative effect on confidence. If the participants' confidence in the functionality of the markets declines, their willingness to trade with each other may also decline, making it more difficult to rapidly buy and sell financial instruments. Among other

consequences, this may affect the ability of banks and companies to manage their risks and obtain funding on the capital market.

Algorithmic trading is presently a normal way of trading on the financial markets and involves automated trading in which orders and executions are handled by computers. It is a sub-category of electronic trading, which is trading via an electronic trading platform. Algorithmic trading includes what is usually referred to as high frequency trading. High frequency trading is thus a sub-category of algorithmic trading and involves placing or executing orders at a very high frequency. The aim is to generate profit through the speed of trading and the informational advantage created by the technology over other participants on the market.

The media and academic studies have primarily focused on algorithmic trading on the stock market. These discussions were given particular impetus by the temporary fall in stock prices of 6 May 2010. On this day, the US equity index Dow Jones fell by 9 per cent within the space of about five minutes before returning to largely the same level as prior to the fall a few minutes later. According to investigations by the US authorities, this short-term crash (also called the 'flash crash') was caused by a hedge fund that had sold a very large block of index futures[1] through a computer programmed with algorithms, which also created pressure to sell on other markets and for other instruments (U.S. Commodity Futures Trading Commission and the U.S. Securities and Exchange Commission, 2010). According, among others, to Kirilenko et al. (2011) high frequency traders also contributed to the fall in stock prices.

In the subsequent discussions of algorithmic trading – and high frequency trading in particular – the focus has been on the possible effects on and risks for the stock market's functioning, among other areas. Haldane (2011) considered that the new computerised trading may entail 'fatter tails' on the financial markets, which is to say greater probabilities of major fluctuations in market prices. IOSCO (2011) described algorithmic trading and high frequency trading on the stock market and pointed out the risks with these forms of trading.

However, relatively little attention has been focused on the foreign exchange market, where algorithmic trading also occurs. The foreign exchange market is much larger than the stock market (see Chart 1). During the time period in Chart 1, the Riksbank's monetary policy counterparties and counterparties in foreign exchange transactions had a daily turnover of about SEK 72 billion on the foreign exchange market for Swedish krona.[2] This can be compared with about SEK 14 billion, which was the daily turnover for the Stockholm Stock Exchange's 30 largest stocks.

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1 A future is a binding agreement between two parties to buy or sell an underlying asset at a certain price at a given point in time.
2 Sveriges Riksbank's SELMA statistics, www.riksbank.se.

Chart 1. Daily turnover on the foreign exchange and stock markets, spot
SEK billion

Foreign exchange market, SEK ■■■■ Stock market, OMXS30
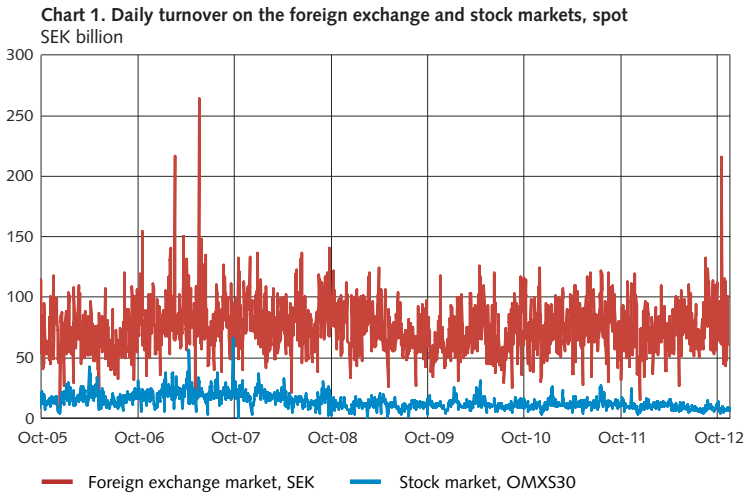
Sources: Reuters, EcoWin and the Riksbank.

The foreign exchange market and its functioning are significant for the safe and efficient functioning of the payments system, which is one of the Riksbank's objectives. Consequently, it is interesting to study how algorithmic trading affects the foreign exchange market's functioning. In this article, we analyse how and why algorithmic trading is used on the foreign exchange market for Swedish krona and how it affects the functioning of the market. Unless stated otherwise, in this article, 'foreign exchange market' refers exclusively to the spot market for currencies.

From the Riksbank's point of view, it is particularly interesting to know whether algorithmic trading takes place in trading with Swedish krona. Consequently, we have interviewed seven market participants who are active, in various ways, on the foreign exchange market and in trading with Swedish krona. The interviewed participants include Swedish and foreign banks, pension fund managers, hedge funds and non-financial companies. The banks included are responsible for about 50 per cent of turnover on the foreign exchange market for Swedish krona.[3]

We open the article by describing a few characteristics of the foreign exchange market. In addition, we present the different functions of algorithms, which we divide into four categories. We then go on to analyse both conceivable reasons for the use of algorithmic trading and the risks we have identified in our analysis. Finally, we observe that the market itself has worked out a practice for the functioning of the algorithmic trading in the foreign exchange market.

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3   Sveriges Riksbank's SELMA statistics, www.riksbank.se.

2. THE STRUCTURE OF THE FOREIGN EXCHANGE MARKET

The foreign exchange market is worldwide and is open around the clock. Its characteristics include trading with large amounts, a large number of participants and the rapid dissemination of price information. The global turnover in this market every day involves amounts corresponding to tens of thousands of billions of Swedish krona.[4] The foreign exchange trading can be divided into two segments, trading between banks (interbank) and trading between banks and their customers.

Market makers have a central function on the foreign exchange market

Currencies are traded over the counter (OTC), meaning that trading does not take place on a regulated market. Trading on the foreign exchange market usually takes place through what are known as market makers. A market maker is a bank that undertakes to quote bid and ask prices and to guarantee that it is possible to buy and sell a minimum volume in one or several currency pairs. In this article, 'market maker' refers to banks with formal and informal commitments to quote prices in various currency pairs.

Foreign exchange trading entails risks for the market maker, for which the market maker compensates itself by quoting the bid and ask prices so that the difference in these is to the market maker's advantage. The market maker is vulnerable to liquidity risk, as it is forced to match orders and interest on the market. Liquidity risk is the risk of being affected by a loss as a result of there not being enough liquidity on the market. Poor liquidity means that it is difficult to find buyers when one wishes to sell and vice-versa.

The market maker may also be vulnerable to market risk, as the value of the position a transaction gives rise to may vary over time if the market maker does not enter an opposite position. Market risk is the risk that fluctuations in market prices will change the market value of assets and liabilities negatively.

In addition, the market maker is vulnerable to credit risk with regard to the counterparty until the transaction has been settled. Credit risk is the risk that a counterparty in a transaction will lose the ability to repay its debts. This risk can be mitigated by establishing limits to restrict exposure to a particular counterparty. In foreign exchange trading – and all trading in financial instruments – credit risks arise but, in this context, these are known as counterparty risks and settlement risks.

The counterparty risk in foreign exchange (spot) trading is limited

The counterparty risk in a foreign exchange transaction (sometimes known as replacement cost risk) is the risk that the counterparty will fail on its debts and that the currency will consequently have to be bought or sold anew for another price. Counterparty risk is limited for spot transactions, as the time between date of trade and settlement is so short, only 2-3 days. Under normal market conditions, price fluctuations and counterparty risk are minimal,

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4   See also King et al. (2011) for a comprehensive survey of trading on the foreign exchange market.

but during crises the risk can be greater as exchange rates can fluctuate more. While counterparty risk is often deemed to be small, settlement risk is higher.

On certain financial markets, counterparty risk is restricted by a central counterparty (CCP).[5] A CCP acts as an intermediary between the buyer and seller in the management of a securities transaction. The original contract between the buyer and the seller is then replaced by two contracts with the CCP. This means that the original counterparties in the transaction are no longer exposed to risk in relation to each other but instead in relation to the CCP. On the foreign exchange market at present, there is no CCP that clears foreign exchange transactions in Swedish krona. Consequently, neither is there any possibility of restricting counterparty risk by trading via such a counterparty.

The settlement risk in foreign exchange trading can be eliminated through CLS

Settlement risk can be eliminated by settling foreign exchange transactions through the system Continuous Linked Settlement (CLS). All payments in CLS are settled according to the principle of payment versus payment. This is achieved by the members making payments to and receiving payments from CLS accounts – one for each currency – with both stages of the foreign exchange transaction being settled through these accounts simultaneously. On January 2013, CLS settles trades in 17 currencies, including the Swedish krona. Statistics from the first six months of 2012 show that about 90 per cent of all foreign exchange transactions made by the four major Swedish banks were settled via CLS. However, the proportion of transactions settled via CLS varies between the banks.

There are different types of trading platforms on the foreign exchange market

Foreign exchange trading takes place either by telephone and chat or electronically via trading platforms. All of the trading platforms mediate contact between the buyer and the seller, and provide information on current prices for various currency pairs. Access to information on details in each currency order – for example the order depth – is much more limited on the foreign exchange market than on marketplaces on the stock market. Even if each price set by a market maker only applies to a specified order volume at a certain point in time, a buyer or a seller cannot know exactly the size of the order volume behind the price. This means, on one hand, that it is more difficult to carry out speculative foreign exchange trading on the basis of the available information on order volumes on each side of the market price than it is in stock exchange trading.[6] On the other hand, it means lower transparency (compared with the stock market). A high level of transparency is fundamentally important for the maintenance of long-term confidence in financial markets.

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5 CCPs are regulated by the EU regulation EMIR (the European Market Infrastructure Regulation) on OTC derivatives, central counterparties and trade repositories, which came into force on 16 August 2012.

6 It should be noted that hidden liquidity also occurs in stock market trading, in what are known as 'dark pools'.

Trading platforms can be divided into three different types:

- *Inter-dealer electronic broking platforms.* These platforms were developed in the 1990s and are regarded, according to the Bank for International Settlements (BIS, 2010), as the dominant source of interbank liquidity on the foreign exchange market. They mediate information on various market makers' indicative prices. EBS and Reuters, based in London, are the two dominant platforms within this category.

- *Multi-bank platforms.* These platforms are also known as multi-bank ECNs (electronic communication networks). They were created in the first decade of this century and resemble the previous category in that they mediate several market makers' prices. One difference is that they have freer access regulations for market makers, which makes it easier for market makers to join these platforms. Another difference is that they are largely used outside the interbank market, which is to say by market participants that are not banks. The US platforms FX All, Currenex, Hotspot FX, State Street and Fx Connect are examples of this type of trading platform. There are also platforms that provide standardised algorithmic trading functions as a service. Currenex is one such platform.

- *Single-bank platforms.* This type of platform is run by an individual bank. The platform mediates only the individual bank's own prices for various currency pairs, unlike the trading platforms discussed above, which mediate several market makers' prices. In Sweden, SEB has a platform of this type, SEB Trading Station. Other examples of banks with such platforms are JP Morgan, Deutsche Bank and Citibank.

A participant on the foreign exchange market can either be directly connected to a platform or indirectly connected via what is known as a prime broker. A bank that is a prime broker allows customers to trade on the foreign exchange market in that bank's name. This means that the bank also takes credit risk exposures to the customers trading in this manner.

3. DIFFERENT PURPOSES FOR ALGORITHMS ON THE FOREIGN EXCHANGE MARKET

Several earlier studies have observed that algorithmic trading exists on the foreign exchange market. The BIS (2011) claims that high frequency trading is most widespread in trading in the largest and most liquid currency pairs such as EUR/USD, GBP/USD and USD/JPY, but that it could spread to trading in less liquid currency pairs. King et al. (2011) also draw the conclusion that high frequency trading is responsible for a large share of turnover in the largest and most liquid currency pairs.

The market participants we interviewed in our study estimate that algorithmic trading constitutes 0-40 per cent of trading in currency pairs in which the Swedish krona is one of the currencies, and 0-75 per cent of trading in other currency pairs. These proportions are assessed to be the highest among market makers (20 and 39 per cent respectively), while they are assessed to be significantly lower by other participants (4 and 2 per cent respectively).

On the foreign exchange market for Swedish krona, our interviews have shown that the algorithms are mainly applied in spot trading, and to a lesser extent in forward[7] trade. Above all, this is said to be because spot trading is the most standardised form of foreign exchange trading, while forward trade may involve specific characteristics and conditions in the traded contracts. Automating forward trade is thus more difficult than automating spot trading.

From our interviews, we draw the conclusion that algorithms on the foreign exchange market for Swedish krona fulfil four different main functions: executing orders; quoting prices; managing risks; and speculating and exploiting price differences when arbitrage opportunities arise.

Order execution

Algorithms are used to automatically execute orders on the basis of one or more predetermined criteria. A few common types of algorithms are those that spread out execution over a predetermined time period, execute an order in batches of a smaller amount, or execute an order for a certain price. Some allow a random generator to determine the amount concerned on each occasion and when the transaction is to be executed.

Banks and trading platforms are developing algorithms as a part of their range of competitive services to attract customers and ultimately generate revenue. For the customers, the algorithms have entailed standardised and automated methods for minimising market manipulation, when they carry out foreign exchange transactions and enter orders anonymously.

Algorithms also make it easier for the user to report exactly how an order has been executed, as all information is automatically stored. However, the asset managers and non-financial companies' treasury departments interviewed say that their usage of algorithms only amounts to at most 10 per cent of the total foreign exchange transactions in Swedish krona.

Price quotation

Certain algorithms have been developed to automatically quote prices in different currency pairs, sometimes with very high frequencies. With the assistance of such algorithms, banks can continually update their prices for different currency pairs on the trading platforms. The algorithms are set to quote market prices and act on the basis of the conditions and variables for which they are programmed. Consequently, under the right conditions, they make it possible for the banks to rapidly quote market prices, at the same time as manual involvement is minimised and the number of working hours per quoted price is reduced.

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7   A forward is a binding agreement between two parties to but or sell an underlying asset at a certain price at a given point in time.

Risk management

Some banks use algorithms to manage the market risks arising in foreign exchange transactions. One example would be if a transaction generated by a customer led to a bank buying USD/SEK, following which an algorithm sold the equivalent amount in USD/SEK to eliminate the market risk. Such algorithms can thus be said to automatically make transactions to achieve the desired risk exposure. Furthermore, these algorithms free up resources for the banks, as risk management no longer needs to be conducted manually.

Speculation and exploitation of arbitrage opportunities

There are also algorithms that can be used to automatically take positions to yield return. The decision criteria that the algorithms are programmed for are defined by the algorithm's owners. These criteria may, for example, be based on correlations between asset type and different currency pairs or other historical relationships. For example, a speculative algorithm may be programmed to sell dollars when the price of gold rises, as the historical relationship has demonstrated a negative correlation between these prices. The positions generated by speculative algorithms are thus associated with market risk.

There are also algorithms that do not take any market risk but take positions when arbitrage opportunities arise through inconsistencies on pricing. Such algorithms can, for example, be programmed to rapidly identify and act on differences in price between a derivative and its underlying assets, or between different marketplaces. This often means that inconsistencies in pricing are rapidly eliminated.

Certain algorithms are high frequency traders, which is to say that they trade at a very high frequency and benefit from temporary possibilities to make risk-free or almost risk-free profits that they can exploit due to their rapidity. By exploiting available information earlier and more rapidly than other market participants, they can act faster on new information and thus generate yield. However, none of the market participants we have interviewed works with such algorithms.

4. ALGORITHMIC FOREIGN EXCHANGE TRADING LEADS TO INCREASED EFFICIENCY

There are several conceivable reasons for the use of algorithmic trading on the financial markets. One of these is structural changes such as changed regulations for marketplaces, which Haldane (2011), among others, have indicated for the stock market. For example, the conditions for algorithmic trading are influenced by whether trading is conducted on one or several marketplaces, and by access to different types of market information. These factors can, in turn, depend on the regulations surrounding trading.

Another reason for algorithmic trading is technological development on the financial markets. Algorithmic trading means that the banks can streamline their foreign exchange trading and provide competitive services to their customers. According to the BIS (2011), high frequency trading on the foreign exchange market (for example) is an increasingly common form of trading and part of a development of technology that is increasing the

use of electronic trading. Algorithmic trading is also replacing often older technology by fulfilling the same functions more efficiently. For example, Menkveld (2013) says that high frequency traders on the stock market to a great extent resemble traditional human market makers. However, it is likely that trading by telephone will continue to be needed to make transactions with large amounts. The interviewed market participants deem that the personal relationships built up by foreign exchange traders by telephone will continue to be valuable, as these are considered to lead to favourable business conditions and thus better prices in major transactions.

Technological development is thus a strong contributory factor in the growth of various types of algorithmic trading. Technological development often leads to a reduction in the number of hours needed to supply a service, which should mean that the market is functioning more efficiently. Among other characteristics, an efficient market is signified by low transaction costs and the presence of assets with high liquidity so that the flow of trade can function smoothly (Fama, 1970).

5. ALGORITHMIC FOREIGN EXCHANGE TRADING MAY ENTAIL RISKS

However, there are a number of conceivable risks with algorithmic trading: operational risks, risks with regard to the liquidity of the market, risks of increased volatility and temporary crashes such as the 'flash crash' in 2010, risks to the access to information and the confidence in the market, and risks of barriers of entry for market makers. These risks exist both for the individual market participant and for the market as a whole. They can also vary depending on how liquid the currencies are. This is because the liquidity in the trade of a currency influences the choice of appropriate trading strategy and the degree to which trading can be automated. It is therefore important to make a distinction between trading in less liquid currencies and trading in the most liquid currencies.

According to the BIS (2010), the Swedish krona was the currency with the ninth highest turnover in April 2010, with 1.1 per cent of the foreign exchange market's total daily turnover of USD 4 000 billion. Under normal conditions, the liquidity of the Swedish krona is high, meaning that market participants can make foreign exchange transactions without influencing exchange rates against other currencies to any great extent. However, during certain, often turbulent periods, there may arise a shortage of liquidity on the market for the Swedish krona. This may make it difficult to make transactions at a reasonable price, as there is suddenly very little interest to trade among market participants. One example of this is following the outbreak of the financial crisis in 2008, when the market participants experienced insufficient liquidity on the market (Sveriges Riksbank, 2009).

Operational risks

The algorithmic trading may contribute to a declining manual handling of transactions and interaction between individuals trading on the financial markets. This may have both benefits and drawbacks. One advantage is that trading is less frequently affected by

temporary, irrational and occasionally impulsive behaviour. Instead of acting on the basis of emotions, the algorithms always make assessments on the same basis, based on their pre-programmed criteria.

On the other hand, one disadvantage of the decrease of manual trading may be that algorithms are unable to quickly assess scenarios for which they are not programmed. For example, if a market should suddenly lose liquidity or be subjected to a major fall in prices, there is a risk that the algorithm will not change its behaviour but will continue to trade or quote prices. Such behaviour may lead to losses for the market participant using the algorithm. One example dates from August 2012, when the US finance company Knight Capital lost USD 440 million after the company's incorrectly programmed algorithm conducted loss-making transactions in 148 different stocks (Financial Times 2, 2012).

Market liquidity risks

To manage operational risks, banks and other market participants often use different types of circuit breakers and other mechanisms to disable the algorithms in turbulent situations. This helps the market participants to avoid losses, but also leads to the sudden disappearance from the marketplace of the liquidity otherwise provided by the algorithms' trading. King et al. (2011) point out that there is unease that high frequency trading market makers on the foreign exchange market may choose to stop trading when turbulence arises in market pricing. There are several studies of this phenomenon on the stock market. For example, Johansson (2012) points out the risk that algorithmic traders on the stock market may stop trading under stressed market conditions. Such behaviour can both create and worsen unease in trading, which can have a negative effect on market liquidity.

Several studies show that algorithmic traders usually make a positive contribution to liquidity on the market. Chaboud et al. (2011) indicate that algorithmic trading entails increased liquidity on the foreign exchange market, in terms of greater order depth. As regards the stock market, Hendershott et al. (2010) show that algorithmic trading on the stock market has generally contributed positively to the market's liquidity, but that another relationship cannot be ruled out under stressed market conditions. The behaviour of algorithmic traders can also be expected to differ, depending on which strategy they choose to apply. Hagströmer and Nordén (2012) divide high frequency traders into market makers and opportunistic traders. They show that the market makers are the dominant high frequency traders on the Swedish stock market and that they contribute positively to liquidity on the market. Gomber et al. (2011) also point out that the traders' strategies form a reasonable starting point for the assessment of high frequency trading.

Risks of increased volatility and temporary crashes

Algorithmic trading that takes place for speculative purposes or to exploit arbitrage opportunities can affect the pricing of currencies and other asset classes. Bicchetti and Maystre (2012) show that inconsistencies in pricing between different asset classes and

currencies, and between derivatives and their underlying assets, are expected to become fewer. Such a development can be seen as positive, as it will lead to a more arbitrage-free market. Chaboud et al. (2011) also show that algorithmic trading has led to fewer arbitrage opportunities, as the market reacts more quickly to new information. This development could also be imagined to lead to increased co-variance between different financial instruments and between different asset markets, as new information is more rapidly reflected in prices.

Authorities and researchers have asked whether algorithmic trading may lead to increased volatility in asset prices, which could impair the functioning of the financial markets. Several studies have been made of this relationship on the stock market. Boehmer et al. (2012) indicate a positive relation between algorithmic trading and volatility on the stock market, that is that algorithmic trading contributes to increased volatility. At the same time, there are studies that indicate the opposite, for example Hagströmer and Nordén (2012). Broogaard et al. (2012) cannot draw any conclusions indicating any clear relation between high frequency trading and volatility. As regards the foreign exchange market, Chaboud et al. (2011) show no clear signs that algorithmic trading influences volatility. In general, there is thus a lack of support for a clear relation between algorithmic trading and volatility.

However, the Government Office for Science (2012) demonstrates that algorithms on the stock market can act in a kind of technological herd behaviour, so called feedback loops, which can create rapid price fluctuations. On these occasions, algorithms act by selling or buying simultaneously, which affects the price of the asset in question either upwards or downwards. As regards the foreign exchange market, Chaboud et al. (2011) show that the algorithmic traders' strategies show more of a correlation than do those of the human traders. As different financial instruments and markets co-vary more, a temporary and exaggerated market fluctuation on one asset market can spread to the foreign exchange market, which can create uncertainty on several financial markets. Such a scenario would be particularly serious for a currency like the Swedish krona, which does not belong to the most liquid currencies, as it may lead to a sudden reduction of liquidity on the market.

However, according to the BIS (2011), the risk of temporary crashes is smaller on the foreign exchange market than it is on the stock market. This is because the foreign exchange market differs from the stock market in several respects. One fundamental difference, according to the report, is that a currency is priced in relation to another currency, while a stock price is an absolute price. When the price of a currency falls, one party loses, while the other party gains. This means a redistribution of wealth rather than a reduction, which is the effect when stock prices fall. A further difference is that there is rather stable demand for foreign exchange related to cross-border trade and financial flows. There is no equivalent flow on the stock market.

Risk related to the access to information and the confidence in the market

An uneven distribution of information may lead slower investors to make less advantageous investment decisions than high frequency traders, as they do not receive information as rapidly. Biais et al. (2011), Jarrow et al. (2011) and McInish and Upson (2012) discuss this and note that high frequency traders have various means of profiting from and acting on information more rapidly than other market participants. Finansinspektionen (2012) and Johansson (2012) discuss the risk of improper behaviour and reach the conclusion that high frequency trading gives rise to new behaviour among market participants that may entail a risk of market abuse. In that trading takes place at a higher speed, thus the possibility of improperly influencing the market price to a trader's own advantage.

However, there are also studies that show that high frequency traders quote the most favourable prices on the market and thus contribute towards efficient price formation. These studies include Hasbrouck and Saar (2011). As regards the foreign exchange market, Chaboud et al. (2011) simultaneously show that the people who are trading still have good access to information and that their trading influences price formation more than that of the algorithmic traders.

Risks of barriers of entry for market makers

Developing algorithms requires more or less comprehensive investments in technology. Those banks investing in electronic systems and algorithms do so partly to streamline their operations to gain economies of scale over other banks. According to King et al. (2011), this is an example of a reason for the banks to choose to develop their own trading platforms for customer trading to a greater extent. This makes it possible for the banks to internally match cash flows in different currencies. At the same time, as this may have advantages for the individual banks, King et al. (2011) observe that an increased fragmentation of the market may, over the long term, occasionally create liquidity shortages on the interbank market.

There is also a risk that the need for comprehensive investments will create barriers of entry on the foreign exchange market. This is because small banks can lack both competence and resources to invest in the technology needed to compete for trade. King et al. (2011) state that such barriers of entry have led fewer banks to choose not to be active in the largest, most liquid currency pairs. At the same time, King et al. (2011) say that the smaller banks are still trading in the smaller local currencies, and that they are thereby becoming experts and earning money on trade with these currencies.

6. SCOPE FOR SELF-REGULATION IN THE FUTURE

In general, the foreign exchange market differs from other financial markets, as foreign exchange trading and the clearing and settlement of foreign exchange transactions are not regulated by authorities. At present, there is no Swedish legislation to regulate trading on the foreign exchange market. However, it is in the market's own interest to counteract trading that may damage the functioning of the market. It is therefore self-regulating in

that the market itself has formulated a practice for how trade functions. Neither is there any global legislation for the trading platforms existing for foreign exchange trading, which is a difference to how the stock market functions (BIS, 2011).

Since the financial crisis, work has started on the formulation of several new regulatory frameworks. However, under their current formulations, none of these regulatory frameworks specifically affect the foreign exchange market. In the EU, MiFID II/MiFIR[8] will entail expanded regulations for the equity and fixed-income markets (both spot and derivative markets), among other areas regarding increased transparency and requirements covering which instruments may be traded on a regulated marketplace. There are at present no equivalent rules for the foreign exchange market. MiFID II will probably also include rules placing requirements on securities companies using algorithmic trading (articles 17 and 51 of the European Commission, 2011). In a similar way, the so-called Dodd-Frank Act in the United States will probably include new rules on algorithmic trading. It is not completely clear whether and how securities companies using algorithmic trading in currency will be affected by these regulations. The legislation is primarily intended to address any negative effects of high frequency trading on the stock market.

Recently, certain trading platforms have tried to counteract elements of algorithmic trading, as it has been seen as disruptive to the functioning of the foreign exchange market. One example of such a platform is EBS. The measures adopted include an increased tick size[9], as well as a reduction of the number of bids a trader may enter without actually trading. Trading behaviour is deemed to have become healthier due to these measures, without trading volumes having been affected negatively (Financial Times 1, 2012). There will continue to be scope for this kind of self-regulation to counteract elements of disruptive trading on the foreign exchange market.

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8 MiFID stands for the Markets in Financial Instruments Directive. MiFIR stands for Markets in Financial instruments Regulation. These regulations will probably be implemented in 2015.
9 Tick size is the smallest possible price change.

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Further development of the index for financial stress for Sweden

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This article describes the Riksbank's new index for financial stress for Sweden. The index is a tool for analysing the development of the financial markets and financial stability. The index aims to provide an aggregate measure of the financial stress in the various sub-markets. One improvement compared with the previous stress index is that the stress on each sub-market is measured using several indicators. It is also important that the levels assessed as normal for these indicators can vary over time. Consequently, in the new stress index, the indicators are systematically ranked at the same time as the comparison period is extended. A further improvement is that the weighting of stress on the various sub-markets more clearly draws attention to periods in which financial stress is widespread. In this article, we show how the new stress index describes the degree of financial stress in Sweden between 1995 and 2013.

Why does the Riksbank use an index for financial stress?

The financial system performs central functions in the economy. One particularly important role is played by financial markets that contribute towards converting savings into investments. Furthermore, the financial markets make it possible for their participants to manage their risks by redistributing them to other market participants. Financial stress can be defined as a disruption that damages the financial markets' ability to efficiently fulfil their roles as intermediary between borrower and lender or buyer and seller.

Financial stress has several different symptoms. If a market is to function well, this requires buyers and sellers so that an asset can rapidly be sold for a fair price and this means that what is known as good market liquidity is required. In turn, this requires the market participants to have confidence in each other. It also requires that information be evenly distributed so that buyers and sellers can agree on fair prices for assets. In periods of unease, confidence among market participants can rapidly deteriorate and the value of a financial asset can suddenly become uncertain leading to a rapid deterioration of market liquidity. This can lead to funding becoming more expensive and more difficult to obtain as investors demand higher compensation for exposing themselves to the risk that they may neither get back what they have invested (meaning a higher credit-risk premium) nor have

the opportunity to sell their investment in time should the need suddenly arise (meaning a higher liquidity risk premium).

In the Riksbank's work of maintaining financial stability, it is important to have tools to analyse symptoms of financial stress on the various parts of the financial markets. Financial stress can rapidly spread from one sub-market to another and it is thus important to consider stress from a systemic perspective. To make an overall assessment of symptoms of financial stress, the Riksbank regularly employs an index in its ongoing analysis of the financial markets. This index – which we call *the previous stress index* in this article – was prepared with the assistance of a method developed at the Riksbank (Forss Sandahl et al., 2011).

The stress index also makes it possible to compare different periods of financial stress with each other. For example, the Riksbank uses the stress index as an independent tool to summarise the development of the financial markets (Financial Stability Report, November 2012). Similarly, the stress index is included in discussions of signals that can be used to activate and deactivate countercyclical capital buffers[1] (Juks et al., 2012).

Why does the Riksbank's stress index need further development?

The previous stress index developed by the Riksbank in 2011 includes four sub-markets: the stock market, the bond market, the money market and the foreign exchange market. These, in turn, are summarised by *one* indicator per sub-market. The indicators are normalised to make them comparable and to give them equal weight in the formation of a stress index (Forss Sandahl et al., 2011). This stress index (see Chart 1) has proved to be easy to use and its results are relatively easy to interpret. However, at the same time, it has become apparent that some of its properties could be improved.

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1   A countercyclical capital buffer is an extra capital buffer that varies over time. During economic upturns and periods of increased lending, the idea is that the banks will apply this extra capital buffer to better prepare themselves for less economically-favourable times.

Chart 1. The previous stress index
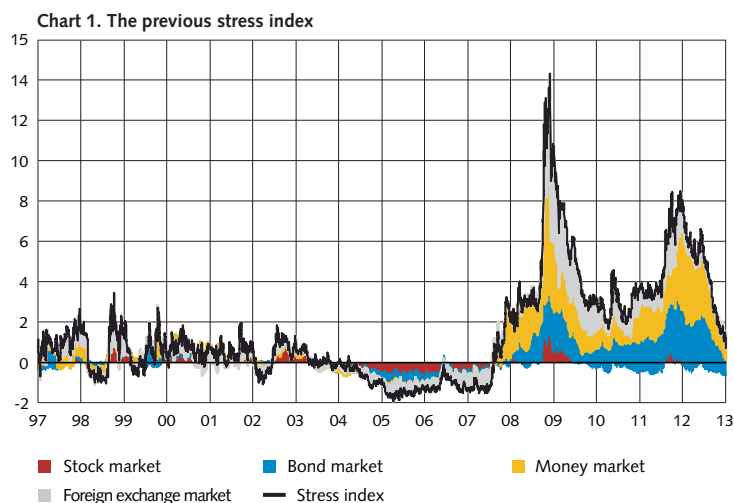
Sources: Bloomberg, Reuters EcoWin and the Riksbank

The stress index is intended to provide an aggregate measure of the financial stress in the various sub-markets. This is best done by measuring the stress on each sub-market with several indicators to reduce the sensitivity of one specific indicator. It also requires a sub-market's impact on the stress index not to be too great in comparison with other sub-markets. This also goes hand in hand with the stress index needing to clearly point out periods in which there is financial stress on many sub-markets, at the same time as it should tone down periods in which stress is not as widespread.

It should also be possible to use the stress index to measure how financial stress varies over time. As financial stress is defined as a disruption of normal market conditions, it is appropriate that the definition of normality should also be allowed to vary over time. Otherwise, long-term changes of specific financial indicators risk leading to incorrect conclusions of financial stress, even though the markets are functioning efficiently.

To meet these requirements and as a part of the continuous development of our internal models, we have created a *new stress index* that we present in this article. Many of the changes we have made are based on the method behind the CISS index (Kremer et al., 2012). This is an index for financial stress in the euro area that is used by, among others, the European Central Bank (Financial Stability Review, June 2010) and the European Systemic Risk Board (ESRB Risk Dashboard, September 2012).

The new stress index uses a greater number of indicators

To adjust the method to Swedish conditions, we select relevant Swedish indicators to be included in the stress index. It should be easy to interpret why each indicator is an appropriate measure of financial stress. Each indicator should also represent the development of a significant part of the sub-market (for example, a broad stock index) or

of an instrument used as a reference point for a sub-market (for example, a benchmark loan interest rate). In addition, it's also desirable to have indicators within a sub-market to measure different symptoms of financial stress. Furthermore, the longest time series possible should be used to include as many periods of financial stress as possible. Finally, the indicators should be published on a daily basis without significant delay so that the index can be used in the ongoing analysis of the financial markets.

In general, the new stress index is based around three different kinds of indicators of financial stress. When the pricing of a financial asset is uncertain, this tends to entail large and rapid price fluctuations – that is to say, volatility. One method for calculating volatility involves calculating the standard deviation of historical observations within a certain period of time. Throughout the new stress index, historical volatility is calculated as the standard deviation over the last 30 days. This results in a volatility indicator that is based on historical data and is thus a backward-looking estimate. However, data on implied volatility is used instead to the extent that this is available. 30-day implied volatility is calculated with the help of a pricing model for financial contracts with 30-day maturities, in which volatility is one of the model variables. Prices for these financial contracts and the values of the other model variables can be used to estimate volatility over the next 30 days, what is known as implied volatility. This volatility indicator is more forward-looking estimate.

However, volatility is a symmetric measure, which is to say that higher volatility can be linked with both unusually negative and unusually positive development. It is thus appropriate to complement it with some form of measure of level shift. Among other things, the new stress index uses a measure that sets an indicator at a certain date in relation to its highest or lowest level over the last two years.

By calculating the differences between various interest rates or expected returns, it is also possible to capture different types of risk premiums. For example, periods of financial stress are often characterised by a greater difference in expected return between higher risk assets and safer assets.

Considering these factors and the actual access to financial data, we have chosen to base the new stress index on the same sub-markets as the previous stress index. However, we have chosen to calculate the stress level for each sub-market on the basis of *three* indicators instead of *one* (see Table 1).[2] This means that the new index is not as sensitive to the outcome of one specific indicator, at the same time as it better captures different symptoms of financial stress. See Appendix 1 for a short description of each sub-market's significance in the financial system and an explanation of each indicator's significance for the analysis of symptoms of financial stress.

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2   The CISS index is also based on three indicators per sub-market, but has an additional sub-market, financial intermediaries. As the amount of relevant financial data for the non-financial sector in Sweden is limited, we exclude this sub-market from our calculations, as the other sub-markets include indicators that are largely influenced by the financial sector.

Table 1. Sub-markets and indicators in the new stress index

SUB-MARKETS	INDICATORS
Stock market	Implied volatility
	Market value in relation to the highest in 2 years
	Estimated liquidity based on turnover data
Bond market	Difference between 5-year covered bond yield and 5-year swap rate
	Difference between 5-year covered bond yield and 5-year swap rate minus the 2-year equivalent
	Difference between 5-year swap rate and 5-year government bond yield
Money market	Difference between 3-month Stibor rate and 3-month treasury bill yield (TED spread)
	Historical volatility of TED spread
	Difference between 3-month Stibor rate and 3-month implied Stibor rate
Foreign exchange market	Implied volatility of USD/SEK
	Implied volatility of EUR/SEK
	30 day change in the value of the krona against a basket of currencies (TCW index) in absolute terms

## The new stress index uses a variable reference period

In the new stress index, we use ranked indicators instead of absolute indicators to improve the stress index's ability to account for new information, possibly involving long-term changes of the indicators. Each observation is ranked by magnitude in relation to earlier observations, so that an observation receives a value that is greater than zero but smaller or equal to one. See Appendix 2 for a technical explanation of this method.

The ranked indicators for each sub-market are then weighed together using equal weights. This means that each indicator makes up one-third of the sub-market in which it is included. In this case, each sub-market indicator receives a value between zero and one, like the ranked indicators.

Ranking the indicators and placing different measures of symptoms of financial stress along the same relative scale makes their influence on the stress index more evenly distributed (see Chart 2). This also means that the historical reference period is continually extended, making it easier to distinguish symptoms of financial stress from normal market conditions.

**Chart 2. Comparison of sub-market indicators**
Values for new indicators are specified on the left-hand axis and values for previous
indicators are specified on the right-hand axis.
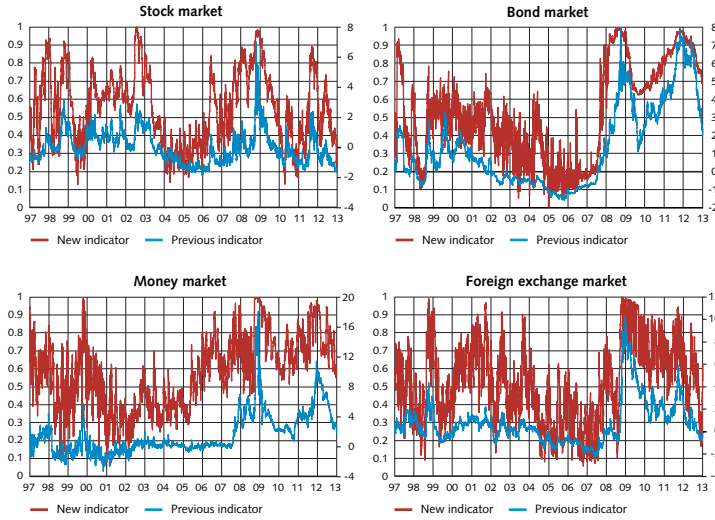
Sources: Bloomberg, Reuters EcoWin and the Riksbank

Consequently, when we rank an observation at a certain point in time, we disregard
observations after this point (recursive ranking). However, it is important that an
observation defined as high financial stress on one occasion is not reassessed at a later
stage. To ensure this, the new stress index using recursive ranking can be compared with
an equivalent stress index calculated with the help of a ranking that takes the entire period
1995-2013 into account (see Chart 3). Both stress indices give a similar result. However,
the recursive ranking emphasises the IT crash in 2000 and the early stage of the financial
crisis in 2008 more clearly. All in all, we assess that the recursive ranking provides reliable
estimates of financial stress over time.

Chart 3. The new stress index with different types of ranking

New stress index, recursive   New stress index, entire period
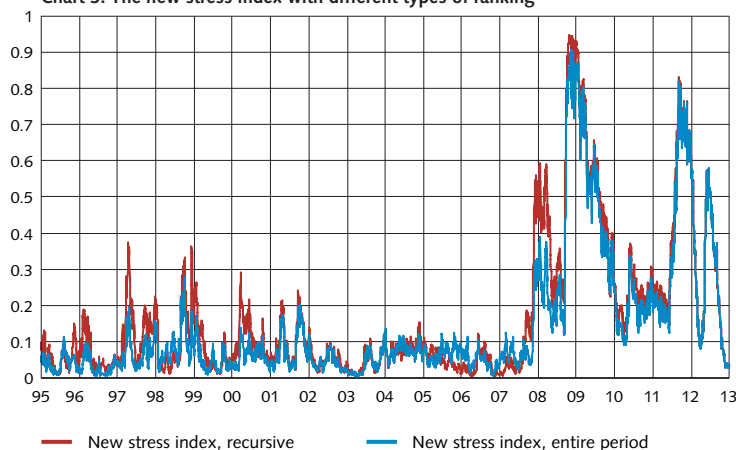
Sources: Bloomberg, Reuters EcoWin och the Riksbank

## The new stress index emphasises widespread financial stress

The new stress index is calculated as an equally-weighted[3] mean value of the sub-market indicators that is squared and adjusted with regards to the correlations between the sub-market indicators (see Appendix 2). The aim of taking these correlations into account is to emphasise periods of widespread financial stress on the financial markets.[4]

A high level of correlation shows that several sub-market indicators simultaneously *exceed or fall below* their theoretical mean values of 0.5. We are most interested in highlighting the first case in the stress index. Charts 4 and 5 show how the correlation effect increases during the financial crisis and the euro crisis. This is because all sub-market indicators show high levels of financial stress and thus a high correlation. The overall stress level thereby becomes relatively higher. When only a few markets show financial stress, as during the IT crash, the correlation is lower, which dampens the overall stress level. A case in which there is high correlation due to the sub-market indicators simultaneously showing a low level of financial stress clearly occurs in the period 2004-2005. Then the value of the stress index increased at the same time as the indicators decreased due to an increased correlation.

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3   The CISS index uses what are known as relevance weights, in which the significance of each sub-market is based on its effect on productivity growth in the European manufacturing industry. However, it also emphasises that the difference between the CISS index calculated with relevance weights and the CISS index calculated with equal weights is marginal.

4   A parallel can be made with classical portfolio theory in which the correlation between assets is included to calculate the aggregate portfolio risk (see Appendix 2). Here, a high level of correlation between assets is interpreted to mean that strong linear connections exist between the assets that risk reducing the diversification effect for the portfolio and increasing the portfolio risk. As regards the stress index, it is the linear connection we wish to consider, above all because this is a result of all sub-market indicators showing financial stress simultaneously.

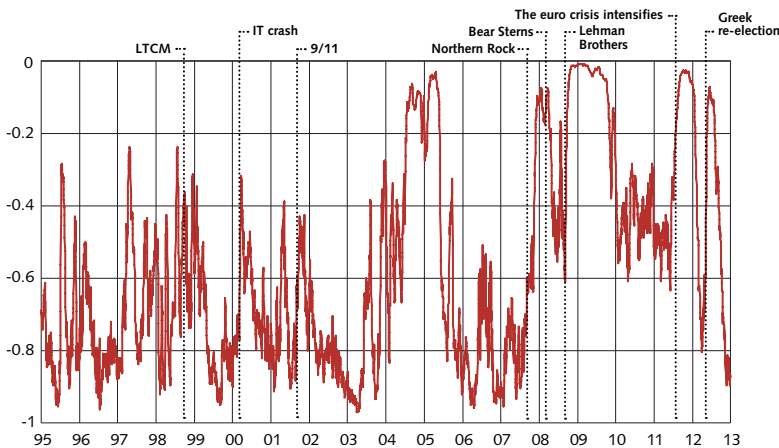**Chart 4. The new stress index**
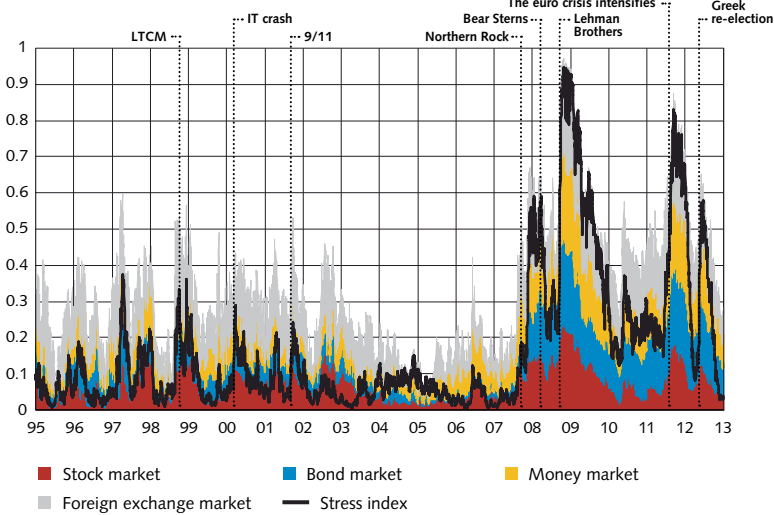
Note. The sum of the sub-markets in the figure actually refers to the squared, equally-weighted mean value of the sub-market indicators.

Sources: Bloomberg, Reuters EcoWin and the Riksbank

Chart 5. Correlation effect
Percentage difference between the stress index and the sum of the sub-market indicators in Chart 4.
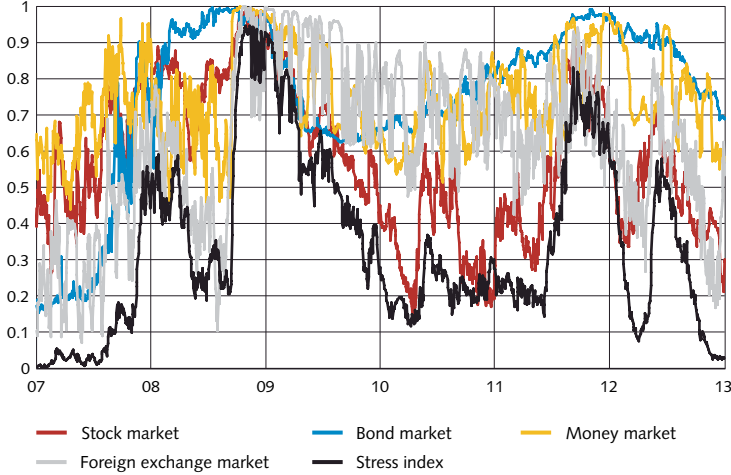

Sources: Bloomberg, Reuters EcoWin and the Riksbank

To further illustrate the factors determining the correlation effect in practice, we focus on Charts 6 and 7 in the period 2007-2013. During this period, the indicators for the money market and the bond market, above all, have been above their theoretical mean value of 0.5 (see Chart 6). This means that the correlation between the bond and money markets has been high (see Chart 7). The indicators for the two other sub-markets, the share market and the foreign exchange market, thus form the factor that has most affected the

overall correlation effect. For example, the correlation effect decreased in the autumn of 2012 (it approaches -1 in Chart 7) and the stress index level decreased rapidly due to both of these sub-market indicators falling below their theoretical mean values (see Chart 6).

Chart 6. Sub-market indicators in the new stress index

Stock market
Bond market
Money market
Foreign exchange market
Stress index

Sources: Bloomberg, Reuters EcoWin and the Riksbank

Chart 7. Estimated correlations in the new stress index

Stock/Bond
Stock/Money
Stock/FX
Bond/Money
Bond/FX
Money/FX
Correlation effect
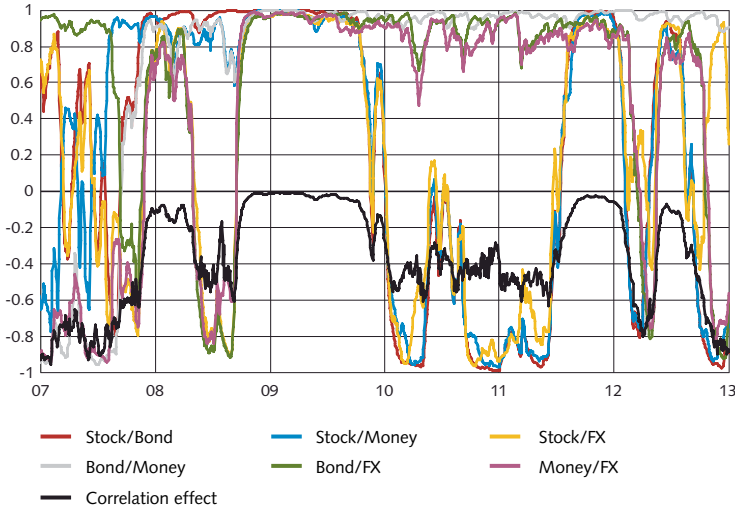
Sources: Bloomberg, Reuters EcoWin and the Riksbank

In the new stress index, we estimate the correlations between the sub-market indicators with the use of an exponentially weighted moving average (see Appendix 2), in line with the CISS index (Kremer et al., 2012). This means that the correlations are updated at each point in time with the starting point in earlier data where most weight has been

placed on the latest observations.[5] Formally, the latest correlation estimate is given the weight β where β is an adjustment parameter. Depending on the choice of parameter, the correlation estimates and thus the stress index change at a different rate. We have chosen an adjustment parameter of 0.93, in line with the CISS index (Kremer et al., 2012), which means that the stress index rapidly responds to situations in which most sub-market indicators exceed their theoretical mean values, at the same time as certain short-term fluctuations are smoothed out. However, regardless of the choice of adjustment parameter, the stress index shows the same pattern (see Chart 8).

Chart 8. The new stress index with different adjustment parameters

0.8   0.93   0.99
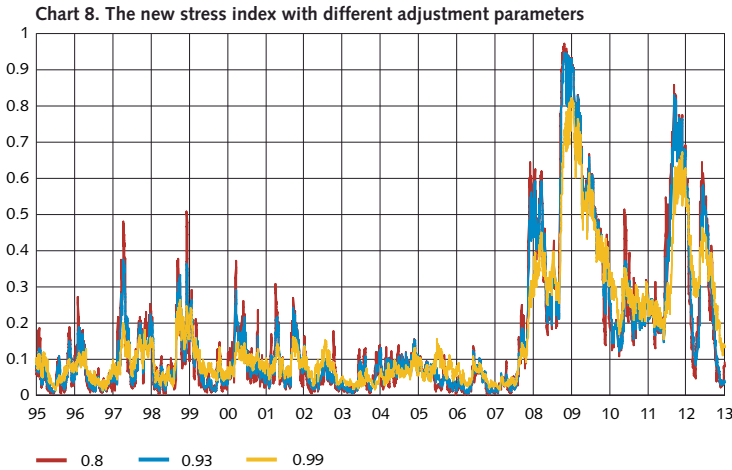
Sources: Bloomberg, Reuters EcoWin and the Riksbank

The new stress index is a better measure of financial stress

We have further developed an index that is intended to function as a tool for measuring financial stress on the financial markets. The stress index should thus give an aggregate measure of a disruption that negatively impacts the financial markets' normal role as intermediary between lender and borrower and seller and buyer, respectively.

This role is central to the functioning of the financial system. It is therefore important that the Riksbank carries out ongoing analyses of the financial markets to safeguard financial stability, not least when high financial stress has shown itself to be related to major real economic costs (see for example Bjellerup et al., 2012 and Kremer et al., 2012). The aim of this article is to describe how the stress index has improved as a measure of financial stress to increase its reliability as both an independent tool and a component of a broader analysis.

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5   The CISS index is based on weekly sub-market indicators, while the new stress index is based on daily sub-market indicators. All else being equal, the correlation estimates will be updated more rapidly over time with the new stress index.

In the new stress index, three times as many indicators are used as in the previous stress index. As these indicators can be explained by economic factors and provide supplementary information, the new index better captures the overall level of stress on the financial markets.

In addition to this, the new stress index is not dominated by individual sub-markets to such a great extent. This is a consequence of the recursive ranking that means that the sub-market indicators are given the same scale and affect the stress index's outcome in a more uniform manner. Structural changes are also continually phased into what the ranking classes as a normal condition, as the reference period is continuously updated and based on all historical data.

Finally, the correlation of the sub-market indicators is taken into account. This means that the new stress index more clearly highlights periods in which several sub-markets show high levels of financial stress simultaneously.

In Chart 9, we make a concrete comparison of the new and the previous stress index which are placed side-by-side so that their highest and lowest levels are about the same (see Chart 9). Even though the methods of calculation of both stress indices differ significantly, they look quite similar. However, the normal level of the new stress index is lower and the historical crises consequently have relatively greater impact. This is because the index is adjusted to take account of the relationship between the sub-market indicators and their theoretical mean values (the correlation effect). As the correlations are rapidly updated over time, the new stress index can rapidly vary between high and low levels. Without the correlation effect. the difference between the previous and the new stress index would be smaller.

However, the difference is also because the ranking of the indicators in the new stress index takes account of a variable reference period, which reduces the dominance of certain sub-market indicators on the earlier stress index. These two factors explain, for example, why the new index more clearly shows financial stress at the start of the financial crisis in 2008, but also shows lower stress in 2010. It also explains why the new stress index highlights the different phases of the euro crisis more clearly, which can largely be said to be defined by the timing of the various policy measures adopted by the European Central Bank: 3-year LTRO loans in late 2011/early 2012 and the announcement of the OMT programme for the purchase of government bonds in the late summer of 2012.

Chart 9. Comparison of stress index
Values for the new stress index are specified on the left-hand y axis, while values for the previous stress index are specified on the right-hand y axis.
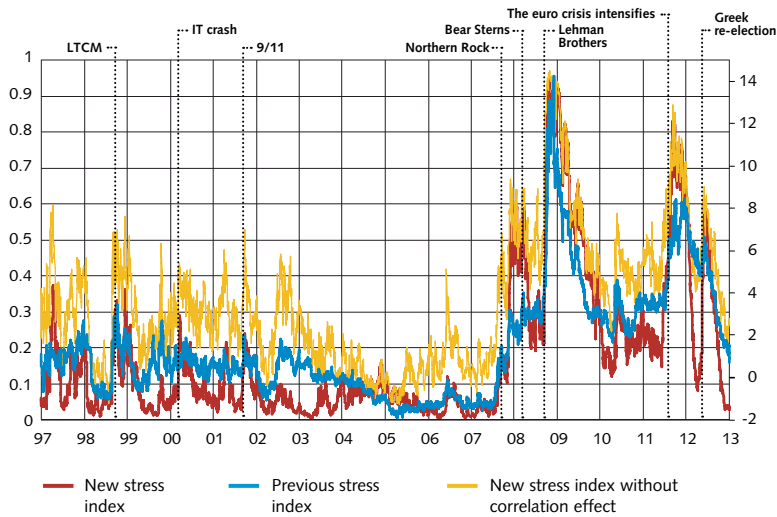

Sources: Bloomberg, Reuters EcoWin and the Riksbank

When the new stress index is interpreted, it should be borne in mind that this is a relative index. The stress level at any point in time is given in relation to historical data on financial stress since 1995 and receives a value of between zero and one, depending on the relative degree of stress. Secondly, the stress index is a non-linear function of the sub-market indicators. It is calculated as a squared average and adjusted to take account of the relationship between the sub-market indicators and their theoretical mean values (the correlation effect). Consequently, it cannot simply be interpreted as the mean of the sub-market indicators. As the sub-market indicators have the same scale in the new stress index, understanding of the index can hopefully be improved when it is presented in combination with the individual sub-market indicators (see Chart 10). This will clearly show the factors driving the stress index and that it does highlight periods in which all sub-market indicators are above their theoretical mean values.

To sum up, the analysis of the new index and its sub-components shows that it provides a useable overall measure of financial stress.

Chart 10. The new stress index
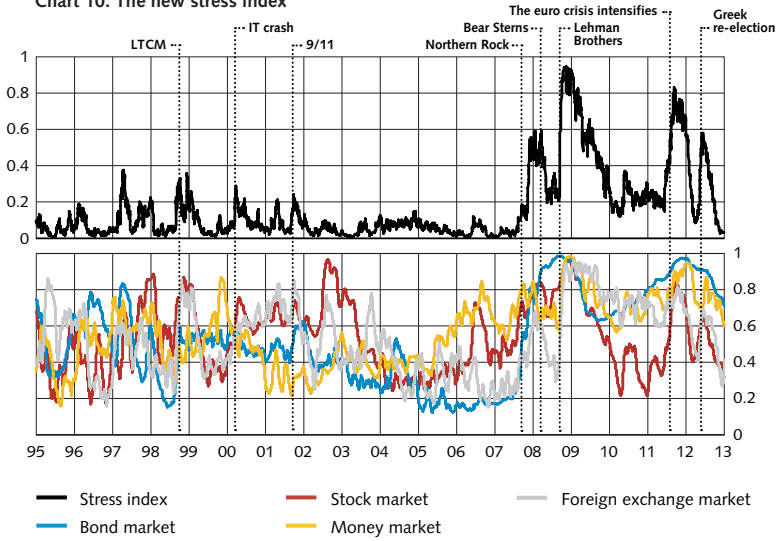
Note. The sub-market indicators in the figure have been smoothed out through the application of an exponentially-weighted moving average with the adjustment parameter 0.93, similarly to how the correlations are estimated in the stress index.

Sources: Bloomberg, Reuters EcoWin and the Riksbank

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Appendix 1. Sub-markets and indicators in the new stress index

THE STOCK MARKET

The stock market is an important source of funding for companies which can obtain capital there through initial public offerings and new issues of shares. At the same time, the stock market makes it possible for investors to get exposure to the risks and returns entrepreneurship entails, at the same time as they can sell shares relatively rapidly through widespread secondary market trading.

Implied volatility

A high level of stock market volatility implies the existence of great uncertainty over the pricing of shares among market participants. This can lead to market liquidity deteriorating and the functioning of the stock market becoming impaired. The Riksbank previously created an index[6] that measures 30 days' implied volatility of the OMXS30[7] price index. It was used in the previous stress index and is also included in the new one.

Market value in relation to the highest in 2 years

A low relative market value means that it is relatively expensive for companies to obtain equity funding as they must surrender a larger equity stake in return for new capital. At the same time, it means that investors' wealth is relatively low which can reduce their risk propensity. This can impair companies' access to equity funding. MSCI Sweden[8] is used for this indicator, as it is one of few relevant stock market indices with enough historical information of dividends. Since dividend payouts decrease the value of shares, it's important to use a total return index where the dividends are reinvested to minimize this effect.

Estimated liquidity based on turnover data

The liquidity of the stock market is linked to both price volatility and market value. However, capturing the liquidity aspect more clearly is relevant, particularly as the stock market is one of the few sub-markets with enough turnover data for liquidity to be directly estimated. To accomplish this, a method is used (Amihud, 2002) that divides daily absolute returns with turnover and where a high value indicates low market liquidity.

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6   It is based on an application (Dahlman et al., 2007) of the Chicago Board Options Exchange's methodology for the VIX index on the Swedish stock market.

7   A return index of the 30 most frequently traded shares on the Stockholm stock exchange.

8   A return index of the largest companies' shares on the Stockholm stock exchange, which represents 85 per cent of the market value available for public trading. This is equivalent to about 35 shares.

THE BOND MARKET

The bond market is the market for fixed income securities with a longer maturity than one year. Its primary role is to bring together market participants who administer long-term investments with banks, companies and institutions that need to borrow money over the longer term. Moreover, mortgage loans and other forms of consumer credits are funded via the bond market.

Difference between 5-year covered bond yield and 5-year swap rate

Covered bonds[9] form one of the main sources of funding for the Swedish banks. To estimate the relative funding cost via bonds, bond yields are often compared to swap rates[10], rather than government bond yields, since there are several practical advantageous of swap rates even though they are not completely risk-free and involves small risk premiums (Fabozzi, 2010). The difference between a bond yield and a swap rate of the same maturity is thought to reflect several different risk premiums as compensation for the anticipated differences in properties of the two financial instruments, where credit risk and liquidity risk are thought to explain a large part of the difference (Fabozzi, 2010). In this case, the difference is primarily due to a liquidity risk premium as the investor of the covered bond ties up capital which is not done to the same extent in a swap whereas the credit risk premium is small due to the collateral pool. Certainly, the covered bond may be sold on the secondary market before the maturity date, however, the investor may incur a loss doing this. A larger liquidity premium may indicate increased uncertainty among covered bond investors which may impair the role of the covered bond market.

Difference between 5-year covered bond yield and 5-year swap rate minus the 2-year equivalent

This indicator should be interpreted as the difference in liquidity risk premium for tying up capital for 5 years compared to tying up capital for 2 years in covered bonds. If an investor suddenly needs to sell these covered bonds on the secondary market before the corresponding maturity dates, there is a larger risk for a loss on the bond with the longer maturity due to the greater inherent interest rate risk. Similarly to the previous indicator, if this difference increases, it may indicate an increased uncertainty among investors which may impair the role of the covered bond market. Also, it may cause banks to issue covered bonds with shorter maturities which increases their refinancing risk.

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9   In the event of a bankruptcy, covered bonds give the bond owner special preferential rights to a collateral pool consisting of credit associated with liens on real property. Covered bonds were introduced into Swedish legislation in 2004. For the period prior to this, mortgage bonds are used instead. Both products have similar characteristics, however.

10 The swap rate is the fixed interest rate in an interest rate swap that is exchanged against a floating interest rate and that gives the swap a market value of zero for both counterparties when they enter into the swap contract.

Difference between 5-year swap rate and 5-year government bond rate

As a slightly simplistic but still illustrative comparison, the 5-year swap rate may be seen as the expected average 3-month Stibor rate during the next 5 years and the 5-year government bond yield may be seen as the expected average 3-month treasury bill yield during the next 5 years. Therefore, this indicator reflects a credit risk premium as well as a liquidity risk premium (Fabozzi, 2010) similar to the TED spread (see below) and should be viewed as another indicator of uncertainty on the bond market.

THE MONEY MARKET

The money market is an important market for banks' and companies' short-term funding. It covers the market for fixed income securities with maturities of up to one year. If the money market does not function well, there is a risk that this will rapidly lead to negative consequences for the liquidity management in the financial system.

Difference between 3-month Stibor rate and 3-month treasury bill yield (TED spread)

The 3-month Stibor rate is the most commonly used reference rate on the money market and corresponds to the average interest rate the Swedish banks charge one another for lending for three months without collateral. The difference between the 3-month Stibor rate and the 3-month treasury bill yield (TED spread) can be seen as the risk premium a bank requires for lending to another bank, compared with lending to the government for the same maturity. This premium corresponds to a credit risk premium as the probability of a bank encountering problems in repaying a loan is greater than the probability that the government would encounter such a problem. Unlike interbank loans, treasury bills can also be traded on the secondary market which means that the premium also involves a liquidity risk premium. This indicator can thus be considered to signal uncertainty on the money market (The Swedish Financial Market 2012) and has therefore also been used in the previous stress index.

Historical volatility of the TED spread

This indicator represents an additional dimension of uncertainty on the money market. Increased volatility in the TED spread can signal a lack of consensus among the banks over a fair interbank rate or increased uncertainty over the pricing of Swedish treasury bills. Together with the size of the TED spread, this indicator can signal how well the money market is functioning.

Difference between 3-month Stibor rate and implied Stibor rate

The covered interest-rate parity condition says that currency risk hedged funding in foreign currency converted to domestic currency should be obtained at the same cost as funding directly in domestic currency (The Swedish Financial Market, 2012). However, it

has become apparent that this parity condition is not valid in periods of financial stress. In particular, such periods have entailed higher costs and less availability for swapping funding in Swedish kronor for US dollar. Studies (Baba et al., 2008) have found that this can be explained by an increasing credit risk premium for funding in Swedish kronor. An increase of this indicator may thus be a sign of declining confidence in the Swedish banking system and the impaired functioning of the Swedish money market.

THE FOREIGN EXCHANGE MARKET

On the foreign exchange market, banks and companies can exchange Swedish kronor for foreign currency and vice versa to match revenue and disbursements in different currencies. These payments are traditionally seen as a consequence of trade in goods and services as well as financial assets. Transactions of this type create a need for foreign exchange risk management.

Implied volatility of USD/SEK and implied volatility of EUR/SEK

The variable value of the Swedish krona can be considered to reflect the capital flows in and out of Sweden that are largely influenced by new macroeconomic and financial information. As there is uncertainty on the financial markets, the capital flows can give rise to increased volatility of the krona's value. This need not mean a deterioration of the possibilities for trading on the foreign exchange market, but it could indicate financial stress in one or more areas of the financial markets.

However, one direct negative aspect of the increased volatility is the increased expense of managing foreign exchange risks through derivative instruments, which, in turn, may impact the conditions of companies for obtaining funding in foreign currency. The two most important foreign currencies for Swedish banks and companies are the euro and the US dollar. The implied volatility for the exchange rate between the Swedish krona and these currencies captures the uncertainty surrounding future exchange rates and gives an indication of the companies' costs for protecting themselves against exchange rate fluctuations. These two indicators have also been included in the previous stress index.

30 day change in the value of the krona against a basket of currencies (TCW index) in absolute figures

A considerable increase in the value of the Swedish krona over a slightly longer period may reflect a change in fundamental economic factors, possibly also affecting other sub-markets. As volatility only provides information on fluctuations of the krona's value, changes of the krona's value on absolute figures compared with a basket of other currencies (TCW index) over 30 days are a good complement to the other indicators.

Appendix 2. Technical calculations

RANKING OF INDICATORS

Assume that we have a time series $x_1, \dots, x_n$ and that these observations are ranked according to size and create a new series of observations, $y_1, \dots, y_n$, in which y_1 is the smallest observation and y_n is the largest. The ranked value z_n of the latest observation x_n is calculated as follows:

$$z_n = f(x_n) = \begin{cases} \dfrac{r}{n} \ for \ y_r \leq x_n < y_{r+1} \ and \ r = 1, 2, \dots, n-1 \\ 1 \ for \ x_n = y_n \end{cases}$$

If a value occurs several times, the ranked value is set as the average ranked value. If, for example, we have 10 observations in which the tenth value has already occurred once and this value has been given the ranks 3 and 4 of the 10 values, the ranked value of the tenth observation will be (3+4)/2/10 = 0.35.

The ranking originally starts with the observations over the first four years being ranked in light of all observations during this period, before then going over to using historical data alone. This is done to increase the initial stability of the ranking.

PARALLEL TO PORTFOLIO THEORY

Assume that a portfolio consists of two assets with the standard deviations σ_1 and σ_2, correlation ρ_{12} and portfolio weights w_1 and w_2 in which $w_1 + w_2 = 1$. The portfolio risk (variance) can then be expressed as follows:

$$\sigma_P^2 = (w * \sigma) \ C \ (w * \sigma)^T = [w_1 \ \ w_2] \begin{bmatrix} \sigma_1 \\ \sigma_2 \end{bmatrix} \begin{bmatrix} 1 & \rho_{12} \\ \rho_{12} & 1 \end{bmatrix} \left[\ [w_1 \ \ w_2] \begin{bmatrix} \sigma_1 \\ \sigma_2 \end{bmatrix} \right]^T$$

$$= w_1^2 \sigma_1^2 + w_2^2 \sigma_2^2 + 2 \ w_1 w_2 \sigma_1 \sigma_2 \rho_{12}$$

The same principle is applied to calculate the new stress index, in which the standard deviations for the assets in the above illustration, σ_1 and σ_2, are replaced by the stress level among the sub-market indicators, and the correlation between the assets, ρ_{12}, is replaced by the correlation between the sub-market indicators.

CALCULATION OF STRESS INDEX AND ESTIMATION OF CORRELATIONS

The new stress index at the time t is calculated as follows:

$$Stress\ index_t = (w * s_t)\ C_t\ (w * s_t)^T$$

in which $w = [w_1\ w_2\ w_3\ w_4]$ is a vector of constant sub-market weights, $s_t = [s_{1,t}\ s_{2,t}\ s_{3,t}\ s_{4,t}]$ is the sub-market indicators at time t and $*$ marks the element-wise multiplication of vectors. C_t is a matrix of correlation coefficients at time t, $\rho_{ij,t}$, between sub-market i and j:

$$C_t = \begin{bmatrix} 1 & \rho_{12,t} & \rho_{13,t} & \rho_{14,t} \\ \rho_{12,t} & 1 & \rho_{23,t} & \rho_{24,t} \\ \rho_{13,t} & \rho_{23,t} & 1 & \rho_{34,t} \\ \rho_{14,t} & \rho_{24,t} & \rho_{34,t} & 1 \end{bmatrix}$$

The time-varying correlation coefficients are recursively estimated on the basis of an exponentially-weighted moving average of covariances $\sigma_{ij,t}$ and variances $\sigma_{i,t}^2$ respectively of the different sub-market indicators i and j:

$$\sigma_{ij,t} = \beta\sigma_{ij,t-1} + (1-\beta)\ z_{i,t}\ z_{j,t}$$

$$\sigma_{i,t}^2 = \beta\sigma_{i,t-1}^2 + (1-\beta)\ z_{i,t}^2$$

$$\rho_{ij,t} = \sigma_{ij,t}/\sigma_{i,t}\sigma_{ij,t}$$

for $i = 1,\dots,4$, $j = 1,\dots,4$ and $z_{i,t} = s_{i,t} - 0{,}5$ where $0{,}5$ is the sub-market indicators' theoretical mean value. The adjustment parameter β is constant at 0.93 (Kremer et al., 2012). For the first observation, which is to say where $t = 1$, the initial values for $\sigma_{ij,0}$ and $\sigma_{i,0}^2$ are set to the estimates of covariance and variance over the first four years.