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Editors: Marianne Nessén and Ulf Söderström

Advisory editorial committee: Mikael Apel, David Kjellberg, André Reslow, and the Communications Division

Sveriges Riksbank SE-103 37 Stockholm Telephone +46 8 787 00 00

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Dear readers,

This year's first issue of Sveriges Riksbank Economic Review contains four articles, all with slightly different themes. In the first article, Governor Stefan Ingves discusses Sweden's role in international economic cooperation, and in the second article, First Deputy Governor Cecilia Skingsley and Björn Segendorf discuss changes in the financial infrastructure. These are followed by an article that gives an overview of the foreign exchange market for Swedish krona, and finally a more technical article on various aspects of foreign exchange hedging.

• Sweden's role in international economic cooperation – then, now and looking ahead

Governor *Stefan Ingves* gives his view on the conditions for Sweden to make its voice heard in international economic cooperation, and how these conditions are affected by changing global power relations and radical changes within the EU. The article is an adaptation and further development of materials from various seminars and presentations that Governor Ingves has given in recent years.

• Rebuilding the financial structures

First Deputy Governor *Cecilia Skingsley* and *Björn Segendorf* discuss how technological advances affect the supply and demand for financial services, and the challenges posed by these changes. In addition, they describe what the Riksbank is doing to future-proof the parts of the financial infrastructure that the Riksbank supplies.

• Understanding the foreign exchange market

Amanda Nordström describes the changes undergone by the foreign exchange market in recent decades, and focuses in particular on the market for Swedish krona. She also presents a measure of market liquidity for Swedish krona, and discusses how liquidity has varied over time.

• Hedging against exchange rate risk – maturity choice and roll-over risk

Christoph Bertsch analyses various aspects relevant to Swedish financial companies that hedge their financial investments in foreign currency. In particular, he compares the risks and benefits of hedging in the short or long term, and presents a conceptual framework that can be used to analyse these questions.

Read and enjoy! Marianne Nessén and Ulf Söderström

Contents

Sweden's role in international economic cooperation – then, now and looking ahead	5
Stefan Ingves	
Rebuilding the financial structures	24
Björn Segendorf and Cecilia Skingsley	
Understanding the foreign exchange market	38
Amanda Nordström	
Hedging against exchange rate risk – maturity choice and roll- over risk	79
Christoph Bertsch	

Sweden's role in international economic cooperation – then, now and looking ahead

Stefan Ingves ^{*} Stefan Ingves has been Governor of the Riksbank since 2006.

Sweden has for a long time had a relatively strong voice in international economic cooperation. This has enabled us to contribute to the development of common regulations and frameworks without being dependent on passively accepting what others have decided. The conditions for a small country such as Sweden to make its voice heard in this cooperation are now changing dramatically, partly as a result of changing global power relations and radical changes within the EU. There is therefore a need for a discussion about Sweden's future role in, for example, EU cooperation, based on the understanding that things are changing rapidly and that we, as a small country dependent on foreign trade, have to deal with these new conditions.

1 Introduction

During the last century, Sweden has been very much involved in international cooperation, a cooperation that has been very favourable for Swedish economic development. The conditions for this economic cooperation are now changing considerably. This is partly due to the fact that the international power balance is shifting. The most recent example of this is, of course, not to be found in the economic but the geopolitical field and Russia's invasion of Ukraine. The full consequences of this action both in the short and long term are hard to grasp, and beyond the scope of this article. What is quite clear, however, is that it will have important repercussions on multilateral cooperation, also in the economic field, even if it is hard to say how. Another sign of the shifting power balance is the fact that China and other emerging economies are growing in strength and political influence, while the opposite is true of Europe. There are also rapid changes taking place in Europe, beyond the crisis in Ukraine. On the one hand, there are the euro countries, which are striving for a better functioning of monetary union and want to deepen their cooperation, not least in the financial field. And on the other hand, we have the

^{*} This article is an adaptation and further development of ideas and thoughts I have put forward at various seminars and presentations in recent years, for instance at the Association of Foreign Affairs in Uppsala in 2019 and the Association of Foreign Affairs in Lund in 2020. I would like to thank Mattias Hector for his help in transforming the lectures into an article. I would also like to thank Mira Barkå, Emma Bylund, José Camacho, Åsa Ekelund, Frida Fallan, Anders Lindström, Marianne Nessén, Jonas Niemeyer, Christina Nordh-Berntsson, Elisabeth Nilsson, Lena Strömberg, Ulf Söderström and Katarina Werder for valuable contributions.

United Kingdom, which recently took the step of leaving the European Union because it believes it is stronger outside.

In this article, I reflect on Sweden's attitude to international cooperation, how the conditions have changed and what challenges Sweden faces in the future. The reflections I make are based on my experience from international contexts, where I have been working in different roles for almost 40 years, something I consider to be a form of economic diplomacy.

2 An historical retrospective

2.1 A small country is dependent on the world around it

The development of the Swedish economy in the 20th century is remarkable. From being classified in the late 19th century as one of the poorest countries in Europe, Sweden is now ranked as the tenth richest country in the world – during parts of the 1970s we were actually as high as fourth ranked – when calculated as GDP per capita, see Bergh (2008) and OECD (2021).

It is not possible to explain this economic success with just one single factor, but one important explanation could be that Swedish decision-makers, both private and elected, appear to have realised at an early stage what particular challenges Sweden faces as a small country. As a small country, for example, we cannot achieve real prosperity by relying solely on our own markets, which is to some extent possible for a larger country. Nor can we impose our will on other countries by our size; we must use other means.





For a small country to achieve economic prosperity, it is instead absolutely necessary to have openness and cooperation with the outside world – something that becomes

Source: Statistics Sweden

very clear when you look at some key facts for the Swedish economy. The importance of foreign trade, for example, has shown a trend increase, and the value of both exports and imports now corresponds to between 40 and 50 per cent of GDP, see Figure 1. It is therefore not surprising that our GDP growth is so closely linked to developments abroad, as shown in Figure 2, which shows how close GDP growth in Sweden co-varies with growth in a weighted average of our main trading partners. However, we are not only dependent on the outside world for trade in goods and services – this becomes clear if we look at capital flows and the financial sector. The stock of Swedish direct investment abroad is the twelfth largest in the world, in relation to our GDP, see the National Board of Trade (2021). The corresponding figure for foreign direct investment in Sweden is the eighteenth highest.¹ The Swedish banks are not only big in relation to Sweden's GDP, but also have extensive international operations, especially in the Nordic-Baltic region, see Figure 3. Free movement of capital is thus an important prerequisite for Swedish companies, financial as well as non-financial, to thrive. Figure 4 illustrates that Swedish authorities are also dependent on the outside world. It shows the limited ability of national central banks to pursue a sovereign interest rate policy, as real interest rates in different countries tend to be strongly correlated.

Figure 2. GDP growth in Sweden and abroad



Annual percentage change

Note: KIX is a weighted geometric chain index, where the weights are based on total flows of processed goods and commodities for just over 30 countries. The weights are updated each year, and are based on data with a time lag of a few years.

Sources: Statistics Sweden and Sveriges Riksbank

¹ Here it should be noted that some of the countries that are higher up on the list are so-called tax havens, where direct investment is not always linked to any real economic activity. Instead, they are motivated by tax advantages of using companies registered in these countries for transactions of various types.



Figure 3. The major Swedish banks' lending in different countries and regions SEK billion

Note: Refers to lending to the public by Handelsbanken, SEB and Swedbank.

Sources: The banks' interim reports and Sveriges Riksbank



Figure 4. Real interest rates in different countries

Note: 10-year real interest rates on government bonds. Data for Germany starting in 2009.

Sources: National central banks and Sveriges Riksbank.

It goes without saying that a country like Sweden, with such a strong dependency on the outside world, therefore has a vested interest in international talks and negotiations which seek to reach agreement on common regulations and institutions, as we benefit from the fact that international integration can take place in a safe and fair manner. Such negotiations can take place bilaterally, that is, between two individual countries, but for a small country it is a great advantage if they are multilateral, between several countries at the same time. On the one hand, this ensures a more uniform playing field, since the agreements cover several countries, and on the other hand it reduces the opportunities for large players to dominate the smaller ones.

If we want to take advantage of the benefits of trading with the outside world, it is important that we make our voice heard. In the multilateral dialogue, in which several countries participate, we can do so in a way that is not possible in a world where each country negotiates for itself and where the largest tend to go first. The realisation of this crass reality has certainly contributed to the Swedish Parliament, Government and authorities having attached such importance to multilateral cooperation within organisations such as the United Nations, the World Trade Organisation, the International Monetary Fund (IMF), the World Bank, the Organisation for Economic Cooperation and Development (OECD), the Bank for International Settlements (BIS) and various regional development banks.² The path to joining different organisations has not always been uncomplicated and has sometimes been lined with caution and hesitation, but in the end the benefits of joining have carried the most weight.

2.2 Our early position on the BIS Board has been important for our influence

Sweden's multilateral engagement thus began early and this is a contributing factor in its success, not least with regard to the Riksbank. Through international lobbying and a great deal of luck, for example, the Riksbank succeeded in becoming a partner in the world's first multilateral financial institution, Bank for International Settlements (BIS) right from the start in 1930, and since 1931 the Riksbank has been represented on the Board, see Rooth (1930) and Sveriges Riksbank (1930). As we will see, it is hardly possible to overestimate the value of this, either for the Riksbank or for Sweden.

The BIS is known as the central banks' central bank and offers, possibly in competition with the IMF, the most important forum for international central bank cooperation. It is no exaggeration to claim that everything of importance that takes place in the world of central banks is somehow discussed in one of the various BIS groups. However, not all BIS members are allowed to participate in the various groups and committees – our Nordic neighbours, for example, participate in a very limited number of groups, which, moreover, applies to the vast majority of countries around the world. However, as a member of the Board, the door has been open for the Riksbank to participate, in principle, everywhere. For example, since the 1930s, Riksbank governors have been going to Basel every two months to meet the heads of the world's leading central banks and discuss current issues in groups with very limited participation.³ We have also been able to influence the shaping of global guidelines for both banks and infrastructure companies, as we are members of the Basel Committee for Banking supervision (BCBS) and the Committee on Payments and

² For a description of various international organisations, see the Appendix.

³ From the beginning, these meetings took place every month. Since 2002, the meetings are held every two months, see Toniolo (2005).

Market Infrastructures (CPMI).⁴ I also had the honour of heading up the Basel Committee two terms of office, between 2011 and 2018. This was a very interesting period, when the Committee had an important role to play in reforming banking regulations, based on the experiences from the global financial crisis. Having access to this exclusive platform, which is a direct consequence of the fact that we managed to join the Board so early, is something that few European countries, and no other Nordic country, have succeeded in.⁵

2.3 Leadership of the IMF and the UN

Sweden was not quite as quick to join the so-called Bretton Woods institutions: The International Monetary Fund and the World Bank. This seems to have been partly due to some doubts in Sweden as to whether membership of the Bretton Woods institutions was appropriate from a stabilisation policy perspective. However, Swedish foreign trade dependence seems to have been an important explanation for the fact that the Swedish position changed – membership of the International Trade Organization (ITO) and the GATT negotiations were namely judged to require IMF membership. Alternatively, it could have been possible to establish foreign currency agreements with the IMF member countries that were based on the IMF's Articles of Agreement, see Ahlström and Carlsson (2005). Faced with this choice, the government applied for membership of the IMF – it was apparently deemed better for Sweden to be part of the organisation, and thereby gain influence, than to remain outside and still have to observe its rules.

However, the delay in joining the IMF was not only due to doubts on the part of Sweden. Our neutrality during the Second World War appears to have led to some suspicion from, for instance, the United States, see Ahlström and Carlsson (2005). However, the distrust was no greater than that Riksbank Governor Ivar Rooth became the head of the International Monetary Fund, as soon as Sweden had become a member in the early 1950s, only to be succeeded by another Swede, Per Jacobsson.⁶ The fact that this happened at the same time as Dag Hammarskjöld was head of the United Nations was no less impressive.⁷ Sweden is thus one of the small number of countries that have had the top post at the International Monetary Fund, and is the only country apart from France that has had the post more than once.

⁴ For a description of the BIS committees, see the BIS website, <u>www.bis.org</u>.

⁵ It was not until 1994 that the Board was expanded to include the governors of the central banks in Japan and Canada. In the same year, the American Central Bank chose to take up its seat on the board, see Toniolo (2005). As one of the founding countries, Japan was represented on the board from the beginning, but it lost its seat in the aftermath of the Second World War. The United States had since 1935 renounced its seat for domestic policy reasons, see Toniolo (2005).

⁶ Ivar Rooth was Managing Director of the IMF from 1951 to 1956 and Per Jacobsson from 1956 to 1963.

⁷ Dag Hammarskjöld was the UN Secretary General from 1953 to 1961. During most of the 1940s, Ivar Rooth and Dag Hammarskjöld managed the Riksbank, Rooth as Governor, Hammarskjöld as Chairman of the Riksbank's General Council, see Barvèll et al. (2019).

2.4 Success factors behind international influence

Small countries must be constructive

It is difficult, as a small country, to exert real influence in international contexts. In negotiations with individual, large countries, I believe that it is more or less impossible, but even in a multilateral context, there are certain factors that I consider to be crucial to whether or not a country can gain influence.

Taking part and sitting at the table when international issues are negotiated is of course a prerequisite for gaining influence, but it is equally important to be committed and constructive, especially if you come from a small country. It is important to show that one contributes to moving matters forward, and not just acting as a brake by taking into account special domestic interests. I believe that we in Sweden have long had a civil service with just that attitude, both within the cabinet offices and in public authorities. We may not always be as well-spoken and elegant as the French and British, but we are diligent and focused on finding effective consensus solutions that are good for everyone – not just individual interest groups. My experience is that the world around us also knows that Swedish civil servants are trained in how to act to get forward and get the job done. This has contributed to the fact that Swedish representatives have sometimes succeeded in gaining an influence that is greater than can be justified by Sweden's economic and political importance. There are surveys that confirm this picture. For example, researchers at the University of Gothenburg have measured the so-called network capital of different EU countries. Sweden is in an honourable fourth place, see Johansson et al. (2019). It is also significant that former first Deputy Governor Kerstin af Jochnick was appointed to be a member of the Banking Union's Supervisory Board as one of four representatives of the European Central Bank (ECB) - even though Sweden is not a member of the Banking Union. I am also sure that this constructive view of my colleagues at various levels can explain to a large extent the fact that I have had the privilege of becoming first Vice-President of the European Systemic Risk Board (ESRB) and Vice-President of the BIS Board of Directors.

Sweden has been there for others when it was needed

Another important condition for a country to have real influence is that other countries understand that it can be relied on if there are problems. In plain language, this means that you are prepared to put your money where your mouth is and offer a loan when others hesitate. And over the years we in Sweden have shown that we are ready to do so. For example, the Riksdag (Swedish parliament) decided that we should be one of the countries that formed the General Arrangements to Borrow in 1962 (GAB), the 'reserve fund' that the IMF could use if its regular sources of funding were not sufficient. Sweden has also provided bilateral loans to the IMF on various occasions, and we are also participating in the so-called New Arrangements to Borrow (NAB) which has replaced GAB as the IMF's reserve financing. In addition, the Riksdag set up bilateral loans to Iceland, Latvia and Ireland in connection with the most recent financial crisis.⁸ In the same vein, the Riksbank also set up swap lines for other central banks to address their urgent needs before support from governments and the IMF/EU had been put in place, see Leung (2020). In 2015 the Riksbank also entered into a swap agreement with the central bank of Ukraine, see Sveriges Riksbank (2015). One can also add to this the whole of Sweden's foreign aid. Part of this consists of the Riksbank's involvement in so-called technical assistance, financed by Sida. The Riksbank is currently working on projects with the central banks of Namibia, Palestine, Rwanda and Ukraine. In relation to the size of the Swedish economy, Sweden is one of the largest foreign aid donors in the world – so it can probably be said that we have done our bit.

This willingness to provide resources, in the case of the Riksbank through loans, has been important for our international influence.⁹ By way of example, I would like to highlight Sweden's membership of the so-called G10 group, which consists of the countries that formed the GAB, namely the G7 countries plus the Netherlands, Belgium and Sweden. After two years, Switzerland also joined, so the number of countries was eleven, but the name G10 was retained. The fact that Sweden came to belong to this group has been extremely important for our international influence. It has offered direct access to the G7 countries and has made it easier for our decisionmakers to build relationships with their counterparts in the most powerful countries in the world. Swedish representatives have thus belonged to a circle of trusted people who have been given access to information that we would not otherwise have received. It is an interesting fact that the same group of countries are those that have formed the board of the BIS for a long time. The fact that we managed to join the BIS Board in 1931, by luck and skill, has thus, in my opinion, been a very important explanation for our relatively strong international influence during the remainder of the 20th century.

2.5 We benefit from the good health of those around us

However, helping others has not only given Sweden influence in various organisations. It is just as much a question of the simple truth that instability risks spreading from one country to another, something that is painfully obvious in the case of Ukraine, although this is primarily a geopolitical issue rather than economic. As a small country, we have a particular interest in preventing instability in the world around us, since we are economically entirely dependent on the outside world to be able to export and maintain our financial stability. This means that "what's good for you is good for me". This is another way of saying that international trade and growth is not a zero-sum game, but an example of a classic win-win situation. From this perspective, it is commendable, for instance, that the EU has managed to agree on

⁸ For information on the various credits (in Swedish), see, Committee on Finance (2009, 2010, 2012). On 28 February 2022, following the Russian invasion of Ukraine, the Swedish Parliament decided to provide not only humanitarian aid, but also support in terms of funding, weapons and protective equipment to the armed forces of Ukraine.

⁹ It is worth noting that the Riksbank has never made any loan losses on its credits to the IMF or other central banks.

financial support for Ukraine as well as the countries that have been relatively hard hit by the pandemic.

3 Challenges for Sweden

Sweden's ability to participate in, and exert influence on, international cooperation is not without challenges, however. As a result of globalisation, the international environment in which Sweden is active is changing rapidly and significantly.

3.1 Changed global power relations pressuring Sweden

Figure 5. Production in various countries and regions

The most direct result of globalisation is that economic power relations have changed. This is a process that has been going on for a long time and the result is, above all, that so-called emerging economies in Asia and Latin America have grown in strength compared to Europe and the United States. Of course, the Chinese development has been particularly remarkable, see Figure 4. The fact that these countries are growing faster than we are is in itself nothing to complain about, even if it would have been nice if certain European countries, in particular, could have performed better. In fact, the world economy would have developed considerably weaker without the impetus provided by these emerging markets. Not least, it would have been felt by Europe over the last ten years. As I mentioned earlier, this is an illustration of the fact that economic growth is not a zero-sum game – in absolute terms, it is better for us if things are better for the world around us.



GDP at current prices, USD billion

Source: The OECD

Sweden has not been able to join the G20 and the FSB

The drawback for Sweden lies instead at the political level, and our scope to pursue economic diplomacy. The emerging economies have legitimate expectations of having political representation in the international community that reflects their growing economic strength. And, to a large extent, it is Europe that is expected to make room. Perhaps the most obvious illustration is the emergence of the G20 and the Financial Stability Board (FSB). These groups were formed because the large countries saw a need to create forums that better reflected the changing global economic power relations than the existing organizations did. On the initiative of the G7 countries, the G20 was therefore created in 1999. The group is not a formal organisation, but rather an organised cooperation. It consists of the G7 countries and a number of the largest and fastest-growing emerging markets, none of which is European. In the same year, the G7 also created the Financial Stability Forum (FSF), which at that time did not include any emerging markets. However, this was changed in the context of the global financial crisis, and in 2009 the FSF became the FSB, with all G20 countries participating, plus the Netherlands, Spain and Switzerland.

By looking at the composition of the G20 and the FSB, we can clearly see the particularly vulnerable position that Sweden has: Instead of making these groups consist of G10 plus strong emerging markets, it was decided to let the FSB consist of G10 minus Sweden and Belgium, but plus Spain and a number of emerging markets.

This is the clearest illustration so far of the fact that Europe in general, and Sweden in particular, no longer enjoys the same privileged position in international cooperation as before. The Riksbank has argued that Sweden should be a Member of the FSB as a representative of the Nordic region, but without much success. We did manage to get the Riksbank and Finansinspektionen (the Swedish Financial Supervisory Authority) included in certain committees where we were deemed particularly relevant, but the Swedish authorities were not made full members. The Riksbank has then delegated to the Swedish National Debt Office to participate as the authority responsible for resolution of banks. The main reason why Sweden managed to get a certain representation was that we were home to the only global systemically important bank in the Nordic region, Nordea – should Nordea get into trouble, it was practical to have the responsible authorities nearby. However, as Nordea has now moved to Finland, Swedish participation in the FSB committees has already begun to decline.¹⁰

Another illustration of Sweden's decreasing role internationally is how our access to swap lines with other central banks has changed. As recently as during the financial crisis in 2008–2009, Sweden was among the countries that were offered a swap line with the US Federal Reserve in the first round. The Riksbank was then in the company of, amongst others, central banks in countries such as Canada, Japan, Switzerland and the United Kingdom, as well as the ECB. The central banks of these other countries have had a standing swap-line with Federal Reserve since 2013. When the Federal Reserve at the beginning of the pandemic offered temporary swap lines to other central banks, the Riksbank was one of nine central banks to be offered one. With

¹⁰ In 2018, Finland took over participation in the FSB group to identify data requirements for globally systemically important banks.

regard to other central banks in need of dollar a new lending facility was introduced.¹¹ The Federal Reserve has since ended the temporary swap-lines and the Riksbank has joined the lending facility.

Europe under pressure in the IMF

Another clear example of Europe and Sweden being pushed back on the international stage can be seen within the IMF. Here, there is great pressure from fast-growing emerging markets for their new economic strength to be reflected in their relative voting power. This is, of course, a legitimate requirement, but at the same time it is not clear how it should be adjusted and calculated technically. Countries such as China, for example, are not shy and if we are not careful, we risk being hit harder than is reasonable. How this is to be achieved in practice is therefore something that civil servants in the cabinet offices and at the Riksbank have to put quite a lot of common effort into negotiating internationally.

This global negotiating game has resulted, among other things, in a commitment from Europe's developed economies to reduce their representation on the IMF's Executive Board.¹² The idea is that this representation should be reduced by the equivalent of two executive director posts. It has developed into a form of bickering within Europe, where the larger EU countries have made it clear that they have no interest whatsoever in contributing to this.¹³ Here, too, we need to be vigilant in guarding our interests. Otherwise, there is a risk that the Nordic-Baltic constituency to which Sweden now belongs will be dissolved and, ultimately, we will have a considerably worse national representation in the IMF.

Sweden's position in the BIS is uncertain

A further organisation in which the Riksbank, and thus Sweden, risks losing influence in the not too distant future is the BIS. As I mentioned earlier, Riksbank governors have been members of the Board since the 1930s, see Toniolo (2005). Until now, each new Governor of the Riksbank has in practice been automatically elected. In fact, from 1942 to 2009, the President of the Board was appointed from one of what we often call the junior countries, that is, Belgium, the Netherlands, Switzerland and Sweden, which makes it clear what a strong influence these countries had at the time. Since then, the model for the appointment of a President has changed, and no

¹¹ Slightly simplified, in using the facility, which is known as the Foreign and International Monetary Authorities (FIMA) Repo Facility, a central bank enters into an agreement to sell US government bonds to the Federal Reserve while simultaneously promising to repurchase them the day after. Contrary to a swapline, where the central bank in need of dollars can create its own currency to get dollars, making use of the lending facility requires the central bank in question to own US government bonds.

¹² The Executive Board is responsible for the day-to-day operations of the IMF and consists of a representative of each constituency, under the chairmanship of the Executive Director of the IMF. Other important bodies within the IMF are the Board of Governors, which is responsible for the IMF's strategic governance, and the International Monetary and Financial Committee (IMFC), which is the IMF's highest policy-making body.

¹³ In many cases, European countries share constituencies with countries from other parts of the world. A reduction in the board representation can then be achieved by adjusting the rotation schemes that govern how often and for how long each constituency country is represented on the Executive Board. Other ways of achieving a reduction are to combine constituencies, or to create more purely European constituencies.

President from these four countries has been appointed. I was actually appointed Vice-President of the Board as recently as November 2021, but it is clear that the position of the small countries in the BIS is weakening. Recently, a reform of the board was made, which entails, for instance, the maximum number of board members being reduced and that it is no longer self-evident that countries will gain renewed confidence, see BIS (2016). Here, too, Sweden is living dangerously - if a new member is to be elected to the Board, there is an imminent risk that a new Governor of Sveriges Riksbank will not have a seat.

3.2 Multilateralism in danger of losing ground

The tougher reality is seen not only in individual organisations, but also in the fact that multilateral cooperation itself is increasingly under pressure, in favour of negotiations between individual countries. This became particularly clear during the previous US administration. Hopefully it will change under the new President, but to some extent this remains to be seen. China is also showing an increasingly clear tendency to use its economic strength to put pressure on individual countries, not least in political contexts. Such pressure can be very difficult to deal with if there are no international regulations and institutions to fall back on. For a free trade-dependent nation like Sweden, it would therefore be very serious if the countries of the world moved away from multilateral cooperation. Weakened multilateral organisations inevitably mean a direct weakening of Sweden's ability to assert its interests in the international negotiating game. This applies not only to the economy; the political effects are at least as worrying, not least linked to China's increasing international self-confidence and Russia's aggressive expansion policy.

3.3 Strengthened role of euro, and Brexit make our exclusion clearer

Within the EU too, there are changes that affect Sweden's ability to exert influence.

For example, one effect of the economic and financial crisis in 2008–2009, which developed into a crisis for the whole of the euro area, has been that the euro area countries have intensified and deepened their economic and political cooperation with a view to improving the functioning of the monetary union. The enhanced cooperation in the euro area is illustrated, among other things, by the clearer role of the so-called Eurogroup, that is, the finance ministers of the euro area countries. They meet regularly on the eve of the ECOFIN meetings and are thus able to coordinate positions for the formal decisions of the ECOFIN Council. Euro area countries also meet in preparation for meetings of Heads of State or Government of the European Council, in so-called euro summits, which provide political guidance on issues of particular importance to the euro area countries, see the Euro Summit Statement (2011).

The work has been particularly intensive in developing a framework for dealing with the deeply interconnected European banking system. With the so-called Banking Union, the European Union has created a system of joint supervision of the major European banks through the ECB and joint resolution of failing banks through the Single Resolution Board.¹⁴ Work is also underway to create the so-called third leg of the Banking Union – a system for a joint deposit guarantee – but this has not yet been achieved.¹⁵ The Banking Union is a response to the so-called financial trilemma, which states that one cannot simultaneously have 1) integrated financial markets and 2) financial stability with 3) national responsibility for supervision and resolution. The countries of the Banking Union have thus given up some national autonomy in exchange for a more integrated and more stable banking system. Through the Banking Union, the euro countries have further reason to cooperate to influence the formulation of EU regulations to suit their own interests. All in all, this means that it is becoming more difficult for countries outside the euro area or the Banking Union to influence the shaping of the rules that will apply to us.

The second important change in Sweden's ability to exert influence within the EU is linked to the United Kingdom's withdrawal from the EU. Brexit is in many ways a tragedy for Europe and will lead to a loss of economic and political strength in both the EU and the UK. The economic consequences will be more serious for the UK, but the EU will also be affected. This is particularly true in the financial field, where London is a global financial centre. The way in which the EU chooses to deal with the fact that this financial centre is now outside the EU is something that will be of great importance to the financial sector in the EU.

Prior to the British withdrawal, the United Kingdom was a very important partner for Sweden in the EU work. The group of non-euro countries, through the UK's involvement, had a political and economic weight which made it difficult for euro countries to ignore this group, particularly regarding issues with bearing on the financial markets.¹⁶ However, with the British withdrawal, this situation has changed radically, with a clear shift of power from non-euro countries to euro countries in terms of power over financial market issues. This is particularly unfortunate for a country like Sweden, with its relatively large financial sector and internationalised business sector. After Brexit, we belong to a far less influential group of countries, a group with which we also have much less in common than with the United Kingdom. We also know that some of these countries have a clear ambition to join the monetary union in the near term. As the group of non-euro countries shrinks, it will become increasingly peripheral in an EU perspective.

 ¹⁴ For information on the Banking Union, see <u>www.consilium.europa.eu/en/policies/banking-union/</u>.
¹⁵ For information on joint deposit guarantee work, see <u>www.consilium.europa.eu/en/policies/banking-union/risk-reduction-european-deposit-insurance-scheme/</u>.

¹⁶ The group of non-euro countries consists of Bulgaria, Denmark, Croatia, Poland, Romania, Sweden, the Czech Republic and Hungary.

4 What does the future have in store?

4.1 Globalisation cannot be stopped – we must do what is necessary to meet the requirements

In my analysis of how we in Sweden should deal with the challenges we face, I use as a starting point two basic circumstances, one of which is the one I mentioned at the beginning: Sweden is still a small country. And in relative terms, this is even more true now than it was 40 to 50 years ago. The second point is that the continued internationalisation process cannot be stopped and that our economic wealth is actually dependent on internationalisation. There are, of course, protectionist forces operating in the opposite direction, but in the long run I find it hard to see that internationalisation would not continue. If nothing else, it will be an inevitable consequence of technological development.

As I have noted, Swedish decision-makers have for a long time shown an understanding of what this requires. The Swedish, or Nordic, model is not based on protecting individual sectors and companies, as in some other countries. Instead, it is a question of facilitating production changeovers by, for example, providing social safety nets for individuals. This unsentimental attitude toward replacing individual industries with new ones is, I believe, fundamental to us being able to survive in an increasingly internationalised world. Having a well-managed, strong economy is also something that gives the necessary weight in a European discussion that will increasingly be dominated by the euro countries.

4.2 Nordic Baltic cooperation can safeguard influence

The fact that Sweden belongs to a region that in many ways is economically and technologically successful is also something that could be used more as an argument in the discussion about representation in international organisations. The four largest Nordic countries each hold rankings located between 40 and 60 in the world in terms of total GDP. If you look to the Nordic countries as a region, however, we have the seventeenth highest GDP in the world. Moreover, the region is economically and financially well-integrated, with a very advanced position in terms of innovation. As an illustration, since 2006 Sweden has been among the top three ranked nations in the Network Readiness Index, which assesses how well countries are able to benefit from the possibilities provided by digitalisation.¹⁷ In the latest measurement in 2021, four of the nine top ranked countries were from the Nordic region, with Sweden and Denmark in second and third places. Therefore, if we could bring more of a 'constituency' way of thinking into different organisations, we might be able to retain more of our international influence. This could be relevant in several organisations, such as the G20, FSB and BIS.

In this context, I am pleased to note that the central banks of Denmark, Iceland, Norway and Sweden have succeeded in becoming host to a so-called BIS Innovation

¹⁷ The Network Readiness Index was initially developed by the World Economic Forum. From 2019, it is produced by the independent think tank Portulans Institute in Washington, DC.

Hub (BISIH), based in Stockholm. This Nordic Innovation Centre, which was officially opened on 16 June 2021, will focus on a more in-depth analysis of technological financial innovation relevant to central banks. The Centre will function as a hub for a network of innovation experts, for research on important trends in financial technology of significance for central banks, and for promoting international collaboration aimed at improving the functioning of the global financial system. The idea is to take advantage of the fact that Sweden and the Nordic-Baltic region are, in many respects, world leaders in innovation related to IT and financial services. The hub is one of seven BISIHs in total distributed around the world.¹⁸

4.3 Self-determination is a chimera

The fact that Sweden is losing relative economic strength and absolute political influence over time, I believe, increases the cost of remaining outside the cooperation that is available. In addition, I would like to argue that the independence and self-determination we in Sweden believe we gain from not belonging to one cooperation or another is increasingly a chimera. Allow me to give some examples: When the Riksdag decides on Swedish legislation in the financial market area, there are not many decisions they can take where there is no more or less restrictive legislation at EU level that must be complied with. EU legislation in turn must be based on global agreements, because the EU, too, is not acting in complete isolation from the outside world. Deals within, for example, the G20, the FSB and the Basel Committee on Banking supervision bind the EU, if not legally, but politically, as the EU and individual EU countries are represented in these groups.

This is, for example, an important aspect when discussing whether Sweden should participate in the Banking Union. The so-called bank package, which is now being implemented in Swedish law, restricts the scope of both the Financial Supervisory Authority and the Swedish National Debt Office quite significantly, and means that the independence we believe we should retain in the event of exclusion is eroded even further – and this development is unlikely to decline in strength.

If we talk about the need for national solutions in the area of payments, for example, we should be aware that the financial infrastructure is already very internationalised, see Segendorf and Skingsley (2022). For example, a payment between two Swedish banks that is settled in the Riksbank's RIX system typically requires the use of technical infrastructures in 4–5 countries. This indicates that it is far better to sit at the table and exert the little influence we have, than to stand alone and have to adopt rules without having any influence over the decision-making process. With Britain's withdrawal from the EU, Sweden's situation risks becoming more and more similar to that of Norway, if we do not have the courage to move closer to the core of EU cooperation.

A pedant might object that some EU countries actually have significant structural problems, and that the euro cooperation has sometimes appeared near to collapse –

¹⁸ The BIS has also opened hubs in Singapore, Hong Kong, Switzerland, Canada, the United Kingdom and the euro area (Frankfurt/Paris).

so is a closer cooperation with these countries really good for Sweden? It is true that there is much room for improvement, both in the way individual economies operate and in the way the cooperation works. For example, the EU's efforts to improve the potential growth and functioning of the Member States have been sluggish. In my view, this partly reflects the fact that the Member States of the Union in many cases focus on short-term costs of reforms and do not see the long-term benefits, as these often benefit future generations, and this is a group that has difficulty in making its voice heard in the debate. However, a stronger Swedish voice in this cooperation could help the EU to better focus on openness and free trade and address the challenges of internationalisation.

From my perspective, we in Sweden must consider what alternatives we actually have, given the changed global circumstances I have described. We must accept that Sweden is a small country and that our economic prosperity depends on free trade and openness. From this perspective, protecting national self-determination, which is in many respects a chimera, would in my opinion be counterproductive, bordering on illogical. If you want to be a little drastic, you could say that you can choose to reverse into the future in the hope that we will be stronger on the sidelines. Or, we can accept that the world is becoming smaller and more competitive every day, and that this process makes new demands of us as a small country. The basic question that I think we in Sweden have to consider is whether it is better to sit at the table than to stand alone outside - in other words, whether we want to be a 'rule maker' or a 'rule taker'. Although our influence at the table will still be limited, I am convinced that we will gradually become more of the latter if we do not actively work to further deepen our international commitments. This is true even if, in some ways, it means that we have a reduction in nominal self-determination, which would be the case, for example, if we were to join the Banking Union and if we were to adopt the euro.

5 Closing comments

In this article, I have tried to give my perspective on Sweden's role in international cooperation, what could also be called economic diplomacy: how it has developed historically, which factors explain our priorities for multilateral cooperation, and the relatively large influence we have had over a long period of time, but also the challenges we are facing now in terms of global, and regional, shifts in various power relationships. If you are not aware of these changed circumstances, it is easy to be led to believe that our international influence is greater than it is in reality, and that we will retain our self-determination and influence if we don't 'rock the boat'. I believe that this is a serious misconception. We must have a serious discussion about Sweden's future role in, for example, the EU cooperation, based on the understanding that things are changing rapidly and that we, as a small country dependent on foreign trade, must deal with these new conditions. Recent events in Eastern Europe put these challenges in the headlights and show just how rapidly and unexpectedly changes can occur, and how important preparedness and institutional knowledge are for managing unforeseen situations.

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APPENDIX A – Glossary

BIS – Bank for International Settlements: The Bank was founded in 1930 and is thus the oldest international financial institution. An early task for the Bank was to participate in the settling of reparation payments imposed on Germany following the First World War. The Bank is owned by 63 central banks worldwide and its mission is to support central banks' pursuit of monetary and financial stability through international cooperation. To this end, extensive analysis and research work is carried out, including through a number of committees and working groups. It also hosts certain groups, such as the Basel Committee on Banking supervision, which sets global standards for banking supervision, and the Financial Stability Board (FSB). The BIS also serves as a bank for central banks. The bank's headquarters are in Basel, Switzerland.

FSB – Financial Stability Board: An organization of representatives from central banks, financial supervisory authorities and ministries of finance, established by the G20 in 2009, with the aim of promoting financial stability by coordinating national financial authorities and the work of international standard setting groups to strengthen the regulation and supervision of the financial sector. The predecessor to the FSB, the Financial Stability Forum (FSF), was founded by the G7 countries in 1999. The FSB secretariat is located in Basel and is financed by the BIS. Members are government agencies from Argentina, Australia, Brazil, the EU, France, India, Indonesia, Italy, Japan, Canada, China, Mexico, the Netherlands, Russia, Saudi Arabia, Switzerland, Spain, the United Kingdom, South Africa, South Korea, Turkey, Germany and the United States.

G20: An informal association of countries without a permanent organisation and with a rotating presidency. The group declared itself the primary forum for economic cooperation in 2009. Its members are Argentina, Australia, Brazil, the EU, France, India, Indonesia, Italy, Japan, Canada, China, Mexico, Russia, Saudi Arabia, the United Kingdom, South Africa, South Korea, Turkey, Germany and the United States. Spain has a seat as a permanently invited guest.

OECD – Organisation for Economic Cooperation and Development: Created in 1961 from the former OEEC (Organization for European Economic Cooperation), which in turn was a product of the Marshall Plan for the reconstruction of Europe. The organisation is a forum for cooperation between member states' governments and aims, among other things, to promote economic growth and employment and a higher standard of living in the Member States.

IMF – International Monetary Fund: Founded in 1944 as one of the two so-called Bretton-Woods institutions (the other is the World Bank). The IMF works to ensure the stability of the global financial system and to prevent international financial crises. The IMF monitors and analyses the development of the 190 countries that are members. The organisation also provides technical assistance and lends money to countries carrying out economic adjustment programmes. The IMF's Board of Directors consists of representatives of the IMF's 24 constituencies, where each constituency covers one country or group of countries.

Rebuilding the financial structures

Björn Segendorf and Cecilia Skingsley^{*}

Cecilia Skingsley is First Deputy Governor of the Riksbank and Björn Segendorf is a Senior Adviser in the Riksbank's Payments Department

Digital technology is developing rapidly and affects the supply and demand for payment services and financial services. But the way in which the financial sector produces these services is also changing. The financial infrastructure is the 'factory' used by the financial sector in this form of production. The Riksbank provides important parts of the financial infrastructure. It is therefore of the utmost importance that the Riksbank's supply of infrastructure services meets the needs of the market.

In this article we describe the changes driven by technological advances, the challenges they pose and what the Riksbank is doing to future-proof the services that the Riksbank supplies to the Swedish market.

1 Introduction

Technological advances are rapid, not least in communication. In the space of 100 years, we have moved from postal services, telegraph and radio to television, e-mail and streaming. We can post images that are instantly available on social media and send text messages that reach the recipient within seconds. This is something we take for granted, and we expect the same speed regardless of national borders everywhere in society.

Payments, securities trading and other financial services are essentially also a matter of transferring information between different parties. But in these areas, developments do not seem to have created the same real-time experience as in other communications, with the instant payment app Swish as a major and important exception on the Swedish market. If you want to pay bills, it usually takes one day before the payment order is executed. If you want to buy or sell securities in a marketplace, you can certainly do it online at the touch of a button, but the actual exchange of money and securities takes place two days after the deal has been made.

Financial services are not only slower than communications services. Physical distance also plays a greater role. Communication services are now virtually independent of geographical distances, while financial services are subject to barriers that increase with distance and geographical borders.

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If you want to call someone in France or Spain, just dial the phone number, and an email reaches Paris and Madrid as quickly as Perstorp and Malung. It doesn't matter where you are, whether you want to follow someone or be a friend of someone on the various social media sites available. In contrast, payments to countries in the eurozone are admittedly relatively simple and quick compared to before, but it still takes a day for them to get there. If you want to buy shares in France or Spain, there are few easy ways to do so. It takes longer than buying Swedish shares and it is more expensive. When it comes to moving financial values, there seems to be a simple rule of thumb: The further the value has to travel, the more complicated it is, the more expensive and the longer it takes.

2 Why financial services are so slow

To explain why financial services are still operating as slowly as they are, we first need to outline the financial infrastructure. In brief, it consists of the technical systems that manage payments and transactions with financial instruments. Money and securities are now mainly recorded and recorded digitally. The general public's demand deposits with banks and the state, that is, money that can be withdrawn immediately or at short notice, amounted to nearly four thousand billion kronor in November 2021, while the public's holding of cash was slightly over SEK 60 billion.¹ Like demand deposits, all securities are also issued and registered digitally. A payment or securities transaction is therefore now essentially a matter of exchanging information between buyers, sellers and their intermediaries, which are usually banks.

Let us take two examples, the first of which is what happens when a payment is to be made, the second when a security is to be purchased.

2.1 How does a payment work?

Let's start with money and a payment to be made digitally. Money is generally recorded in accounts with a bank. When making a payment, it must be possible for the paying party and the recipient to have accounts in different banks. The payer's and payee's banks therefore need to communicate, record and exchange money with one another. The latter step is called settlement, which means that payment is finally regulated between the banks involved. Settlement almost always takes place by the banks having accounts with the Riksbank that they use to transfer money between one another. This is done in the Riksbank's RIX-RTGS payment system, where around 531,000 payments are made per month, with an average value of approximately SEK 35 million. The annual turnover in RIX-RTGS is around SEK 130,000 billion, that is nearly 26 times Sweden's annual GDP.

RIX-RTGS is built to carry out relatively few but large payments between banks and not to handle large amounts of payments or the information accompanying payments by the general public, such as reference numbers, invoice numbers, customer numbers and similar information. As the number of payments in the economy is very high, the banks therefore cannot send all payment instructions between themselves

¹ Statistics Sweden, Financial Market Statistics, November 2021, Table 5.1.

one by one via RIX-RTGS, but use a central hub called a clearing house, and that merges payment information from many small payments into large files to ensure that each bank gets the right information at the right time.² The clearing houses are thus responsible for communication, consolidation of payments, including calculation of the amounts to be paid to one another at the time of settlement, and provide a base for the accounting needed before and after settlement.³ Clearing houses can also help banks to implement the settlement by sending instructions to the settlement system. Because of the clearinghouse, each bank has to process only a few information exchanges instead of many thousands per time interval. The clearing house used by a bank depends on the type of payments it makes. For example, Bankgirot is used for bank giro payments and most often Visa or Mastercard is used for card payments.⁴ See Figure 1 for an illustration of a payment between a buyer and a seller with different banks.

Figure 1. Payment between buyers and sellers with different banks where the payment information goes through a clearing house



2.2 How does the purchase of securities work?

Our next example concerns trading in securities that takes place on a trading place, that is, a stock exchange, where price and quantity are agreed. Buyers and sellers use a bank or other financial institution as an intermediary to place the buy or sell order on the stock exchange. However, the transfer of ownership is not registered there but with a so-called central securities depository, CSD. In Sweden's case the CSD is Euroclear Sweden AB, where securities are issued and ownership is registered.⁵ The

² The following anecdote can illustrate the practical value of using a central hub. In London in the 1770s there were so-called walk clerks that went between the banks to redeem and pay cheques. It is said that two of them were eating lunch at the Five Bells Inn on Lombard Street. During their well-deserved break, one of them suggested that all walking clerks should meet at the Five Bells to exchange cheques instead of walking around as they did now. This was the birth of the modern clearing house. See Shafik (2016).

³ These amounts to be paid by the banks to one another can be calculated in two ways: net or gross. Almost all payment flows via Bankgirot are gross amounts, while card payments are net amounts.

⁴ However, card payments via Visa and Mastercard are an exception to the rule that all payments within Sweden are settled in RIX-RTGS. These payments are settled at selected banks abroad.

⁵ A central securities depository is a company that provides securities accounts, securities storage and issuance and often associated services such as voting lists for annual general meetings, dividends, interest payments and so on. When securities are issued, they are registered with the securities depository, which registers ownership and transfers and ensures that the information is accurate and complete. A securities

ownership information then forms the basis for dividends, interest payments and so on.⁶ For certain types of transactions, clearing houses are also used for securities trading.⁷

The purchase of securities is not complete until the seller has received money for the security. Ideally, money and securities should exchange hands at the same time, to reduce the risk that one of the parties will not receive what they have agreed on (credit risk) or that they will receive it too late (liquidity risk).⁸ This type of exchange is much easier if the accounts for both securities and money are in the same place, which they are in Sweden. Euroclear carries out the transfer of the securities at the same time as it transfers money between the buyer and the seller, or in their agent's accounts with Euroclear. These accounts can be regarded as part of RIX-RTGS in that the Riksbank allows Euroclear to administer special RIX accounts in Euroclear's own systems.

2.3 A safe infrastructure is important for the krona to function

Why does the Riksbank allow Euroclear to administer special RIX accounts? Well, central banks have a particular responsibility for the proper functioning of financial infrastructures, see Figure 2.⁹ This is because the Riksbank's tasks regarding price stability and a safe and efficient payment system presuppose that the financial infrastructure is safe and efficient. There is an interdependence between these tasks. Price stability and a secure and efficient infrastructure contribute to making the Swedish krona attractive for payments within Sweden. The use of the Swedish krona is in turn a prerequisite for the Riksbank to conduct monetary policy and for the use of the payment infrastructure provided by the Riksbank, including cash. If the Swedish krona is not used for economic transactions, the Riksbank loses the tools necessary for the Riksbank to carry out its tasks.

depository usually operates a securities settlement system and sometimes, as in the case of Euroclear Sweden AB, also a settlement system for the associated payment.

⁶ In our review, we disregard, for the sake of simplicity, so-called custodians, which are companies, usually a bank, that store and administer securities or other assets on behalf of their customers and which can also provide other associated services such as clearing and settlement, liquidity management, currency exchange and cross-border payments, credit and pledging.

⁷ These clearing houses are often so-called central counterparties (CCPs). In the Swedish market, two such clearing houses offer their services: NASDAQ for derivatives trading and Euro CCP for equity.

⁸ A simultaneous exchange of securities and money is often referred to as DVP, which stands for Deliveryversus-Payment.

⁹ In most countries, the situation is similar to Sweden; they have one or two clearing houses for payments, one central securities depository and one central counterparty. The settlement of payments takes place at the central bank. These similarities have made it possible to develop common and global standards for the financial infrastructure to comply with, see CPMI and IOSCO (2012) and CPMI (2005).



Figure 2. How a safe and efficient financial infrastructure contributes to monetary stability and financial stability

2.4 Countries have already designed their own infrastructures

Financial infrastructures are almost always built to work in only one country or currency area. There are several reasons for this. One is that different countries have different laws which the infrastructures are built on and must comply with. Laws may differ between jurisdictions, and often there are historical reasons for this. Although the EU is striving for common legislation and convergence in national legislation, there are still differences. For example, there is a requirement for payments in euro to comply with certain standards and rules, known as SEPA (Single Euro Payment Area), but this does not apply to payments in Swedish krona.

These legal and historical differences mean that financial services and payment products are often different in different countries. For example, in Sweden we usually use Visa and Mastercard cards, while Denmark has its own national card, the Dankort. A Swedish household bill or invoice has a Bankgiro or Plusgiro number and a special reference number for the payment that follows a specific Swedish standard.¹⁰ Most payments and transactions are also made within the country. Households pay bills for electricity and water, for example, to local suppliers, they work locally and are paid in local currency. In the same way, companies often have a large proportion of their payments locally. Securities are also traded mostly on the domestic market. In addition, there are generally established export and import supply chains and established banking relationships that enable companies to make payments between countries.

Then there are economic factors that contribute to the national structures having remained national. Financial infrastructure is complicated and expensive to build. Once you have invested in IT systems, design processes, routines and regulations, the infrastructure has a long economic lifetime. It is therefore often cheaper to continue using the existing infrastructure than to build a new one. Moreover, banks, companies, government agencies and other players have already invested in

¹⁰ The reference number is called an OCR number, where OCR stands for Optical Character Recognition. The number usually includes information on the invoice number, or the customer number, or both, and is intended to allow the payment recipient to automatically register and book the payments.

equipment, software and internal processes based on the existing standard. There is also a lock-in effect here. The fact that most of the transactions are domestic also means that the economic drivers for changing an existing infrastructure are small. Making major changes requires a firm commitment from the providers of infrastructure services and those who use them, and firm deadlines for things to happen. Take, for example, the introduction of the new ISO 20022 standard for financial communications. Originally published in 2004, this is an open international standard that is intended to be used worldwide. It was not until 16 years later that SWIFT, a global provider of communications and messaging services to the financial sector, decided to changeover to the new standard.¹¹ The Riksbank and the Swedish market plan to change to it during a transitional period with a closing date in 2025 for the RIX system. In other words, a changeover to something new tends to take a long time, to require careful planning and to use considerable resources.

3 How can things be changed?

A monetary system consists of a currency and the institutions and frameworks necessary for the money to be used in the economy. The Swedish monetary system consists, for example, of the Swedish krona, the Riksbank, the Swedish National Debt Office, the Swedish banks, the financial infrastructure and the legal framework. History also shows that there is a need for interaction between the public and the private side to develop and safeguard well-functioning monetary systems. We believe that history has taught us at least four lessons:

- Firstly: For a monetary system to work, there needs to be confidence in the money. This is ensured by having a credible issuer that guarantees the value of the money. Agreeing on a monetary unit in a country – what economists usually call uniformity in money – also makes the system function more smoothly and simply.
- Secondly: *Technological advances*, which are often linked to something quite different from payments, are an important driving force for change. This goes hand in hand with *ingenuity*, man's ability to respond creatively to needs that arise. Sometimes it can also lead to the emergence of new forms of business.
- Thirdly: *The private and public sectors* complement one another because they have different tasks. Where the public sector stands for trust and stability, the private sector offers innovation. Throughout history, the public sector has sometimes also had to take the lead in order for changes to take place in a way that benefits everyone in society.

¹¹ SWIFT (Society for Worldwide Interbank Financial Telecommunication) is a limited liability cooperative company, registered in Belgium. As of early 2022, SWIFT supplies secure messaging services in 202 countries and to more than 7,500 financial institutions, including banks, broker/dealers, investment managers, and over 100 market infrastructures in payments, treasury, securities and trade etc. SWIFT messages are used for payments in large-value payment systems such as RIX-RTGS. However, the bulk of SWIFT messaging activity is related to the exchange of payment information between banks involved in correspondent banking arrangements. Access to the SWIFT network is thus key for banks in executing cross-border payments.

• Fourthly: *Network effects and economies of scale* are important factors to consider when it comes to payments. They prevent new agents from entering the market, but they also provide scope for efficiency gains. These two effects are in themselves nothing new, but they have become more important now that payments have been digitalised.

Central governments play an important role with regard to the financial infrastructure. It is the central government that makes the laws to ensure the sound functioning of financial activities. It is also the central government that must ensure that the financial infrastructure and its participants comply with the laws and regulations that exist, have a sound financial position and meet international standards and other requirements. In Sweden, the private sector has often been able to coordinate itself and build much of the financial infrastructure itself. But this is not always the case, either in Sweden or in other countries. The central bank often needs to intervene and either try to get the market to coordinate itself, that is, the central bank assumes a catalyst role, or builds and provides the infrastructure itself.

In almost all countries, it is the central bank that provides settlement for large-value payments in the same way as the Riksbank does through RIX-RTGS. The money used for settlement is a claim on the central bank and is known as central bank money. Settlement in this way minimises credit and liquidity risks because the money is a claim on the central bank and not on any private agent who could become insolvent. The central bank is also neutral to competition for the participants. Historically, the central government has occasionally been dissatisfied with the private sector's supply on the payment market and provided services in other ways. One such example is Postgirot, a postal giro system which was formed in 1925 as part of the Postsparbanken bank (a subsidiary to the Swedish postal service) because the banks' long-distance payment services in Sweden were considered to be substandard.¹² Sending cash and cheques in envelopes, which was the technique prevailing at the time, was not sufficient.

To move from a situation of nationally-defined infrastructure to a situation with a more cross-border infrastructure, the government needs to take a leading role, but in close cooperation with the private sector. And the Swedish government also needs to cooperate with governments in other countries. For Sweden, this is happening above all at two levels: In the EU and in global regulations.

3.1 Cooperation between countries is intensifying

Both market players and public sector policy makers are increasingly realising that nationally defined infrastructures are not fully capable of providing the services

¹² The system with cheques and postal orders was very costly for companies and banks, and in 1917 the Post Cheque Committee was established. Its purpose was to investigate the need for a post-cheque operation that was adopted to a large extent could simplify payments, facilitate accounting and at the same time have low charges, as it would be relatively cheap to administer. The postal service would also be released of the cumbersome procedure of postal orders. There was also an aim to reduce the handling of cash. A proposal was submitted to the Riksdag (the Swedish parliament) in 1922, but was rejected. In 1924 it was time again after pressure from the National Accounting Board and the General Post Office. Postgirot was set up as part of the Postsparbanken, see SOU 1979:35.

required in a world that is increasingly economically integrated and digitalised. This insight has emerged over a long time but has been particularly topical in recent years.¹³

In 2017, the Swedish major banks joined forces with their Danish and Finnish counterparts to build a Nordic clearing platform for payments – the so-called P27 initiative.¹⁴ The purpose of this was both to continue to exploit economies of scale and to facilitate payments between the Nordic countries.

The central banks also include a number of initiatives that we will be talking about in Section 3.4. First, however, we want to focus specifically on what the Riksbank is doing to modernise its service offering.

3.2 The Riksbank adjusts its range of services

RIX and its current services have contributed to financial stability and served the Swedish banks well for a number of years. However, the demands for a modern central bank system for payments have evolved gradually. Globalisation also increases the need for an adaptation of Swedish services and standards to those used in the world around us. New functions are requested and as the number of participants grows, higher operating loads and risks follow. New types of threat are also emerging, particularly cyber-attacks, and specific security measures are needed to deal with them.

Above we have talked about settlement in RIX-RTGS, which manages large amounts, and about the role of clearing houses. For the end customer, this means that the transaction typically takes one day or more. However, since 2012, Swish, a Swedish instant payment app, has been available as an alternative for small transactions that can be executed immediately.

Swish payments are settled in BiR, a settlement system for instant payments owned and operated by Bankgirot. The BiR system settles payments between the banks and not in central bank money but in private money that is not a risk-free claim on the Riksbank. To reduce the credit and liquidity risk that arises from this, the Riksbank and the banks have prepared a solution whereby the banks make special BiR provisions in RIX-RTGS that serve as a guarantee for payments in BiR. However, in the future, when a large proportion of all payments are made instantly, this arrangement will not be sufficient. This is partly due to the fact that the amounts will be much higher than today, which again raises the credit and liquidity risks arising from settlement in private money. The banks' needs for liquidity and to be able to adjust their liquidity in the system will also be greater. Allocating funds in RIX-RTGS as in the current system is not the easiest way of meeting these needs, and it also has certain disadvantages for forecasts of liquidity in RIX. All in all, the present solution could in the long term pose risks to financial stability.

¹³ An analogy is when Ernest Hemingway in the book *The Sun Also Rises* writes: "How did you go bankrupt?" Bill asked. "Two ways," Mike said. "Gradually, then suddenly."

¹⁴ See <u>P27 Nordic Payments</u>.

Following an in-depth analysis, the Riksbank has therefore decided to develop a new service for instant payments. RIX-INST, as we call it, is based on the European Central Bank's (ECB) TIPS platform (Target Instant Payment Settlement), which was launched in November 2018 to settle instant payments in euros *and possibly other currencies*. This service will mean that the banks can settle payments instantly in central bank money, 24 hours a day, all year round. Based on RIX-INST, the banks can then develop services for instant payments to their customers.

RIX-INST also means that the Riksbank will share the TIPS platform with other central banks, which has several advantages. Firstly, it offers efficiency gains because of the economies of scale we mentioned earlier. It is not only the fixed development and operating costs that are distributed over higher volumes, but also the future costs of protecting against cyber attacks and similar. This is one of the few things we know about future payments: These costs will increase in the future.

Secondly, a common platform helps the Swedish market harmonise to European standards. It is already based on the standards applied in the eurozone and increasingly on the European payments market as a whole. It benefits Swedish banks and their customers operating in other European countries if they are able to manage their payments in a uniform manner regardless of currency. Such streamlining of payment processes both in Sweden and abroad will promote competition in the payments market.

Thirdly, competition will be further strengthened by RIX-INST being provided in a competition-neutral manner. The Riksbank will decide on access and prices without consideration of the commercial interests that private systems might have. This is particularly important in view of the barriers created by network effects and economies of scale, especially when taking into account that this type of payment is becoming increasingly frequent.

This new service will be opened for the private sector in spring 2022 and will be available to participants in RIX (see below).¹⁵ The Riksbank and the ECB are at the same time investigating the possibility of using the TIPS platform for instant payments between currencies such as the Swedish krona and the euro. This could be a further advantage of sharing this platform. Norway and Denmark are also intending to use TIPS for instant payments in their national currencies, see Danmarks Nationalbank (2020) and Norges Bank (2021). It is also likely that more countries will want to join the platform. It can then act as a hub for instant payments between a number of currencies.

The RIX-INST service will be offered as part of RIX, the Riksbank's payment system. The Riksbank is also investigating the possibility of using other ECB platforms for large inter-bank payments (RIX-RTGS) and for securities settlement in Swedish krona, see Figure 3. For the latter services, see Section 3.3.

¹⁵ The participants who can participate in RIX are credit institutions, investment firms, clearing organisations, central securities depositories, central counterparties and the Swedish National Debt Office, see <u>Terms and conditions</u> | <u>Sveriges Riksbank</u>.



Figure 3. How RIX can be transferred to the Eurosystem platforms.

3.3 A holistic approach to RIX

The Riksbank will use the ECB'S TIPS platform for the RIX-INST service, while the existing RIX-RTGS service has been provided since 2009 through the Riksbank's own system. However, this service needs to be renewed. For this reason, the Riksbank decided in September 2021 that it would start preparing to be able to use the Eurosystem's future platform T2 for the next generation of RIX-RTGS, see Sveriges Riksbank (2021). T2 will replace TARGET2, which is the current Eurosystem real-time gross settlement system. It will include a number of services that have been improved in relation to TARGET2, and be based on the global messaging standard ISO 20022. Like TIPS, T2 will also be able to facilitate payments in several different currencies – possibly including the Swedish krona. T2 will come into operation in November 2022.

At the same time, the Executive Board of the Riksbank decided to also initiate a similar process for TARGET2-Securities, T2S, which is a platform for simultaneous settlement of securities and money. At present, only one central securities depository, Euroclear Sweden AB, has access to central bank money in Swedish krona for securities settlement. By joining T2S, other CSDs would also have access to Swedish krona. They could then offer services on the Swedish market, which would improve the competitiveness of the Swedish market. T2S started operations in 2015 and has developed into a platform for multiple currencies. For example, the Danish Krone has been available for settlement since October 2018.

As with TIPS as a common platform, it would give Sweden significant economies of scale to use the T2 and T2S platforms together with the Eurosystem. This would mean that Sweden, via the Riksbank, has access to the resources and expertise of the Eurosystem. This in turn will help to ensure that the service can continue to develop in line with best practice. In addition, joining the two platforms would help to harmonise the Swedish financial market with the European financial market. The

Riksbank considers this to be the best strategy to enable Swedish and foreign banks and investors to make payments and trade securities efficiently.

Since these are platforms for large-value payments, the effects of joining T2 and T2S will primarily have an impact on participants in the Riksbank's current RIX-RTGS settlement service. But, by extension, it should also save costs for end-users of financial services. One example could be companies that want to issue bonds to finance their activities. It will then be a clear benefit to them if they can do so within an infrastructure that harmonises with larger European markets.

The preparations that the Riksbank has decided to initiate will serve as a basis for the Executive Board's decision on whether to start contractual negotiations with the Eurosystem. The Riksbank needs to analyse a number of important points more carefully. These concern everything from the consequences of these decisions for monetary policy and financial stability, to possible reserve solutions. We also need to further examine what possible requirements must be met under Swedish protective security legislation.

This is not something that will happen overnight. The decision to proceed will be followed by work that takes several years – negotiations with the Eurosystem, implementation, testing, and so on. The first transaction using Swedish krona on T2 or T2S is likely to occur in perhaps seven or eight years' time.

3.4 Global work is moving fast

As we all know, the world does not stop at the borders of the European Union; the general public needs to be able to move economic values around the entire globe. That is why G20 countries have developed a comprehensive programme to improve cross-border payments. The work is structured as a 19-building block road map, with 16 building blocks focused on improving the current systems. Building blocks 17, 18 and 19 instead see different possibilities for exploring future, not yet fully operational methods for improving payments.¹⁶

One could say that the work that the G20 is now carrying out is a modern and more comprehensive version of when the Swedish state introduced Postgirot. In the same way as then, the public sector is dissatisfied with the current situation and sees a need to both guide and drive the private sector. Here too, however, the public and private sectors must cooperate. Cross-border payments only work well if there are harmonisation, standards and a reliable legal framework. These are areas where the public sector at global level has promised to improve, but ultimately it is the private sector that has to deliver the end products. However, it is now the public sector that has set the course, and in a few years' time, it is hoped that payments between countries can be made almost as smoothly as within the country.

¹⁶ Building blocks 17, 18 and 19 cover multilateral platforms, stablecoins (see Section 3.5) and digital central bank currencies. For more information on this work, see <u>CPMI cross-border payments program</u>.

3.5 Crypto assets create both threats and opportunities

While the public sector has taken the initiative to improve payment infrastructure at a global level, there is a lot of activity in the private sector. We have previously mentioned P27, but in this section we want to describe a more difficult development: Crypto assets. Crypto assets are created through the issuer creating a digital representation of its asset, a so-called token. The most well-known crypto assets are crypto currencies such as bitcoins.¹⁷ In general, crypto currencies are not regulated in the way that traditional assets such as shares and money market funds are, which means that they lack consumer protection and are therefore more risky investments. Nor are they regulated to act as reliable money. For money to function as a means of payment, it has to be safe and generally accepted. Crypto currencies do not have a state behind them that ensures financial infrastructures, well-functioning banks, sound public finances or anchors the value of the money. This is why their value varies so much.

A sub-group of crypto assets is called stablecoins. Their value is typically tied to the value of other assets, such as a national currency.¹⁸ The stablecoin issuer claims to hold a reserve in, for example, dollars. Stablecoins have similarities to money market funds, since the reserve for certain stablecoins is largely invested in short-term assets such as commercial paper. But they are not subject to the same regulations and requirements as these funds. In financial crises, it is common for market actors to move their holdings to safer assets and for the value of certain other assets to decline. If the assets in the reserves for stablecoins fall in value, this can lead to the issuers of stablecoins having liquidity problems. If this in turn leads to the demand for stablecoins declining, the issuers may need to sell off their underlying assets quickly, which can lead to the price of the underlying assets falling further and reinforcing a negative spiral.

Extensive cooperation is now taking place at global level to ensure that these stablecoins are regulated and monitored in a way that does not make them a source of financial crises. Properly designed and monitored, there is a possibility that stablecoins could contribute to the better functioning of cross-border payments.

Within the EU, the European Commission has presented proposals for a regulation on the markets for crypto assets, the so-called MiCA Regulation. It is intended to regulate issuers and providers of services for crypto assets.¹⁹ At present, crypto assets are not covered by the EU regulations for financial services – apart from the regulations for combating money laundering and terrorist financing. The proposal, which can be expected to begin to apply in full some time during 2023 or 2024, contains more

¹⁷ The pseudonym Satoshi Nakamoti's online article about bitcoins in 2009 is usually counted as the starting signal for the creation of crypto assets, see Söderberg (2018) and Segendorf (2014).

¹⁸ In June 2019, the Libra Association, a consortium led by Facebook, took the initiative for a global stablecoin, see Cicović et al. (2019). One argument was to promote financial inclusion. The World Bank estimates that more than 1.5 billion people are outside of the financial system. For these, it has so far been too difficult and too costly to use services that we in Sweden happily take for granted: having a bank account, being able to pay and, if necessary, to take a loan. This initiative was then renamed Diem and was abandoned in January 2022.

¹⁹ MiCA stands for Markets in Crypto Assets. For more information on MiCA, see MICA Regulation.

demands on suppliers of services linked to crypto assets. One purpose is to reinforce consumer protection and reduce the risks of market abuse. The proposal also aims to manage the threats to financial stability and the national currencies that might arise if stablecoins were to become more common.

4 Conclusions

Financial services infrastructures are under severe pressure to transform. Consumers, businesses and governments expect faster, cheaper and smoother services. The private sector is pushing for the consolidation of various market-owned infrastructures, which we are already seeing at Nordic level. Similarly, the central banks of the eurozone are striving to consolidate their infrastructure and other countries have started to use these systems. We can also see that legislation and standards continue to be harmonized between countries. Strong forces are also pressing for the creation of global payment systems or at least linking the national ones to a better functioning whole. The indications are that this development will continue.

Sweden, which is a small and open economy, has a lot to gain from this if it is done in the right way. Cheaper, faster and smoother payment services make the markets for services and goods more efficient. At the same time, such a development involves new investment and adjustment costs that may be substantial. It is a question of finding a good division of labour between the private and public sectors. The Riksbank, which is responsible for part of the infrastructure, will use the ECB's TIPS platform to offer instant settlement of payments in Swedish krona. The Riksbank has also begun work on preparing to use the ECB's platforms for settlement services for large-value payments between financial institutions and for securities transactions. The purpose of this is to improve the functioning of the Swedish payment markets and financial markets. The long-term goal is that it should be as easy and fast to make a payment abroad as to send e-mail or follow someone on social media.
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Understanding the foreign exchange market

Amanda Nordström*

The author is a Senior Economist in the Riksbank's Monetary Policy Department

The foreign exchange market is an essential part of the global financial system and plays an important role in the economy. Over the last four decades, it has undergone large structural changes, from an opaque and slow-moving, clearly two-tiered market to today's fast-paced, interconnected yet fragmented market. Trading is becoming increasingly electronic and automated, and new participants, tools and strategies have entered the market. These structural changes have had considerable impact on the way foreign exchange is traded, priced and monitored. In this article I survey how the structure of the market has evolved over the last few decades, with a particular focus on the market for Swedish krona (SEK). I also discuss important mechanisms and features of the FX market; price discovery, liquidity and market functioning, and I present a measure of liquidity of the Swedish krona market.

1 Introduction

The foreign exchange (FX) market is an essential part of the global financial system and plays an important role in the economy. It is crucial in sustaining efficiency and arbitrage conditions in most other international financial markets, including the bond, stock and derivatives markets. The pricing mechanisms of the FX market affect financial conditions, resource utilisation and inflation, and so a proper understanding of these mechanisms is at the heart of central bank mandates and operations in many countries around the world. For the Riksbank, an inflation targeting central bank in a small open economy, understanding the drivers and fundamentals of the krona exchange rate, and how the FX market structure is evolving, is important to monetary policy and financial stability.

Over the last four decades, the FX market has undergone large structural changes. Beginning with the introduction of floating exchange rate regimes in the 1970s, currency trading has gone from an opaque and slow-moving, clearly two-tiered

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market to today's fast-paced and interconnected, yet fragmented, market with a growing number of participants and trading venues. Both price discovery and execution of trade, that is, the process by which trades are finalised, are to an increasing degree taking place electronically and automatically. As a result, new market participants, trading strategies and tools have emerged, affecting exchange rate determination and market functioning. In addition, the technological advances and increased competition between trading venues have resulted in enormous amounts of data being available to researchers and practitioners, albeit non-uniform in access and dispersed across multiple platforms.

Above and beyond changes to the structure of the FX market, exchange rate movements themselves are often difficult to explain, and even harder to predict. Conventional macroeconomic theory often assumes that exchange rates are determined as a price that equilibrates the returns to investing in foreign and domestic assets. In particular, these models rely on the so-called *uncovered interest rate parity (UIP)* condition, stating that the expected change in the exchange rate is determined by the interest rate differential between the two currencies in question. More specifically, the currency with the higher interest rate is expected to depreciate by the amount of the interest rate differential.

However, in reality, the empirical evidence of UIP remains elusive. Research offers many different explanations to this puzzling empirical fact, often related to the assumptions on which the UIP condition relies (for a survey of related research, see for example, Engel 2016). First, the UIP is based on the assumption of risk neutrality and, most often, empirical tests of UIP assume rational expectations among investors. Second, it assumes symmetric information among participants and that market prices immediately incorporate all available information. Since all participants have the same information set, which at any given point in time reflects the latest available information, only one price exists at any given point in time. Third, it requires a lack of trading costs or barriers and equal liquidity, maturity and default risk of the assets traded, see Engel (2014).

Few, if any, of these assumptions of market efficiency hold in the FX market and there is an extensive literature studying modified models that better capture exchange rate dynamics (see for example Fama 1984, Lyons 2001, Bacchetta and van Wincoop 2010 and Lustig and Verdelhan 2019). In fact, as this article will show in more detail, FX market participants are heterogeneous, transparency is limited and information is asymmetric. As a consequence, there are arbitrage opportunities that market participants are unable, or unwilling, to exploit because of the features of the FX market.

The structural changes to the FX market since the 1970s have had considerable impact on the way FX is traded, priced and monitored. Technological advances have made markets more efficient, reduced operational risks and lowered trading costs. Barriers to entering the FX market have been lowered, with new participants, trading venues and tools active in the market. The FX market of today is complex, fast-paced and highly fragmented; liquidity is deep but dispersed over a large number of venues that are to various extent interconnected to each other. Price formation is to an increasing degree taking place outside of the conventional bank sphere, and as a consequence, agents or organisations wanting to monitor the market have had to turn to new venues and tools for information. The use of computers, algorithms and the ever-increasing speed of the FX market has also given rise to new challenges and risks. For instance, algorithms may amplify and intensify market movements, causing disorderly price movements even in the most traded and liquid instruments.

In sum, the lack of empirical support for traditional modelling of exchange rates and the rapid evolution of the FX market motivates a better understanding of the structure and functioning of this unique and complex market. Moreover, the FX market is integral to the international financial network and affects financial conditions. Therefore, in this article I survey the structure of the FX market: its current state and how it has evolved over the last few decades, with a particular focus on the market for Swedish krona (SEK). I also discuss important mechanisms and features of the FX market; price discovery, liquidity and market functioning, and present a measure of liquidity of the Swedish krona market.

The rest of this paper is structured as follows: the next two sections explore the evolution of the FX market structure from the 1970s to today. The fourth section discusses the implications of these developments for market monitoring, efficiency and market conditions. In addition, it covers the concept of market liquidity and presents an index for systematic measuring of liquidity in the SEK. The last section presents my conclusions.

2 FX market turnover and instruments

With a daily average turnover in 2019 of approximately USD 6.6 trillion, the global FX market is by far the largest and deepest of all financial markets.¹ It consists of several submarkets; the spot market, the FX swap market, the forwards market, the currency swap market and the options market being the largest five, see BIS (2019).² Every third year, the Bank for International Settlements (BIS) publishes statistical information on turnover in the FX market sorted by region, counterpart and instrument in the BIS Triennial Survey. It is the most comprehensive source of information on the size and structure of the global FX market, with data collections starting in 1986.³ From this survey, we know that the Swedish krona, being one of the smallest of the ten most traded currencies (*G10 currencies*), has a daily turnover of around USD 134 billion. To put these numbers into perspective, daily global FX market

¹ Turnover is defined as the gross value of all new deals entered into during a given period, and is measured in terms of the nominal or notional amount of the contracts adjusted for double-counting, see BIS (2019).

² These five submarkets make up the majority of the total market in terms of turnover, although the list is not exhaustive. In addition, each submarket is divided into many additional markets depending on where and how contracts are traded.

³ The most recent edition, published in December 2019, took place in April 2019 and involved central banks and other authorities in 53 jurisdictions. These actors collected data from close to 1,300 banks and other dealers in their jurisdictions and reported national aggregates to the BIS, which then calculated global aggregates. Turnover data are reported by the sales desks of reporting dealers, regardless of where a trade is booked, and are reported on an unconsolidated basis, that is, including trades between related entities that are part of the same group, see BIS (2019).

turnover is approximately 27 times as large as daily world GDP, and turnover in SEK is over 90 times larger than the daily Swedish GDP.⁴

Non-financial customers, which is the client segment most closely linked to real economic activity, are counterparties in only a fraction of all FX trading. SEK turnover is, like the FX market in general, dominated by financial flows (see Figure 1 and 2). Financial institutions are counterparties in nearly 90 per cent of the turnover of all trades involving SEK.



Figure 1. Daily global turnover by counterpart USD trillion

Source: BIS Triennial Survey (2019).

⁴ The average daily global GDP in 2019 was approximately USD 240 billion while the Swedish daily average was around USD 1.45 billion per day. Daily GDP is calculated using the gross domestic product of 2019 in current USD, as reported by the World Bank, for the World and Sweden respectively, divided by the number of days in 2019 (365).



Figure 2. Daily SEK turnover by counterpart

Source: BIS Triennial Survey (2019).

The most direct form of FX trading is the *spot market*, which covers around 30 per cent of the total global turnover, thereby making it the second largest of the submarkets (see Figure 3). Spot transactions involve the exchange of two currencies at a rate agreed on the date of the contract for value or delivery in two business days or less. The FX *forward market* is the third largest, covering around 15 per cent of reported turnover.⁵ Forward transactions are defined as contracts between two parties for the delayed exchange of two currencies in which the buyer agrees to purchase and the seller agrees to deliver, at an agreed future date at an agreed price, see BIS (2016).

⁵ FX forward transactions should not be confused with *FX futures*, which are exchange-traded, standardised contracts. *Forward* contracts are traded OTC (over-the-counter) and are privately agreed upon between two parties. *Futures contracts* are traded on an exchange and have standardised terms. Futures contract prices are settled daily until expiry of the contract. With the exception of the futures for the Mexican peso and the South African rand, FX futures are physically delivered on the four International Money Market dates (the third Wednesday of March, June, September and December). Futures are not reported as part of the foreign exchange market in the BIS Triennial Survey, nor are they considered in this article.





Source: BIS Triennial Survey (2019).

The largest FX submarket in terms of turnover is the FX swap market, which with its USD 3.2 trillion comprises almost half of the total turnover of the global FX market. An FX swap is a transaction involving the exchange of two currencies on a specific date at a rate agreed upon at the time of the start of the contract (the near leg), and a reverse exchange of the same two currencies at a date further in the future at a rate agreed at the time of the contract (the far leg), see Baba et al. (2008). The near leg may be a spot transaction or a forward transaction, while the far leg is a forward transaction. FX swaps are used to raise foreign currency, both for financial institutions and their customers, including exporters and importers, as well as institutional investors who wish to hedge their holdings of foreign assets. Swedish banks are frequent users of FX swaps, using them to swap foreign currency denominated financing (typically USD or EUR) into SEK. Swedish pension and investment funds and corporates are typical counterparts in the swaps, having an interest in obtaining foreign currency in exchange for SEK to invest abroad, at very little currency risk. Swedish banks, on the other hand, obtain relatively cheap financing in SEK through such swap agreements.⁶ FX swaps comprise more than half of total SEK turnover (see Figure 4).

⁶ See for example Sveriges Riksbank (2020) and Bertsch (2022).



Figure 4. Daily SEK turnover by instrument

Source: BIS Triennial Survey (2019).

FX swaps should not be confused with *currency swaps*, known also as *cross-currency swaps*, which are contracts which commit two counterparties to exchange streams of interest payments in different currencies for an agreed period of time and/or to exchange principal amounts in different currencies at a pre-agreed exchange rate at maturity, see Baba et al. (2008). Hence, FX swaps and currency swaps are technically similar, but differ in that currency swaps also include the exchange of interest payments and principal amounts. In general, currency swaps also tend to have longer duration than FX swaps.

Finally, *options* are contracts that confer on the owner the right to buy or sell one currency for another currency at a specified exchange rate at a specified point in time. Currency swaps and options make up only a small part of the market as a whole and are normally traded separately from spot and forward contracts and for different purposes, see King et al. (2012).

Historically, most FX trading has been located in London and New York. In 2019, sales desks in these two locations intermediated around 60 per cent of all FX trading; 43 and 17 per cent, respectively, according to the BIS Triennial Survey. Indeed, trading has remained highly concentrated to a handful of trading hubs throughout the last four decades, with the United Kingdom, the United States, Singapore, Hong Kong SAR and Japan accounting for almost 80 per cent of all trading activity (see Figure 5). The internal distribution between these has varied over time, but the United Kingdom share has always been the largest.





Percentage of total, all instruments

Source: BIS Triennial Survey 1986-2019. Author's own calculations.

Data on the geographical distribution of SEK turnover have been collected since 2001. The share of Sweden-based trading has decreased markedly since the beginning of the survey sample. In 2019, only 10 per cent of the SEK trading flows were intermediated by sales desks located in Sweden, compared to around 35 per cent in 2001 (see Figure 6). Similar to the situation globally, trading activity in SEK is highly concentrated to the United Kingdom and the United States. Contrastingly, the three remaining large trading hubs – Singapore, Hong Kong SAR and Japan – account for only a small share of all trades; around 4 per cent in total in 2019. Instead, the third largest geographical trading hub for the SEK is Sweden, followed by Denmark. However, only approximately 3 per cent of spot trading in SEK takes place in Sweden; the vast majority of spot SEK trading flows is done in the UK.



Figure 6. Geographic distribution of SEK turnover

Percentage of total, all instruments

Source: BIS Triennial Survey 2001-2019. Author's own calculations.

Many of the floating exchange rate currencies can be traded 24 hours a day, every day of the year. However, although the FX market is always open to some extent, trading mainly starts when markets open in Sydney and ends when markets close in New York, with the bulk of traded volumes passing through markets from London opening to New York closing. This pattern is highly visible in the two most actively traded currency pairs with SEK on one side, EURSEK (the exchange of euro against SEK and vice versa) and USDSEK (the exchange of US dollars against SEK and vice versa), see Figure 7. Trading flows for individual currency pairs are typically consistent with UK and US trading hours, with the European currencies being traded most actively during London opening hours and the North American currencies during New York hours (King et al., 2011).⁷

⁷ It should be noted that global intraday turnover exhibits three "peaks" rather than only two; Asian trading hours are typically associated with heightened activity as well. However, the UK and US trading hours dominate intraday trading activity.



Figure 7. Intraday spot trade volume

Note: Intraday spot trade volumes in EURSEK and USDSEK submitted to the settlement firm CLS on 2019-01-01 to 2019-02-02.⁸ London local time.

Source: CLS.

Technological advances in FX trading have generally begun within the spot, and to some extent the forwards markets, and have also been most pronounced within these segments. The more complex instruments, such as swaps and options, are following the developments in spot and forwards, albeit with a slower uptake of the new technologies. Given this, the rest of this article will focus mainly on the spot and forward markets.

3 Structural developments of the FX market⁹

3.1 1970s to 1980s

Since the introduction of floating exchange rate regimes in many advanced economies in the early 1970s, the global FX market has undergone large structural changes. Far from today's volumes, the global daily average turnover in 1989, the farthest the BIS Triennial Survey goes back in time, was approximately USD 540 billion. The SEK, at that time a managed exchange rate fixed to a basket of currencies, recorded an average turnover of USD 6 billion per day.

During the 1970s and the 1980s, currencies were almost exclusively traded directly via telephone, in an over-the-counter (OTC) market. The OTC market structure refers to

⁸ CLS is the world's largest FX settlement firm, providing settlement for around USD 460 billion in daily spot volumes globally (November 2021). Their data are adjusted to equate to the same reporting convention used by the Bank for International Settlements (BIS).

⁹ Sections 3.1–3.2 are largely based on the extensive *Handbook on Foreign Exchange*, in particular King et al. (2013). More on the evolution of the FX market structure may also be found in Lyons (2001), Sager and Taylor (2006), King et al. (2012), Moore et al. (2016) and Schrimpf and Sushko (2019a,b).

bilateral transactions not conducted on a formal exchange. A small number of major *dealer banks* were the main *liquidity providers*, financial institutions which intermediate in the FX market by selling and buying the same currency. ¹⁰ In the FX market, these dealers emerged to solve the search problem among market participants to match opposing exchange flows. Non-bank financial institutions and large corporations constituted the major part of the client base, the *liquidity consumers*.¹¹ Their motives for currency trading stemmed primarily from the exchange of currencies due to international trade of goods and services, including financial services, and hedging of FX exposures owing to foreign-currency assets and liabilities.

The FX market consisted of a clearly delineated two-tiered system where dealers constituted the *primary* market tier, called the *interbank* or *interdealer market*, and dealer-to-client trades took place in the *secondary* market tier. In the interbank market, dealer banks managed their currency flows between each other (dealer-to-dealer trading). Interbank prices are the prices banks quote to each other. Trades in both tiers took place directly and predominantly via phone, so called "voice trades". In the interbank market, dealers could also choose to trade indirectly, using a *voice broker* as an intermediary.

Voice brokers are human intermediaries active in the interbank market, matching dealer trades with each other. They receive quotes and orders via telephone from a set of dealer banks connected to the brokerage, and then match corresponding orders into trades without disclosing the identity of parties pre-trade, that is, before the parties have agreed upon transaction. This type of brokering is referred to as *direct dealing*, see Melvin and Wen (2013). Upon receiving an order to, for example, sell US dollars against the Swedish krona, voice brokers would shout out the current best bid and ask prices into all open telephone lines connected to dealers. The *bid price* in this example is the price at which a dealer is willing to buy US dollars in exchange for Swedish krona. Vice versa, the *ask price (offer)* is the price at which a dealer is willing to sell US dollars in exchange for Swedish krona.

Since currency trading always involves the purchase of one currency and the sale of another, the concept of a buyer and a seller might be somewhat confusing, especially when both counterparts are dealers. In this article, and as is conventional in FX trading, it will depend on who initiates the trade. If dealer A posts a bid price with the voice broker, she wants to purchase the base currency (she is the price *maker*). If dealer B accepts dealer A's bid price, she sells the base currency to dealer A (she is the price *taker*). Market practice is to always express the *base currency* first in labelling currency pairs, that is, the units of a given currency to purchase one unit of the base

¹⁰ Dealers are financial intermediaries whose primary business is to enter both buy and sell transactions and which seek profit by taking the associated inventory risk, see Committee on the Global Financial System (2001). Liquidity provision is a term used to describe the practice of continually trading in and out of relatively short-term positions. Liquidity providers are essentially market-makers of the FX market: they sell and buy the same currency pairs, acting as intermediaries for other participants by entering and holding currency positions, normally to make a profit on the difference between the purchasing (bid) price and the selling (ask) price.

¹¹ Liquidity consumers are clients of the liquidity providers. They typically buy *or* sell currencies for reasons such as international trade or hedging by entering one side of a trading agreement.

currency. Most exchange rates are expressed as units of a currency in order to purchase one US dollar (USD), with the exception of the euro (EUR), the British pound (GBP), the Australian dollar (AUD) and the New Zealand dollar (NZD).¹² For example, the exchange rate of the Swedish krona (SEK) against the US dollar is conventionally expressed as USDSEK, meaning SEK per USD. In this example, the US dollar is the base currency. A buyer of USDSEK purchases USD using SEK as payment; a seller of USDSEK sells USD and receives SEK as payment.

The FX market of the 1970s and the 1980s was characterised by an opaque *price discovery process* (the process through which prices are determined and set) with large discrepancies between the interbank market prices and the prices set to end clients. Information about trades were proprietary to the two counterparties and no market-wide source of information was accessible for end clients. Dealer banks, however, arguably had an information advantage relative to end clients. In addition to small, informal networks among banks, they had access to the voice brokers who would continuously announce the current market prices. Brokers do not enter positions, and could, at least in theory, not trade upon the information they received.¹³ End clients would not see the prices traded interbank, only the final price quoted by their dealer bank(s). Post-trade, that is, after the trade had been agreed upon between the counterparties, the parties would exchange physical paperwork to settle the transaction, making the process cumbersome and prone to human error.

3.2 Late 1980s to 2000s

Computers made their first real entrance into FX trading in 1987, when Thomson Reuters Dealing was introduced. This computer system, available only to dealers, offered an alternative to telephone communication, enabling electronic messages to be sent amongst dealers while enhancing operational efficiency by the creation of electronic records of trading. Around the same point in time, Thomson Reuters also released their FXFX product, a proprietary computer site within the Reuters Terminal where dealers' *indicative quotes* for the most commonly traded currencies were shown in real time.¹⁴ Both Reuters Dealing and FXFX quickly became popular and as such, important information hubs for price discovery and trading, see King et al. (2013). The FXFX page contributed to greater transparency in the interbank market, but as indicative quotes are not tradeable per se, the informational content of FXFX quotes as an indicator of the tradeable current exchange rates was questionable, see Martens and Kofman (1998).

¹² In order: euro, British pound, Australian dollar, New Zealand dollar and US dollar. For example, the exchange rate of euros against US dollars is expressed as EURUSD and the exchange rate of British pounds against Australian dollars is expressed as GBPAUD.

¹³ Brokers that also act as dealers are called *broker-dealers* or *dealing desk brokers*. When a broker-dealer acts as an *agent*, the trade is on behalf of the client (broker), and when acting as *principal*, the trade is on its own account (dealer).

¹⁴ Indicative prices are prices quoted by dealers that are not necessarily tradable. Dealers submit indicative prices to give clients an indication of the price they are willing to trade at without being committed to trade. For example, if a client requests a quote without specifying the volume, dealers would normally provide an indicative quote. In contrast, tradable quotes are typically attached to a specified volume.

In the early 1990s, FX trading took another crucial step towards electronification when a new type of broker emerged: the *electronic brokering systems*, or *electronic* brokerages (EB). These electronic systems automatically match orders submitted by dealers to buy and sell currencies. The two main electronic brokerages were run by EBS and Thomson Reuters Matching, both of them available only for interbank trading. These are often referred to as the *primary venues*, see BIS (2019).¹⁵ Similar to stock market exchanges, electronic brokerages are structured so that the limit orders (bids to buy and/or offers to sell a given amount of a currency at a given price) with the highest bid price and the lowest ask price are prioritised and matched first with incoming market orders (orders to trade a certain amount at the current market price). Dealers submit limit orders in a centralised limit order book (CLOB). The brokerage system then automatically matches these offers and bids with incoming orders from other dealers. Both EBS and Reuters Matching operated anonymous limit order books, meaning that the identities of counterparties were unknown prior to the trade. Instead of having to reveal their interest in trading prior to the actual trading, dealers could now post their quotes anonymously on the CLOB. In addition, the CLOB offered not only indicative prices but actual tradeable prices, "firm" liquidity and more reliable information on the price discovery process.

The introduction of electronic brokering made FX trading more efficient; it increased competition between dealer banks and made interbank risk-sharing more effective, requiring fewer trades to distribute a given volume within a given set of constraints, see Evans and Rime (2019). Nevertheless, much of the electronification in the 1980s and 1990s focused on the interbank market and left the dealer-client relationship largely intact. While operational efficiency increased and execution costs decreased in the interbank market, leading to smaller bid-ask spreads in the primary tier, the bid-ask spreads of the secondary tier remained virtually unchanged until the end of the 1990s. Dealers, who profit from the spreads charged on the liquidity they provide, could earn substantial revenue from their informational advantage and the large difference in trading costs between the tiers.

Early examples of electronic solutions for end clients started emerging around the middle of the 1990s (for example FX Connect and Hotspot FX), but the main shift towards electronification of the secondary tier of the FX market began first around 1999, when the electronic *multi-bank trading platform* Currenex was launched. Multi-bank platforms (*MBPs*, also known as *multi-dealer platforms*) are electronic trading venues which connect a set of clients with its dealers and enables electronic negotiation and execution in competition. They facilitate electronic price discovery and execution in a competitive environment as several dealers are connected to the network at the same time. Currenex, and a number of platforms with similar business ideas that followed, gave end clients access to several dealer banks simultaneously

¹⁵ The term primary venue is often used with specific reference to a certain currency pair. Traditionally, Refinitiv (Reuters) Matching is referred to as the primary venue for the Commonwealth currencies and the Scandinavian currencies, while EBS is the primary venue for the euro, the US dollar, the Japanese yen, the Swiss franc and the Chinese renminbi.

through tools such as *request-for-quote* (RFQ) and electronic limit order books directed at end clients rather than dealers alone.¹⁶

Many of the pioneers of end-client trading platforms were independent *non-bank firms*, often related to the booming tech sector of those years around the turn of the millenium.¹⁷ Spurred by competition for customer business, the number of new, electronic trading venues virtually exploded. To retain some of the information flows and the market dominance that characterised their role in the 1980s, several of the major dealer banks formed a consortium and launched the multi-bank trading platform FXall in 2001, see King et al. (2013). FXall gave members of the platform access to several dealers simultaneously through an RFQ solution. At approximately the same time, dealer banks started introducing their own proprietary electronic platforms, so called *single-bank platforms (SBTs,* also *single-dealer platforms*). Single-bank platforms typically offer similar solutions as non-bank and multi-bank platforms, but are owned and run by the dealer bank itself.

Both single- and multi-bank platforms are in different ways and to various extent interconnected with each other and with other trading venues, and dealers typically operate on several platforms simultaneously. They may be disclosed or anonymous, that is, either the counterparty identities are or are not known pre-trade. Trading venues for dealer-to-client transactions are sometimes referred to as *secondary venues*, as opposed to the interbank primary markets. Generally, at least one of the main brokerages is connected to the trading platforms.¹⁸

Another important impetus for the development of the FX market was *prime brokerage.* The service emerged in the early 1990s, and is offered by banks that allow clients to get access to multiple executing dealers while maintaining a credit relationship and placing collateral and settlement with a single entity, the prime broker, see Federal Reserve Bank of New York (2010). While electronic brokering provides access to dealers, practical aspects of trading such as credit agreements and settlement instructions are needed for each single dealer. Although this is feasible for large clients, it is often too costly for smaller entities. Instead, with prime brokerage accounts clients are given the opportunity to access the primary market through top FX dealers. Clients then trade directly in the bank's name with its established counterparties, subject to credit limits. Prior to the introduction of prime brokerage, dealer banks would charge smaller investors high transaction costs, as their trades were considered too small to be economically interesting. With trade now grouped

¹⁶ When using the RFQ function, clients simultaneously ask several banks to supply them with a price that they are willing to trade on. The dealer banks are required to respond to the request within a few seconds, and the client may then choose which bank to trade with.

¹⁷ The term *non-banks* generally refers to institutions which perform services traditionally associated with banks, but which lack banking licences.

¹⁸ To exemplify, Refinitiv (Reuters) FX Matching is the electronic broker (for interbank trading) on the Refinitiv multi-bank platform FXall (for dealer-to-client trading, or "all-to-all" trading), accessed via the desktop platform FX Trading, all connected to the financial analysis tool Eikon. Although primary venues' market share has decreased since its introduction, EBS (NEX) and Refinitiv FX Matching (Reuters) remain two of the largest brokerages globally, as are their respective platforms, see Euromoney (2019).

together into much larger trade sizes, dealers were willing to trade with prime brokers at more attractive prices.

The effect of these technological changes was to accelerate the pace and increase the volume of FX trading that could be intermediated at a given time. Transparency and trading efficiency increased with access to price streams provided by electronic brokerages and trading platforms. Client-access solutions helped narrow bid-ask spreads faced by clients in the second tier vis-à-vis interbank pricing. New types of intermediaries, particularly the introduction of prime brokerage, gave smaller clients access to more competitive prices and deeper liquidity. Nonetheless, the technological revolution of the FX market had only begun; the 2000s would see a rapid evolution of electronic execution, new participants, the introduction of algorithmic trading and a fragmented, interconnected and fast-paced electronic FX market.

3.3 2000s to today

Today's FX market is complex, consisting of a large number of trading platforms; market participants wanting to trade FX have more than 75 different venues to choose from, see Sinclair (2018). This proliferation has been driven by technological advances as well as competition between both banks and new market participants seeking to capture, or maintain, a share of the FX market. Electronification in FX first took off in interbank trading, but it is the dealer-to-customer segment that has seen the strongest rise in electronification in recent years, see Schrimpf and Sushko (2019b). The resulting market structure is fragmented yet highly interconnected. According to the 2019 BIS Triennial FX survey, 56 per cent of all FX trading, and 70 per cent of all FX spot trading, takes place electronically (BIS, 2019). Or perhaps even more, as according to a study from 2013, some market reporters suggested that as much as 95 per cent of all spot transactions could in fact be electronic, as most voice trades are booked electronically due to the practical benefits from electronic execution, see Rime and Schrimpf (2013).

Modern market participants rely on technologically advanced and sophisticated trading solutions. *Algorithms* became available in FX trading around the early 2000s and grew rapidly with the availability and improvement of data, becoming a tool for navigating an increasingly fragmented market, see Markets Committee (2020). In addition, reporting requirements and regulations have increased the demand for traceable execution, which in turn has contributed to the growth of electronic and automated trading (see below for more details on reporting requirements and regulation). Algorithms are used in many areas of trading, such as the execution of trades, statistical algorithmic trading and high-frequency trading.¹⁹ As executable liquidity is dispersed over a large number of venues, algorithms have also become a tool to source liquidity from many different venues simultaneously.

¹⁹ In statistical algorithmic trading, algorithms are used to collect and analyse large amounts of data to identify favourable trading opportunities and strategies. This type of trading includes, for example, the employment of algorithms to analyse historical time series data to identify whether a currency is suitable for buying, selling or keeping, and portfolios based on mathematical mean-reversion models.

Execution algorithms use mathematical models and automated trading programs to create specific sets of trading rules and models and then automatically execute orders and transactions. For example, traders commonly place limit orders using algorithms. When a pre-defined limit value is reached, the algorithm is programmed to automatically execute or cancel. Since their introduction, they have evolved from simple mechanical forms to highly sophisticated and adaptive types based on machine learning techniques that respond to real-time changes in market conditions. As of 2020, execution algorithms are estimated to account for around 10–20 per cent of global FX spot trading, but are less frequently used in other types of FX trading, see Markets Committee (2020).

Users and usage of algorithms have also evolved during these years, and today, algorithmic solutions are available to a range of market participants. With the advent of *retail trading platforms*, algorithmic trading was also made available for non-bank participants, see King et al. (2013).²⁰ A Greenwich Associates study from 2021 showed that nearly 40 per cent of financial FX traders used algorithms in 2020 and that approximately as many saw their usage increase in 2021, see Greenwich Associates (2021). Measured since autumn 2018, the Riksbank's Financial Markets Survey shows that approximately 90 per cent of the participants active in the market for SEK often or always use electronic platforms in trading, but only 20 per cent of participants often or always use algorithms.²¹

Algorithms are also the key building blocks of *high-frequency trading (HFT)*. HFT refers to the use of algorithms for the purpose of arbitrage on slower market players by very high speed and high frequency, also called *latency arbitrage*. The nature of HFT is typically speculative and as with algorithmic trading in general, it has its roots in equity markets where it has been common since the late 1990s. Several of the pioneering HFT firms are becoming increasingly important to the FX market in their roles as liquidity providers.

As data quality improves, so do the prospects of using *machine learning* techniques.²² Algorithms can handle massive amounts of unstructured data; sort, analyse and act upon it in fractions of the time it would take a human trader. The term *artificial intelligence* (AI) is frequently used to describe this human-like intelligence that today is possible to program into electronic systems, making machines trade like humans but without human involvement or intervention. Several major international dealer banks have launched adaptive algorithms; algorithms that self-adapt to the ongoing market conditions, see Greenwich Associates (2021). Still, AI and machine learning

²⁰ Retail trading platforms are trading solutions, typically software programs, available for retail clients. One example is MetaTrader4, launched in 2005.

²¹ See Sveriges Riksbank (2021).

²² Machine learning is a technique in which a computer processes data and essentially writes its own program based on the statistical relationships it discovers, see Ford (2015). The technique is used in many everyday functions, such as the recommendations of what to watch on streaming platforms or spam filters in emailing software. In finance, one example of machine learning techniques is that used for scraping data, in which a computer program extracts data from human-readable output coming from another program. Noting the entrance of AI and machine learning as separate from algorithms may be slightly precarious. Algorithms have undergone a series of evolutions since their first emergence, with AI and machine learning techniques developing alongside rather than at separate stages in history.

techniques have only recently started to play an important role in transforming electronic FX trading (see for example Refinitiv 2019 and Golden 2021). Despite the rapid evolution of technology, this type of trading is highly resource demanding, both in terms of human skill and computer power.

As trading has become increasingly electronic and automated, it has also gained markedly in speed. The BIS describes the FX market as a *fast-paced electronic market*, a market where the price development predominantly occurs via electronic means, and which is characterized by a sizeable penetration of high-speed, algorithmic-driven order placements. Along with an increase in the use of electronic brokerages, the introduction of *data aggregators* and live *price feeds* has resulted in an increase in the updating frequency of data feeds.²³ As an example, the EBS platform increased its pricing update frequency from every 100 milliseconds to every 20 milliseconds in 2016, and further to every 5 milliseconds for selected platform participants in 2017, see Markets Committee (2018).

3.3.1 Market participants

The new, digital infrastructure of the FX market has led to the emergence of new players, functions and possibilities. Nearly half of all reported turnover in spot trading went through prime brokerage accounts in 2019, according to the BIS Triennial Survey, see BIS (2019). For the currencies of small open economies, 56 per cent of all spot turnover of the SEK was prime brokered, which is similar to the Australian, Canadian and New Zealand dollars as well as the Norwegian krone. Higher turnover currencies, such as the British pound, the US dollar, the Japanese yen and the Swiss franc, have a smaller share of transactions conducted through prime brokerage accounts.

Driven by the proliferation of prime brokerage, smaller banks, hedge funds and other players have entered the market to much greater extent than previously. Today, some of the top providers of spot liquidity are non-banks, see Euromoney (2019). The market is no longer centered solely on the dealers; the share of global FX market turnover accounted for by interdealer trading in the BIS Triennial Surveys has declined considerably since the 1990s, from 67 per cent of the total global FX turnover in 1992 to below 40 per cent in 2019, see BIS (2019). They make up even less of the turnover in SEK, their share falling from 48 per cent in 1992 to just above 30 per cent in 2019. In the SEK spot market, only 22 per cent of the turnover have reporting dealers as counterpart (see Figure 8). Interestingly, this is similar to the NOK spot market, but markedly lower than that of the other G10 currencies. Instead, financial institutions other than the dealer banks now represent one side of 60 per cent of all turnover in SEK and over 70 per cent of all SEK spot turnover.

²³ A data aggregator is a technological service where prices are streamed from several liquidity providers and/or platforms simultaneously.



Figure 8. Turnover by counterpart, SEK spot market Per cent

An increasingly important new group of participants in the FX market are the *principal trading firms (PTFs,* also known as *proprietary trading firms)*. PTFs are firms that invest, hedge or speculate for their own account, not on behalf of clients. They are sophisticated non-banks which provide and consume liquidity primarily through high-frequency and algorithmic trading and typically trade with high speed and frequency to turn over large volumes. This heterogeneous group of players, which includes HFT firms, gains access to the FX market via prime brokers and accounts for roughly a third of total turnover in electronic FX spot markets see BIS (2019). Their share of turnover in the spot market for SEK is lower; around 18 per cent.

In recent decades, several non-bank PTFs have transformed into market-making liquidity providers that have taken over parts of the FX market that were previously exclusive to dealer banks. This subset of PTFs is sometimes referred to as *non-bank electronic liquidity providers*, or *non-bank electronic market-makers*. While banks rely on large balance sheets and client relationships that can generate volumes of flows that may be matched with one another, the non-bank PTFs instead use their speed and technological advantage to intermediate in the markets.

Another reason for dealers' declining share of turnover is that major dealing banks net more trades internally. Typically, dealers would quickly, or even immediately, try to match the opposite side of a client's trade within the interbank market. This is sometimes referred to as "hot-potato trading" or *externalisation*, see Butz and Oomen (2019).²⁴ On the opposite, *internalisation* refers to the process of warehousing one client's transaction flow until it is offset against an opposing client's flow. Through internalisation, dealers are able to match more client trades directly on their own books, which reduces the need to offload and hedge risk via the traditional interbank

Source: BIS Triennial Survey (2019).

²⁴ Dealers engage in hot-potato trading when offloading their exposure to open positions onto the interbank market (King et al. 2012).

market, see Schrimpf and Sushko (2019a). With more trades managed internally, hotpotato trading, and thereby also interbank trading, becomes less necessary.

Internalisation ratios are highest within the spot market and have increased along with electronic execution (see Moore et al. 2016 and Schrimpf and Sushko 2019b). Similarly, the use of algorithms has been shown to reinforce the growing trend towards internalisation among dealer banks, see Markets Committee (2020). Internalisation has also coincided with an increase in market concentration: the average number of banks covering 75 per cent of total FX turnover has about halved since first measured in 1989, to a count of 7 in 2019, see Schrimpf and Sushko (2019b).²⁵ Arguably, internalisation and high market concentration are mutually reinforcing. Dealer banks with large and diverse trading flows can internalise trades more efficiently, allowing them to offer competitive prices and attract even more client flows. Butz and Oomen (2018) show that internalisation is both quicker and less risky among large dealers, who benefit from their size and the possibility of reducing costs doing so. This is in line with the finding that internalisation ratios tend to be higher for large trading centres, as this is typically where the largest dealer banks are located, see Schrimpf and Sushko (2019b).

In addition, the Global Financial Crisis of 2007-2009 brought on a rapid decline in dealer banks' *proprietary trading* (trading for direct market gain, contrary to earning commission on client trades). Increased regulatory scrutiny and greater risk-aversion were important drivers of this development, see King et al. (2011). Banks' balance sheets have become more constrained and costly to deploy in the aftermath of the crisis, which has resulted in a notable reduction in risk appetite and principal risk warehousing, see Debelle (2018).²⁶

Nonetheless, the major international banks still constitute an important part of the market as liquidity providers, but are now accompanied by other types of financial institutions that intermediate in the market. This development has dissolved the clearly delineated market structure of the 1980s, and there are no longer two well-defined market tiers with just as well-defined roles of its participants. The distinction between liquidity provider and liquidity consumer is also becoming less clear, both because trading can occur without intermediation and because new types of participants have entered the market.²⁷

The BIS Triennial Surveys also illustrate how consumers of liquidity have evolved during the last few decades. Today, FX trading volumes mostly reflect financial motives, as opposed to needs arising directly from real economic activity. As noted earlier, FX trading volumes continue to be dominated mostly by financial institutions, with the share of non-dealer financial institutions growing from below 12 per cent in 1992 to nearly 55 per cent of all trading in 2019. Non-dealer financial institutions

²⁵ Although interdealer trading, that is, trading with dealer banks as both counterparts, has declined, banks remain one of the counterparts in most FX trading.

²⁶ Providing algorithms has thus become a tool for banks to transfer the risk bearing onto the end client, as algorithms rely less on liquidity providers' capacity to absorb risk (BIS 2020).

²⁷ Clients wishing to trade FX no longer *require* a dealer to do so. Today, while clients may access liquidity with various degrees of intermediation: from client-to-client in disclosed or anonymous liquidity pools all the way to the more traditional alternative of using a dealer and a broker.

include market participants such as smaller banks, pension and investment funds, hedge funds and PTFs.

3.3.2 Reporting requirements and regulation

Despite its size and importance, the FX market is subject to relatively little regulation and reporting requirements. There is no central regulatory body, instead, local jurisdictions are set up across the globe. Two influential legislations are the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act) in the US and the MiFID II legislation in the EU.²⁸ Neither of these applies to the FX spot market.²⁹

The Dodd-Frank Act was written in the aftermath of the 2008-2009 financial crisis to reduce risk, increase transparency and provide accountability for market participants. Enacted in July 2010, it is a widely encompassing federal law that applies to US-based financial companies. The Dodd-Frank Act applies to all FX derivatives, although some instruments are mainly subject to reporting requirement. All FX derivatives except FX swaps and outright forwards, are subject to certain mandatory derivatives requirements, including central clearing and exchange trading.

The MiFID II regulation, adopted in January 2018, applies to all financial participants across the EU, including fund managers, banks, exchange trading venues, pension funds and retail investors. MiFID II aims to make markets safer, fairer and more efficient. For instance, the MiFID II legislation requires reporting and record-keeping on transactions of all financial instruments in the EU. It does not apply to the spot market, which is not considered to be a financial instrument according to the European Securities and Markets Authority (ESMA), but to all of the other major FX instruments including forwards and swaps. Firms need to take "all sufficient steps" to obtain the best possible results for their clients when executing orders, referred to as *best execution*. The adaptation of the MiFID II regulation has led to firms taking a more systematic approach to monitoring their trades, increasing the demand for so-called *transaction cost analysis* (TCA). While it is not legally mandatory for the spot FX market, demand for such analysis has increased there, too.

Instead of formal legislation, the FX market has largely been governed by informal rules and codes of conduct, often regional. Following a number of high profile FX misconduct cases in 2013 and 2014, the BIS Markets Committee was commissioned to develop a single, global code of conduct for the wholesale FX market to restore trust and confidence in the market. The Global Code of Conduct was developed through a partnership of central banks and private sector market participants under the auspices of the BIS Markets Committee, and the first complete version was launched in 2017. The code is maintained by the Global FX Committee (GFXC), established in 2017. The GFXC is a forum of central banks and private sector participants that aim to promote a robust, liquid, open and appropriately transparent FX market. The code does not impose any legal or regulatory obligations on market participants, rather it is

²⁸ The UK implemented the UK MiFID II in December 2020, which essentially mirrors the EU MiFID II framework.

intended to serve as a supplement to any and all local law, rules and regulations by identifying global good practises and processes. Sveriges Riksbank is a member of the GFXC and its local Scandinavian committee, the Scandinavian FX Committee (SFXC), and signed the Terms of Commitment in 2017.

4 A fragmented, fast-paced and electronic FX market

With electronification, barriers to entering the FX market have been lowered and transparency has increased. New players have entered the market, both as providers and consumers of liquidity. Technological advances have made comparable and tradeable prices easily available and updated with high frequency, reduced operational risks and lowered trading costs. Sophisticated tools of trading have become available to an increasingly large and heterogeneous group of FX traders. But as always, development brings new challenges. The FX market is complex, fast-paced and highly fragmented, which has implications for market monitoring and analysis, market efficiency and market conditions.

4.1 Information flows and market monitoring

As a consequence of trading taking place simultaneously on a bilateral basis and at many different trading venues, there is no unique market exchange rate at any given point in time. Rather, the same currency can simultaneously be traded at different exchange rates at different trading venues. The lack of common reference points makes it costly and difficult to obtain a representative overview of the market as a whole, and complicates comparison between venues and providers. The electronic information systems of the primary market venues, EBS and Refinitiv (previously Reuters), are often used by practitioners and researchers as representative references for volume and price data.³⁰ However, while they remain important sources of information, their market share has dwindled in recent years, and many alternative trading venues and liquidity pools have emerged and taken over market shares, see Schrimpf and Sushko (2019a).³¹

Moreover, the electronification of FX trading results in enormous amounts of data and information being produced and collected. A widespread commoditisation of such data has led to an increased availability via different technological solutions, but this typically entails high costs, advanced quantitative analysis skills and large storage requirements. For those with access, it allows for analysis of order flows, positioning, technical levels, liquidity conditions and trading patterns – information previously exclusive to the interbank dealers. However, the fragmentation of the market causes this information to be dispersed over a large number of trading venues. In this sense, somewhat paradoxically, electronification has increased the amount of information available but made market monitoring and surveillance more difficult. The structure of the FX market, combined with minimal regulation and reporting requirements,

³⁰ The FX trading unit of Thomson Reuters was renamed Refinitiv in 2018.

³¹ Liquidity pools are centralised trading volumes created by orders executed on an exchange or other trading venue.

results in there being no consolidated record of the turnover at any given point in time.

Many central banks, including Sveriges Riksbank, track turnover in their respective FX markets, but relatively few central banks publish this information regularly. In addition, the international nature of the FX market ultimately complicates compilation and consolidation of statistical data. For instance, the data collected by Sveriges Riksbank are reported by the major Swedish banks. Trading of SEK between other market participants, including reporting dealers domiciled abroad, will not be registered in the Riksbank's statistics. This means that trading between non-Swedish dealers and non-bank participants is not captured by the Riksbank statistics, although provided that at least one of two counterparts in a trade report to any of the other central banks participating in the BIS survey, such trading will be captured by the BIS statistics.

Furthermore, the structural changes to the FX market during the last four decades have had an impact on the price discovery process. Fundamentally, the idea is that trading is an integral part of the price discovery process through which information relevant to exchange rate determination becomes embedded in the market price. Information flows, a concept frequently explored in the research fields of market microstructure and order flow analysis, are at the core of the price discovery process (see for example Bacchetta and van Wincoop 2006, Breedon and Vitale 2010). Essentially, informed agents have information about the currency's fundamental value, and this information becomes embedded in the price when the trade is executed.

Early research on information flows focused on consumers of FX liquidity as the most informed, as they would have information on trading flows of foreign and domestic assets, but several empirical studies contradict this (see for example Bjønnes et al. 2005, Evans and Lyons 2006, Nolte and Nolte 2014, Osler and Vandrovych 2009, King et al. 2010, Bjønnes et al. 2014). More recent research instead points to FX market dealers as the most informed participants (see for example Evans and Lyon 2002, Moore and Payne 2011, Chaboud et al. 2020). Information appears to become embedded in the market price through at least three steps. First, end clients reveal their information to dealers by trading. Second, the information becomes embedded in interbank prices, and third, information is dispersed into the general market as dealer-to-client quotes are adjusted to reflect interbank prices, see King et al. (2011).

Dealers' information advantage as central counterparts with large electronic networks of client relationships, their analytical muscles and their ability to quickly act upon new information suggest that dealers are the most well-informed FX market participants. In line with this, market monitors have generally turned to the banks and to the primary electronic venues for information on exchange rate developments. At the same time, even though some of the major dealer-banks have managed to retain some of their information advantage via their own trading platforms, several of the largest trading venues of today belong to non-banks. Trading on primary venues has fallen markedly. As a result, part of these information flows has migrated from the interbank market to external networks. These structural changes have had implications not only for the monitoring and surveillance of FX trading, but potentially also for the price discovery process itself. As long as central banks and other monitoring agents rely on banks and primary venues as their main source of information, they might overlook information important to exchange rate determination, because banks might not be informed, or because the price discovery process is increasingly taking place outside of the banks' sphere. Central banks have therefore had to diversify their FX monitoring from the usual electronic brokerage screens and voice contact with dealers to monitoring more electronic platforms and obtaining information about market conditions from a broader range of market actors (for a detailed report on how monitoring of the FX market has evolved over time, see Markets Committee 2018).

4.2 Technological advance, market conditions and market efficiency

The use of ever-more advanced financial technology is steadily increasing in a pursuit of more efficient and faster trading. Technological advances and an increase in both the number and variety of participants active in the market have forced the traditional players of the FX market to charge more competitive prices in order to maintain their market shares. To exemplify, the spread between bid and ask prices has in general narrowed as the market has become increasingly electronic, see Rime and Schrimpf (2013). Ding and Hiltrop (2010) demonstrated that the introduction of electronic trading systems narrowed both the immediate and long-term bid-ask spreads. This finding is in line with early studies on the topic, such as Pagano and Roell (1996) and Flood et al. (1999), who suggested that electronic systems should lead to narrower spreads due to lower operation costs, inventory risk and the costs of attaining information. With comparable and tradeable prices easily accessible and updated with high frequency the price discovery process has become less opaque, especially to end clients and even non-active participants. In a more recent study, Geromichalos and Jung (2018) suggested that the introduction of dealer-to-client platforms led to lower spreads by lowering the bargaining power of dealers.

However, quite interestingly, Ding and Hiltrop (2010) also showed that large dealers tended to quote relatively wider spreads on multibank platforms. This, they argued, was indicating that these dealers were compensating for the loss of the information advantage they used to possess in the more opaque market prior to the introduction of electronic trading venues. On the other hand, their research focused on the primary venues, Reuters and EBS, while data indicate that dealers are shifting away from these, see Schrimpf and Sushko (2019a). Instead, dealers are turning to single-bank platforms and direct price streams, a development that is driven principally by the growing trend of internalising trades. The largest dealer banks are reporting internalisation ratios as high as 90 per cent, see Moore et al. (2016).

While internalisation may be beneficial for both dealers and end clients, it is also associated with lower visibility (known as *hidden liquidity*). On the positive side, internalisation may benefit dealers by reducing intermediation costs, while end clients may benefit from a reduction in information leakage and consequently market impact (see for example Butz and Oomen 2019 and Markets Committee 2020). On the negative side, internalisation shifts trading volumes from more transparent venues (so called *lit* venues) to more opaque internal liquidity pools. Hence, for the same reason that electronic brokerages have had a positive impact on the transparency of price formation, internalisation has the potential of obscuring it.

The growing use of algorithmic execution has been shown to improve overall market functioning by increasing the efficiency of the matching process between liquidity providers and liquidity consumers (see for example Rime and Schrimpf 2013 and Chaboud et al. 2020). Assessing liquidity in a fragmented market is challenging, but with more counterparties connected to each other, search costs have decreased and the velocity of trading has increased, see Rime and Schrimpf (2013).³² Moreover, studies indicate that algorithmic trading has had a positive impact on *price informativeness* in the FX market (see for example Biais et al. 2015, Roşu 2019 and Chaboud et al. 2014).³³ Simply put, computers are better at finding and exploiting arbitrage opportunities. The increasing use of algorithmic trading has therefore led to a more efficient market by speeding up the price discovery process, thereby improving informational efficiency. Chaboud et al. (2020) find that the price discovery process has become faster during the last decade, consistent with improvements in market efficiency during the same period, potentially a result of the increase in algorithmic trading participation.

Nevertheless, algorithms, machines and the ever-increasing speed of the FX market give rise to new challenges and risks. For instance, algorithms may amplify and intensify market movements, causing disorderly price movements even in the most traded and liquid instruments.

Flash events are perhaps the most dramatic examples of this, with the flash rally of the Japanese yen in January 2019 being one of the most recent.³⁴ Flash events are unforeseen, abrupt and volatile movements in prices within a very short period of time (typically seconds). Flash events to date have generally proved short-lived and without immediate consequences for financial stability. But even though they may happen rarely, they are important tests of the market's resilience to stress. If reoccurring and with lasting impact on financial market pricing, such events have the

³² King et al. (2012) suggest that trading, and in extension exchange rates, should be modelled as a search problem. Constraints and costs that are related to this search are in turn affected by the structure of the market.

³³ The term price informativeness is used to describe the ability of the price of an asset to convey all information that is available to all traders at any given time.

³⁴ On January 3rd 2019, the Japanese yen appreciated sharply during the early Asian trading hours, most notably against the Turkish lira and the Australian and US dollars. Liquidity is generally scarce during these hours, which was further exacerbated by a public holiday in Japan. Previous to the event, Japanese retail investors had been building up currency positions in high-interest yielding currencies, speculating that the Japanese yen would not strengthen above a certain level. After news reports of Apple's profit warning on January 2nd, the yen started appreciating sharply – but orderly – triggering so called *loss-cuts*. Loss-cuts are part of a regulation put on all FX firms in Japan that will be executed if a client's margin deposits falls below a required amount and the client does not deposit the required amount by the deadline (issued in a socalled *margin call*). In this particular case, the appreciation of the yen caused large-enough losses to the retail investors' positions, which were then automatically closed, causing the yen to appreciate even more as the high-yielding currency was sold off and yen bought back. Consequently, more positions had to be closed. In just 5 seconds, the yen appreciated approximately 4 per cent against the US dollar (and approximately 9 and 7 per cent against the Turkish lira and the Australian dollar), before retracing over half of the move within a few seconds. For more details, see Reserve Bank of Australia (2019).

potential to undermine confidence in financial markets and hence impact the real economy. When currencies swing very sharply, a certain depth of liquidity is needed to absorb those moves and allow firms to unwind positions. Hence, it is important to continue to develop a deeper understanding of modern market structure and its associated vulnerabilities, see Markets Committee (2017). Nonetheless, initial observations from the COVID-19 pandemic suggest that the risk of algorithmic execution giving rise to self-reinforcing loops, exacerbating sharp movement in prices, may not be as acute as previously believed, see Markets Committee (2020).

The fragmentation and speed of the market also implicate a risk of *liquidity mirage*: a phenomenon that arises due to the combination of highly fragmented and interconnected market venues and liquidity providers. Typically, several trading venues show the same liquidity providers' interest to trade simultaneously, which in aggregation creates an illusion of deep market liquidity. Combined with high speed, there is a risk that the liquidity suddenly vanishes when an order is executed at the quoted price, as the transacted amount is then withdrawn from several platforms at once. In this new electronic context, the market dynamics of a multitude of liquidity venues need to be taken into consideration.

In addition, trend-driven trading, also known as momentum trading, may exacerbate otherwise small movements. These strategies are typically built on algorithmic programs that identify trends in exchange rates and trade in that direction. Anecdotal evidence from market participants indicate that in periods of low liquidity and in absence of human traders, these trend-driven trades gain momentum as they move markets in their traded direction (see for example Engel 2014).

4.3 Liquidity in the FX market

In general, market liquidity makes transactions smoother and more cost-effective, rendering liquid assets more attractive to investors. Liquid markets improve allocation and information efficiency, allowing for more efficient risk-sharing and thereby permitting financial institutions to accept larger asset-liability mismatches. As such, market liquidity is essential for a well-functioning market, and a sudden disappearance of liquidity from markets may develop into a systemic crisis. For instance, a decline in FX liquidity affects funding costs, impairs hedging strategies and increases rollover risks due to the common practice of using the FX swap market for short-term funding, see Mancini et al. (2013).³⁵

Liquidity is a prerequisite for an efficient market that eliminates opportunities for arbitrage, see Shleifer and Vishny (1997). As a result, varying liquidity conditions likely disrupt FX market efficiency and alter exchange rate dynamics. The nature and development of the FX market, which has resulted in limited transparency, a high degree of fragmentation and heterogeneity of agents, have important implications for

³⁵ Brunnermeier and Pedersen (2009) distinguish between an asset's market liquidity (that is, the ease with which it is traded) and traders' funding liquidity (that is, the ease with which they can obtain funding). This article focuses mainly on what Brunnermeier and Pedersen term market liquidity; costs of trade execution and the ability to trade large volumes without sizeable market impact. Nonetheless, these concepts of liquidity are profoundly linked. Under certain conditions, the two are mutually reinforcing and may lead to liquidity spirals.

both price and liquidity patterns. Several studies suggest that foreign exchange rates contain liquidity premia and that there are noticeable differences in the level of systematic liquidity across currency pairs and time (see for example Engel 1992, Christiansen at al. 2011 and Banti et al. 2012). Furthermore, liquid markets also generally contribute to a more stable and efficient monetary transmission process through the financial system, see Sarr and Lybek (2002). Understanding FX market liquidity and market conditions therefore is important, not only from a financial stability perspective but also for the transmission of monetary policy. Even so, there is no consensus on why and how liquidity in the FX market materialises, not even on what constitutes liquidity, see Karnaukh et al. (2015).

4.3.1 Measuring FX market liquidity

Both theoretically and in practice, market liquidity is a multifaceted concept. A widely recognised definition of market liquidity is the ability to rapidly trade large volumes of a financial instrument at low or no transaction cost without the transaction noticeably and adversely affecting the market price of the instrument, see IMF (2015). In the FX market, this translates into the ability to rapidly trade large volumes of a currency against another at low cost without having a large impact on the effective exchange rate. Kyle (1985) summarised the characteristics of liquid markets as tight, deep and resilient.

There is no universally accepted unequivocal measure of FX market liquidity that captures all of these dimensions, and it is not obvious that each of these characteristics of liquidity remain the same over time. For example, volume-based measures such as the turnover rate may be used as a proxy for market liquidity as more active markets also tend to be more liquid. But while the FX market generally is perceived to be extremely liquid given its massive daily turnover volumes, an increase in turnover may not always be associated with increasing liquidity conditions. As documented in Melvin and Taylor (2009), FX trading activity rose sharply during the financial crisis, which they attribute to the so called "hot-potato trading" rather than an actual increase in liquidity.

Certainly, the turmoil during the onset of the COVID-19 pandemic in spring 2020 was also characterised by large increases in volumes and quite poor liquidity (see for instance Dobrev and Meldrum 2020 and CLS 2020). For example, the NOK, which was heavily affected by the turbulence in financial markets, experienced large but onesided flows (selling of NOK against foreign currencies) and severely deteriorating liquidity conditions in March 2020, see Alstadheim et al. (2021). Naturally, a volumebased measure such as turnover would provide a false reflection of the actual liquidity situation.

Furthermore, the FX market lack both a consolidated measure of turnover (at least one that is updated more frequently than that of the BIS Triennial Survey) and a proper denominator; there is no measureable stock of foreign exchange or outstanding number of instruments to be turned over.³⁶ Instead, bid-ask spreads may

³⁶ However, Sarr and Lybek (2002) suggest that the sum of exports, imports and capital transactions or the level of central bank reserves, potentially including short-term net foreign assets of the banking system,

be better suited as a proxy for market liquidity. Indeed, most liquidity measures for the FX market focuses on bid-ask spreads and exchange rate volatility, see Sarr and Lybek (2002).

Bid-ask spreads provide a simple and easily available measure of liquidity. However, although many of the trading venues provide tradable bid-ask prices, trades are not always executed at the posted bid and ask quotes – some trading is hidden, some is bilateral and once again, dispersed over venues and alternative trading methods, see Mancini (2013).

Electronic brokerages generally also have live and recorded data of order books at any given point of time, which may be used to calculate the *order book depth*; a metric based on the quantity available at any given price level. A thin order book may result in quickly changing prices, while deep order books means more liquidity is available at prices at or close to the top prices in the book. This metric may be useful as a real-time indicator of liquidity conditions or for event studies or short-run analysis of liquidity conditions. For example, microdata from brokerages on order depth were used to analyse the British pound (sterling) flash event in 2016 (see for example Noss et al. 2017 and BIS 2017).

Another measure of liquidity is *price impact on execution*, also called *slippage*. It is defined as the difference between the expected market price when requesting to trade and the actual price that the trade is executed at. The higher the price impact, the more the exchange rate moves following a trade, reflecting lower liquidity. While relatively simple to calculate for any specific transaction post-trade, this metric requires vast amounts of data on millisecond frequency, including the identified direction of single transactions, to use as a systematic measure of liquidity conditions.

Finally, to capture the cost aspect of liquidity, another frequently used measure is the *effective cost* of transactions. Similar to slippage, measuring the effective costs is an attempt to capture the actual trading cost and compare it with the price quoted at the point of execution. As such, the measure can be used as a benchmark measure of (the inverse of) liquidity. Examples are found in Mancini et al. (2013) as well as Karnaukh et al. (2015).

4.3.2 A liquidity index for the Swedish krona

Liquidity is thus a complex and multifaceted concept and no single measure is able to capture all aspects of liquidity. Several measures require vast amounts of detailed and precise high-frequency data, which restricts the analysis to a few of the major currencies and a limited time period historically. In addition, such data are typically expensive and the data handling and filtering techniques necessary are time consuming and cumbersome. Moreover, while the research on FX market liquidity is indeed evolving, it tends to focus heavily on the major currencies: the euro, the US dollar, the British pound and to lesser extent the Japanese yen and the Swiss franc.

could be used as potential proxies for the outstanding value of FX. As for turnover, transaction data from any of the larger trading venues or settlement institutions could be used as a proxy.

In an attempt to capture systematic liquidity specifically in terms of the SEK, I construct a Krona liquidity index. The index is based on Karnaukh et al. (2015), who offer a method to accurately measure systematic market liquidity using daily and readily available data. Evaluating several low-frequency measures against a high-frequency benchmark capturing the effective cost of transactions, they demonstrate that a low-frequency index based on bid-ask spreads and the Corwin-Schultz (2012) method accurately captures how liquidity changes over time.³⁷ The Corwin-Schultz estimates combine high and low values over one day with high and low values over two days, assuming that daily high prices are buyer-initiated trades and daily low prices are seller-initiated trades. The ratio of high-to-low prices for a day therefore reflects both the fundamental volatility of the currency pair and its bid-ask spread.

The Krona liquidity index is based on daily prices of bilateral exchange rates of 21 currencies quoted against the SEK.³⁸ Data are retrieved from Bloomberg, spanning 2001-2021.³⁹ Bid-ask spreads are relative, computed by averaging the daily bid-ask estimates over time. Corwin-Schultz estimates are calculated using daily high bid prices and daily low ask prices adjusted for overnight returns, see the appendix for more details. The index is constructed by first calculating monthly averages of the relative bid-ask spreads across all daily bid-ask estimates for each individual currency pair. Second, monthly averages across all positive two-day Corwin-Schulz estimates are computed, also for each individual currency pair. Third, all series are standardised by subtracting the mean and dividing it by the standard deviation. Fourth, the two measures are combined by taking a simple average across all currency pairs. A global liquidity index based on the same 30 currency pairs as Karnaukh et al. (2015) is computed for comparison (see Figure 9).⁴⁰

³⁷ Karnaukh et al. (2015) use precise intraday data to calculate a high-frequency benchmark measure for evaluating the accuracy of their low-frequency measure. The high-frequency measure is constructed from tradable best bid and ask quotes, transaction prices and volume indicators where the direction of trades is known. Using these, they compute the midpoint of best bid and ask quotes and log return based on the transaction price of deals, which capture the effective cost measure described in section 4.3.1. They conclude that a low-frequency measure based on bid-ask spreads and the Corwin-Schultz model (2012) offer the highest correlation with the high-frequency measure. Their results are robust to several high-frequency measures.

³⁸ The currencies used are those that are part of KIX ("Kronindex"). KIX is a currency index for the Swedish krona based on currencies from the OECD countries, China, India, Brazil and Russia. The index consists of 32 countries and 21 currencies. For more information on KIX, see Alsterlind (2006).

³⁹ For some currency pairs, data availability starts already in January 1991. However, due to poor coverage in many other currency pairs, I have chosen to restrict the sample to a period with higher coverage in pricing data in both the SEK currency pairs and the pairs included in the global index.

⁴⁰ Currency pairs are listed in the Appendix.



Figure 9. Systematic FX liquidity indices and Kronindex (KIX) Standard deviation (left) and index units (inverted, right)

Note: Liquidity indices (left hand scale) capture systematic liquidity conditions in a set of currency pairs across time (currency pairs listed in the appendix). Negative values indicate worse liquidity conditions relative to a historical average, and vice versa for positive values. The KIX ("Kronindex") index (right-hand scale) is inverted so that downwards movements illustrate a depreciation of the krona, and vice versa for upwards movements.

Source: Sveriges Riksbank and Bloomberg. Author's own calculations.

Quite interestingly, there is no clear indication of systematic improvements in liquidity conditions across this time period in any of the indices. Given the decrease in bid-ask spreads documented in for example Ding and Hiltrop (2010), this may seem somewhat surprising. Improvements in transparency and efficiency suggest that liquidity should as well have improved systematically during these few decades. On the other hand, Ding and Hiltrop's findings indicate that it was the introduction of electronic trading that significantly caused bid-ask spreads to decrease, which would suggest that the major improvement in liquidity took place during an earlier stage in time than is covered by this sample. In contrast, the 2000s have been characterised by increasing fragmentation and complexity. In addition, Ding and Hiltrop's finding that large dealers actually even quoted larger spreads on multibank platforms may also be part of the explanation of why systematic liquidity seems to be fairly stable in this sample, given that Bloomberg is such as venue.⁴¹

Both indices show a clear pattern of deteriorating liquidity conditions around periods of financial distress, with the 2008-2009 financial crisis and the COVID-19 pandemic crisis in 2020 by far being the most severe. The European debt crisis that escalated throughout the early 2010s is also associated with negative spikes in liquidity conditions. The link between financial turmoil and deteriorating FX liquidity conditions is related to several different factors. Karnaukh et al. (2015) provide empirical support

⁴¹ In addition, Rime and Schrimpf (2013) showed that the trend towards more narrow bid-ask spreads between 2004 and 2013 was driven solely by emerging markets' currencies; currency pairs of advanced economies were approximately unchanged during the period. The currency sample therefore also affects the dynamics of the liquidity indices across time.

that FX liquidity systematically worsens with more severe funding constraints and global risk. Sudden drops in liquidity have been key in several currency crashes: when liquidity is low, traders become reluctant to take on positions, which in turn contribute to lower liquidity, see Brunnermeier and Pedersen (2009). In addition, lower liquidity leads to higher volatility, which may exacerbate such liquidity spirals even further if it increases the risk of financing a trade, thus increasing the capital requirements of margins. Market-wide systematic liquidity also tend to deteriorate when both global stock and bond markets are more volatile and illiquid, suggesting spillovers from related markets (Mancini et al. 2013).

Moreover, the correlation between the two indices across the time sample is close to 90 per cent, indicating that liquidity conditions in the krona are strongly linked to global liquidity conditions. This is in line with previous research on commonality in liquidity across currencies, suggesting that individual currencies share drivers of liquidity. Brunnermeier and Pedersen (2009) point to shocks to funding constraints of investors as an explanation for commonality across financial markets, suggesting that financial turmoil affect funding constraints of investors across all asset classes. Research also points to general market conditions (risk aversion) and supply- and demand-side factors such as flight-to-quality dynamics, carry trades and the propensity of intermediaries to provide liquidity being such common factors (see for example Karnaukh et al. 2015, Lustig et al. 2011, Mancini et al. 2013 and Menkhoff et al. 2012).

Furthermore, quarter- and year-ends seem to be connected to sharp but short-lived drops in liquidity in both indices, especially since 2014 (see Figure 9). Part of the explanation may be related to regulatory requirements and banks' balance sheet management. In line with previous research, Krohn and Sushko (2022) find additional support of FX funding conditions being correlated with market liquidity and strong indications of co-movement in FX spot and swap market liquidity. They also show that this link has strengthened significantly since mid-2014, which coincides with the introduction of the Basel III framework for global systemically important banks (G-SIBs).⁴² They demonstrate that G-SIBs tend to cut back significantly on their quoting activity around quarter- and year-ends, which causes liquidity to deteriorate. Given the strong link between the two, worsening liquidity conditions in the swap market might provide at least a partial explanation to quarter- and year-end drops in liquidity conditions in the spot market.

Given the global and interconnected nature of the FX market, tight links between liquidity conditions are unsurprising. Nonetheless, there are differences between the indices that seem to indicate that liquidity conditions are not only common across

⁴² The Basel III framework was introduced in 2011, with the regulation on loss absorbency covering global systemically important banks (the G-SIB buffer) being introduced in 2014. Some regulatory requirements did not become fully binding until 2018, although banks started shifting to the Basel III reporting templates around 2014, see Krohn and Sushko (2022). While liquidity always has tended to deteriorate slightly around quarter-ends, the effect has become several times larger since 2014, when the G-SIB buffer was introduced. FX swaps are counted as more complex assets, which adds on the complexity score component of the G-SIB framework. A higher complexity score might put the bank into a higher G-SIB bucket, which means the bank will be subject to higher loss absorbency requirements via additional capital surcharges. As a result, G-SIBs have an incentive to pull out of the FX swap market around regulatory reporting periods.

currencies; some are idiosyncratic to the Swedish krona. For instance, the Krona index tends to show slightly sharper drops in liquidity during periods of high financial stress, which might imply that the currency pairs used in the Krona index are in general riskier than those in the Global index.⁴³ Karnaukh et al. (2015) find that such currencies are more likely to suffer larger liquidity drops when global risk, such as global stock and bond volatility, increases.

Furthermore, empirical studies document that the krona tends to depreciate in response to financial stress (see for example Bacchetta and Chikhani 2021 and Ceh 2020). Gardberg (forthcoming) finds that the krona is particularly sensitive to changes in global risk; among all G10 currencies, the krona responds the most.⁴⁴ This pattern is visible also in Figure 9, where the above mentioned episodes of elevated financial stress are associated with not only a drop in liquidity but also a weaker krona in terms of the krona currency index KIX. In addition, improvements in liquidity conditions seem to be associated with an appreciation of the krona.

As noted in Markets Committee (2017), sudden shifts in liquidity conditions may exacerbate otherwise orderly movements in exchange rates. In addition, existing research on liquidity risk premia imply that liquidity risk is priced in the FX market; investors demand compensation for holding assets that exhibit low liquidity. This suggests that monitoring the liquidity conditions of the krona might be helpful in understanding krona exchange rate movements, both in short-term and mediumterm analysis. Nevertheless, further research is necessary to fully understand the dynamics and relations between liquidity conditions and how liquidity premia might impact price formation. The rapid changes and increasing complexity of the market structure further complicates the question; both depth and ability to trade are important aspects of liquidity, but in today's FX market, tradeable quotes are mixed with indicative ones, all quoted on several platforms simultaneously. With the increasing availability of comprehensive data sets, the effects of such structural aspects particular to the FX market are hopefully to become subject to further research.

In sum, a comparison of the Krona liquidity index and the Global liquidity index indicates that liquidity conditions show a high degree of commonality. Liquidity tends to deteriorate in periods of financial stress, most recently during the onset of the COVID-19 pandemic. The krona tends to be weaker during such periods of financial stress, while improvements in liquidity seem to be associated with the krona appreciating. Interestingly, however, not all movements in the Krona liquidity index can be explained by changes in global liquidity conditions, indicating that some components of liquidity conditions are idiosyncratic to the krona.

⁴³ Here, riskier currencies refer to currencies bearing larger exposure to systematic risk factors such as carry trade risk and volatility risk (see for example Lustig et al. 2011 and Menkhoff et al. 2012).

⁴⁴ Gardberg (forthcoming) show that currencies in countries with large private net external debt, particularly net portfolio debt and other investment liabilities, tend to depreciate during financial turbulence. She uses VIX, an option-implied index of investors' willingness to hedge themselves against large price movements in the American stock market index S&P 500, as a proxy for global risk. All currencies are quoted with USD as the base currency.

5 Conclusion

The FX market has undergone significant structural changes during the last four decades. Both trading and price formation are to an increasing degree taking place electronically and new participants, venues and strategies have emerged. The clear division between the interbank and the end-client tiers that characterised the FX market in the 1970s and 1980s has effectively been dissolved into the fragmented yet interconnected fast-paced electronic market of today. Moreover, the rapid evolution of electronic trading, particularly the use of algorithms, has increased trading efficiency and the speed of trading, but has also had an impact on market liquidity conditions, with potential risks to financial stability and the pricing mechanisms as a consequence. Furthermore, these structural changes have had considerable implications for liquidity distribution and market conditions, and market participants wanting to monitor the market have had to diversify their sources of information. Finally, this article has presented a Krona liquidity index in an attempt to capture changes to the structural liquidity conditions in the krona specifically. Commonality links are strong between global liquidity conditions and those for the krona, although some changes in liquidity appear to be specific to the krona.

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APPENDIX A – Liquidity index calculations

The data used are retrieved from Bloomberg, see field names in Table 1 and currency pairs in Table 2 and Table 3.

Ticker	Description	
XXXYYY Curncy	Code for currency pair (i.e. EURUSD Curncy)	
PR002	Bid price (closing value)	
PQ690	High bid price	
PQ677	Low bid price	
PR004	Ask price (closing value)	
PQ678	High ask price	
PQ691	Low ask price	

Note: As of 3 January, 2022.

Source: Bloomberg.

Table 2. Currency pairs in the Krona liquidity index

Currency pair	Description
AUDSEK	Swedish krona per Australian dollar
BRLSEK	Swedish krona per Brazilian real
DKKSEK	Swedish krona per Danish krone
EURSEK	Swedish krona per Euro
INRSEK	Swedish krona per Indian rupee
ISKSEK	Swedish krona per Icelandic krona
JPYSEK	Swedish krona per Japanese yen
CADSEK	Swedish krona per Canadian dollar
CNYSEK	Swedish krona per Chinese renminbi
MXNSEK	Swedish krona per Mexican peso
NOKSEK	Swedish krona per Norwegian krone
NZDSEK	Swedish krona per New Zealand dollar
PLNSEK	Swedish krona per Polish zloty
RUBSEK	Swedish krona per Russian rubel
CHFSEK	Swedish krona per Swiss franc
GBPSEK	Swedish krona per British pound
KRWSEK	Swedish krona per South Korean won
CZKSEK	Swedish krona per Czech koruna
TRYSEK	Swedish krona per Turkish lira
HUFSEK	Swedish krona per Hungarian forint
USDSEK	Swedish krona per US dollar

Currency pair	Description	
EURUSD	US dollar per euro	
USDJPY	Japanese yen per US dollar	
GBPUSD	US dollar per British pound	
AUDUSD	US dollar per Australian dollar	
CADUSD	US dollar per Canadian dollar	
USDCHF	Swiss franc per US dollar	
EURJPY	Japanese yen per Euro	
EURGBP	British pound per Euro	
EURCHF	Swiss franc per Euro	
USDSEK	Swedish krona per US dollar	
EURCAD	Canadian dollar per Euro	
EURAUD	Australian dollar per Euro	
GBPAUD	Australian dollar per British pound	
GBPCAD	Canadian dollar per British pound	
GBPCHF	Swiss franc per British pound	
GBPJPY	Japanese yen per British pound	
EURNOK	Norwegian krone per Euro	
GBPNOK	Norwegian krone per British pound	
USDNOK	Norwegian krone per US dollar	
EURNZD	New Zealand dollar per Euro	
GBPNZD	New Zealand dollar per British pound	
NZDUSD	New Zealand dollar per US dollar	
GBPSEK	Swedish krona per British pound	
USDINR	Indian rupee per US dollar	
USDMXN	Mexican peso per US dollar	
EURSGD	Singapore dollar per Euro	
GBPDGD	Singapore dollar per British pound	
USDSGD	Singapore dollar per US dollar	
GBPZAR	South African rand per British pound	
USDZAR	South African rand per US dollar	

Table 3. Currency pairs in the Global liquidity index

Data are cleaned following Brownlees and Gallo (2006). Observations are removed from the sample if both bid and ask prices are zero or if the price p_{t_i} is such that:

$$\left|p_{t_{i}}-\bar{p}_{i}(\alpha,k)\right|>3s_{i}(\alpha,k)+\nu$$

Where $\overline{p}_i(\alpha, k)$ and $s_i(\alpha, k)$ denote the α -trimmed sample mean and standard deviation based on k observations in the neighbourhood of t_i , respectively. ν is added on the right side of the inequality to avoid zero variance for a sequence of equal

prices and is set to equal one pip (that is, 0.0001). α is set to 5 percent and k is set to 100.

Bid-ask spread estimates BA_t are calculated according to:

$$BA_t = (ask_t - bid_t) \div \frac{(ask_t + bid_t)}{2}$$

To calculate the Corwin-Schultz estimates, data are first corrected for overnight returns. If the low value at day t + 1 is higher than the closing value at day t, both the high and the low values for day t + 1 are decreased by the amount of the overnight spread. If the high value at day t + 1 is lower than the closing value at day t, both the high and the low values for day t + 1 are increased by the amount of the overnight spread.

Corwin-Schultz estimates are thereafter calculated according to:

$$CS_t = \frac{2(e^{\alpha} - 1)}{1 + e^{\alpha}} \approx \alpha$$

for small values of $\alpha \in [-0.25, 0.25]$, where

$$\begin{split} \alpha &= \left(1 + \sqrt{2}\right) \left(\sqrt{\beta} - \sqrt{\gamma}\right), \\ \beta &= \left[ln\left(\frac{H_t}{L_t}\right)\right]^2 + \left[ln\left(\frac{H_{t+1}}{L_t+1}\right)\right]^2 \text{ and } \gamma = \left[ln\left(\frac{H_{t,t+1}}{L_t,t+1}\right)\right]^2, \end{split}$$

where H_t and L_t denote the observed high and low prices on day t (also for day t + 1), while $H_{t,t+1}$ and $L_{t,t+1}$ are the high and low over two days (t to t + 1).

All negative two-day spreads are excluded.

Monthly averages are calculated as simple averages for both estimates.

Both series of estimates are standardised (individually) by subtracting the mean and dividing by the standard deviation. The two standardised series are then combined by taking the simple average across them.

Finally, the index is computed by taking the simple average of the liquidity measure across all currency pairs and taking the negative of the series so that negative values indicate worse conditions and positive values indicate better conditions than the historical average.

Hedging against exchange rate risk – maturity choice and roll-over risk

Christoph Bertsch*

The author is a Senior Economist in the Riksbank's Research Division

The Swedish market for hedging foreign exchange (FX) risk is about double the size of the annual Swedish gross domestic product. Key buyers of FX risk protection are Swedish insurance companies and pension funds who regularly invest in foreign currency assets, which exposes them to exchange rate risk. The dominant sellers of FX risk protection are Swedish banks. The most commonly used financial instruments are FX swaps with a duration of 3 months or less. Since the typical investment horizon of insurance companies or pension funds can span multiple years, shorter-term FX hedging arrangements need to be rolled over repeatedly. In this article, we offer a conceptual framework to discuss the risks and benefits associated with short-term hedging for six risk categories: FX risk, asset price risk, FX market distress, premature liquidation risk, counterparty risk and inflation risk. The focus is on economic considerations that have to do with uncertainty and information.

1 Introduction

A substantial part of the assets held by Swedish insurance companies, pension funds and other asset managers are issued by foreign entities and denominated in foreign currency. This is because Swedish investors seek to take advantage of investment opportunities abroad and to diversify their investment returns. Figure 1 shows a currency breakdown of the asset holdings of Swedish insurance companies and national pension funds (AP funds), who are the dominant Swedish asset managers. We can see that in 2020 almost 43% of the assets on their balance sheets were denominated in foreign currency with an important role played by US dollar and euro investments. At the same time, the vast majority of the liabilities of Swedish insurance companies and pension funds are denominated in Swedish krona. Therefore, Swedish asset managers have a "currency mismatch" on their balance sheets. In other words, the currency composition of their assets (domestic and foreign currency) and liabilities (domestic currency) differs markedly.

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Figure 1. Currency decomposition of assets held by Swedish insurance companies and national pension funds

Per cent

Note. Currency breakdown of the consolidated asset side of Swedish insurance companies and Swedish national pension funds on December 30, 2020. The total market value of assets held amounted to 5,629 billion Swedish kronor (or 687 billion US dollar).

Source: Sveriges Riksbank.

The currency mismatch exposes Swedish investment portfolios to risk due to fluctuations in foreign exchange rates; an unexpected weakening of the US dollar (USD) against the Swedish krona (SEK) will reduce the krona value of assets denominated in dollars and lead to losses on the investment portfolio, and an unexpected strengthening of the dollar will lead to portfolio gains. To reduce such risk, financial market participants use various financial instruments to "hedge" their risk exposure. The most common FX hedging instruments are "FX swaps", which consist of an FX spot transaction and a "forward contract". In essence, FX swaps allow Swedish insurance companies and pension funds to raise foreign currency funding and to protect against exchange rate risk by agreeing to swap cash flows in different currencies at an agreed conversion rate on a future date. For example, a Swedish pension fund (protection buyer) who wants to invest in a US corporate bond can engage in an FX swap contract with a Swedish bank (protection seller) that comprises two parts: (1) the exchange of SEK against USD today through a spot transaction, which the pension fund then uses to purchase a US corporate bond; and (2) a forward contract that specifies a future date when the pension fund has to return USD and receives SEK at a pre-specified conversion rate. In this way, the pension fund can protect the income from its US corporate bond investment from an unexpected weakening or strengthening of the US dollar.

The Swedish market for hedging FX risk is large. In 2020, the total amount of outstanding contracts averaged around 10,000 billion Swedish kronor, roughly twice as large as the annual gross domestic product. The average FX hedging contract had a volume of 80–90 million Swedish kronor (Levander et al. 2021). Figure 2 shows a

decomposition of the maturity profile of these contracts.¹ Importantly, more than 70% of the nominal amount of outstanding FX hedging contracts had a remaining duration of 3 months or shorter. We can see that 5.87% had a duration of less than 7 days, 22.23% had a duration of 8-30 days, 24.32% had a duration of 1-2 months, 21.70% had a duration of 2-3 months and 22.98% had a duration of 3-6 months.





Note. Decomposition of the maturity profile of the nominal outstanding FX hedging contracts in the Swedish market. 2020 averages for the remaining maturity calculated over the end-of-month values. The slice corresponding to maturities exceeding 12 months (0.01% of the outstanding contracts) is not visible.

Source: Sveriges Riksbank.

The short duration of the FX hedging contracts contrasts with the typically longer duration of the foreign currency denominated assets in Swedish investment portfolios. In fact, the expected investment horizon of Swedish asset managers often spans multiple years, meaning that many of the assets in their investment portfolios have long maturities. An example for a popular foreign currency denominated asset is US government bonds with a duration of 5–10 years. Nevertheless, Swedish insurance companies, pension funds and other asset managers often use short-term FX hedging contracts to insure such investments in long-dated US government bonds.

Whenever the expected duration of the foreign currency denominated investments exceeds the duration of the FX hedging arrangements, asset managers have to rely on rolling over short-term hedging contracts. In a given month, around 250 billion Swedish kronor of US dollar FX hedges mature (Sveriges Riksbank 2021). This can pose challenges for asset managers and it can have implications for financial markets and for financial stability. The challenges are especially acute in periods of financial

¹ We thank Mats Levander for sharing the data. More detailed statistics can be found in Levander et al. (2021). While the financial market turmoil in the spring of 2020 following the outbreak of the COVID-19 pandemic had an effect (Sveriges Riksbank 2020a,b), the maturity decomposition for 2019 is similar.

distress such as the financial market turbulence during the spring of 2020, which severely affected the markets for hedging foreign exchange risk around the world.²

This article attempts to provide a conceptual framework to discuss the maturity choice and roll-over risk in the market for hedging FX risk. Using a simple theoretical model, we try to provide answers to questions like: What exactly are the risks associated with a duration mismatch between the underlying asset and the FX hedge? What could be potential reasons for why asset managers do not prefer longer-term FX hedging arrangements, for example hedging contracts that match the expected duration of the foreign currency denominated assets? What are the implications for episodes of financial distress?

Our focus is exclusively on aspects related to economic considerations that have to do with uncertainty and information. Therefore, we abstract from certain institutional details and other factors that can be important determinants of the supply and demand for different FX hedging products and their pricing, such as financial regulation and market power. In the article, we describe potential risks and benefits of short- and long-term FX hedging strategies stemming from uncertainty about different payoff-relevant variables (such as the exchange rate, the asset return and interest rates) and from assumptions about the flow of information over time. To this end, we distinguish between six risk categories: FX risk, asset price risk, FX market distress, premature liquidation risk, counterparty risk and inflation risk.

Exactly what risks and considerations are most relevant in relation to FX hedging arrangements is ultimately an empirical question, but we hope that this article can give some guidance by offering a suitable conceptual framework to think about a series of important economic considerations, while being flexible enough to capture additional features. A complete assessment of whether the observed FX hedging strategies are individually and socially optimal crucially hinges on the mandates of asset managers and the nature of the foreign currency denominated assets (bonds, equities, etc.). It is also contingent on expectations about the volatility of exchange rates, the persistence of exchange rate trends, inflation risk and other factors such as the microstructure of financial markets.

Taking a high-level perspective, episodes of financial market distress play a crucial role for FX markets. Severe financial distress can affect both the asset managers who seek FX risk protection and the providers of FX risk protection, who are primarily domestic banks. In normal times, asset managers appreciate the flexibility of short-term FX hedging arrangements, and we describe a number of potential advantages and disadvantages of short-term hedging strategies. However, from a policy viewpoint, an overreliance on short-term FX hedging strategies can have repercussions that are primarily felt in periods of financial distress. This is seen as a potential concern (Sveriges Riksbank 2020a), which resonates with the broader regulatory debate about the build-up of systemic risks. While this article does not intend to make normative

² See Sveriges Riksbank (2020a,b) for the Swedish dimension and Avdjiev et al. (2020) for the international dimension.

statements, we hope that it can offer inputs to the discussion of drivers behind the current shape of the market and point at potential policy trade-offs.

The article is organized as follows. In Section 2, we present a simple model framework that we will use for our analysis. In Section 3, we illustrate and evaluate different hedging strategies in situations characterized by different types of risk. In Section 4, we summarize our main findings and discuss how one may think about the trade-offs, the overall risk assessment and potential policy concerns.

For the fast reader, Table 2 in Section 4 offers for each of the six risk categories a summary of the potential advantages and disadvantages associated with short- and long-term FX hedging strategies.

2 Basic model

The formal analysis is based on a stylized theoretical model with two periods. This section describes the basic model used for the analysis in Section 3, where we also consider various extensions to capture different risk categories.

In the model, there are three dates (t = 0, 1, 2) and three risk-neutral actors: a Swedish household (henceforth HH), a Swedish asset manager (AM), who is seeking FX risk protection, and a Swedish or international bank (BANK), who sells FX risk protection. The HH has an endowment of *SEK* 20 at t = 0, which she places with the AM. We consider an investment horizon that spans two periods, that is, from t = 0 to t = 2. The investment decision is delegated to the AM and we assume that the AM's objective is to seek a balanced (50%–50%) exposure to a domestic *SEK*-denominated asset and to a foreign *USD*-denominated asset, as depicted in Figure 3. It shows that the HH invests *SEK* 20 with the AM and receives a claim denominated in *SEK*. The AM, in turn, invests *SEK* 10, respectively, in the domestic and foreign assets. The underlying rationale is that Swedish households do not want to rely exclusively on the Swedish financial market. Instead, they want to take advantage of investment opportunities in Sweden and abroad by constructing a portfolio that comprises domestic and foreign assets.³

Given the HH's two-period investment horizon, the AM pursues a long-term investment strategy and expects to divest the assets at t = 2, thereafter converting the proceeds from the *USD* denominated asset into *SEK*. Then the funds are used to serve the *SEK* denominated claim of the Swedish HH. Crucially, the AM wants to insure against exchange rate risk.⁴

³ In practice, Swedish asset managers diversify their asset holdings globally. Characteristically, small open economies have a large share of investments in foreign currency denominated assets. Important benefits of such an investment strategy include the possibility to insure against domestic shocks and to take advantage of a wider range of investment opportunities. Our stylized model does not offer micro foundations for the diversification motive and we just assume that HHs want a 50%–50% exposure.

⁴ The assumption that the AM wants to insure against FX risk can be justified by the regulation of pension funds and insurance companies who are obliged to hedge certain exchange rate risks. In practice, Swedish asset managers like mutual funds and Swedish households investing directly in foreign currency





We assume that the *SEK* and *USD* denominated assets deliver the cash-flows depicted in Table 1. Both investments are "long-term" with a duration of two periods. One *USD* invested at t = 0 delivers a gross return of *USD* \tilde{r}_2^* at t = 2 if held to maturity. The investment is potentially risky, meaning that it has a stochastic return (indicated by the tilde ~). In practice, the AM may not always wait until the asset matures but sell it on the financial market at a gain or loss. If the *USD* denominated asset is divested prematurely at t = 1, the return is *USD* \tilde{p}_1^* . Similarly, one *SEK* invested at t = 0 delivers a gross return of *SEK* \tilde{r}_2 at t = 2 if held to maturity and a return of *SEK* \tilde{p}_1 if divested at t = 1.

Table 1. Asset returns

Returns per unit of USD or SEK invested

Time		t=0	t=1	t=2
Payoff from USD asset	If held to maturity	-USD 1		+USD \tilde{r}_2^*
	If sold prematurely	-USD 1	+USD \tilde{p}_1^*	
Payoff from SEK asset	If held to maturity	<i>—SEK</i> 1		+SEK \tilde{r}_2
	If sold prematurely	-SEK 1	+SEK \tilde{p}_1	

There is a foreign exchange market, which is open at dates t = 0, 1, 2 for spot transactions and at dates t = 0, 1 for forward contracts that can be used to hedge against exchange rate risk.⁵ These contracts describe an agreement that stipulates the exchange of currency at a specified future date using a contractually agreed conversion rate, the so-called forward rate. In our model, the BANK offers protection

denominated assets may deliberately refrain from hedging exchange rate risk for speculative reasons, because the cost of hedging FX risk is too high for them or because of risk management considerations. ⁵ In practice, FX swaps are more common than forward contracts. As explained in the introduction, FX swap contracts consist of a spot transaction where the AM "borrows" *USD* at t = 0 and "lends" *SEK*, and a

forward transaction with reversed payments of a pre-specified amount.

at t = 0 and t = 1; the cost of the protection depends on the duration of the forward contract and may be time-varying.

Formally, we denote with S_0 the *SEK/USD* spot exchange rate at t = 0. The future spot exchange rates at t = 1 and t = 2 are stochastic (indicated by the tilde ~) and denoted by \tilde{S}_1 and \tilde{S}_2 , respectively. Next, let F_{01} be the t = 1 forward exchange rate which is agreed upon at t = 0. Similarly, F_{02} is the t = 2 forward exchange rate agreed at t = 0 and F_{12} is the t = 2 forward exchange rate agreed at t = 1. Finally, let τ_{01} be the insurance premium (or contractual cost) in *SEK* for a forward contract spanning from t = 0 to t = 1. The parameters τ_{12} and τ_{02} are defined analogously.⁶

Besides the foreign exchange market, there is a domestic and a foreign credit market at dates t = 0, 1. Let i_{01} be the short-term interest rate in the domestic credit market at t = 0 and let i_{02} be the long-term interest rate; the future short-term rate at t = 1is potentially stochastic and denoted by \tilde{i}_{12} . Analogously, we denote with i_{01}^* the short-term interest rate in the foreign credit market at t = 0 and with i_{02}^* the longterm interest rate; the potentially stochastic future short-term rate at t = 1 is \tilde{i}_{12}^* .

2.1 No arbitrage

Suppose for now that the insurance premia for forward contracts are zero, so $\tau_{01} = \tau_{12} = \tau_{02} = 0$. In a perfectly competitive risk-neutral environment with no arbitrage opportunities, interest rates and prices are in the following relationship. First, the price of the domestic asset at t = 1 has to equal its discounted expected cash flow: $p_1 = E[\tilde{r}_2/(1 + \tilde{\iota}_{12})]$. The same holds for the foreign asset: $p_1^* = E[\tilde{r}_2^*/(1 + \tilde{\iota}_{12})]$. Second, the domestic *SEK* long-term interest rate has to equal the expected return of the domestic asset, so $i_{02} = (1 + i_{01}) \times E[1 + \tilde{\iota}_{12}] - 1 = E[\tilde{r}_2] - 1$, and the foreign USD long-term interest rate has to equal the expected return of the foreign asset: $i_{02}^* = (1 + \tilde{\iota}_{12}^*] - 1 = E[\tilde{r}_2^*] - 1$.

If one of the above relationships does not hold, there are arbitrage opportunities in the domestic and foreign financial markets, which could be exploited by financial market participants. As an example, consider a situation where $i_{02} < E[\tilde{r}_2] - 1$. Here a risk-neutral arbitrageur could borrow funds cheaply in the domestic credit market and generate vast profits by investing them in the domestic asset, which offers a higher expected return. In practice, competitive financial markets do not offer such opportunities to generate potentially unlimited profits, provided there are no relevant limits to arbitrage (such as tight credit limits) that prevent arbitrageurs from exploiting arbitrage opportunities.

Since we are operating in an environment where there is a domestic and a foreign financial market, the assumption of no arbitrage implies additional conditions that link interest rates, exchange rates and forward rates.

To rule out the possibility that there is an opportunity to earn riskless profits from covered interest arbitrage, the covered interest parity (CIP) demands that $F_{01}/S_0 =$

⁶ We can interpret τ as a catch-all that also includes factors like liquidity risk and counterparty risk, which are important determinants of how expensive it is to protect against exchange rate risk.

 $(1 + i_{01})/(1 + i_{01}^*)$ and $F_{02}/S_0 = (1 + i_{02})/(1 + i_{02}^*)$ at t = 0, and $F_{12}/S_1 = (1 + i_{12})/(1 + i_{12}^*)$ at t = 1.⁷ These relationships assure that it is not possible to generate a profit by borrowing in the credit market in one currency and investing in the credit market in another currency.

Finally, in our risk-neutral world, the equalization of expected returns (domestic and foreign) demands that $S_0 \times (1 + i_{01}) = E[\tilde{S}_1] \times (1 + i_{01}^*)$ and $S_0 \times (1 + i_{02}) = E[\tilde{S}_2] \times (1 + i_{02}^*)$ at t = 0, and $S_1 \times (1 + i_{01}) = E[\tilde{S}_2|S_1] \times (1 + i_{12}^*)$ at t = 1. The uncovered interest parity (UIP) conditions imply $E[\tilde{S}_1] = F_{01}$ and $E[\tilde{S}_2|S_1] = F_{12}$.⁸

2.2 Baseline example

To guide our analysis of the basic model, we use an example with some numbers. Figure 4 provides an illustration. As seen in Figure 4, we assume that the spot exchange rate at t = 0 is $S_0 = 10 SEK/USD$ and that the future exchange rates at t = 1 and t = 2 are unknown. We also assume that the domestic one-period interest rate is $i_{01} = i_{12} = 10\%$, while the foreign one-period interest rate is $i_{01}^* = i_{12}^* =$ 20%. The asset returns follow from the assumption of no arbitrage as specified above. That is, the domestic long-term interest rate is given by $i_{02} = (1 + i_{01})(1 + i_{12}) - 1 = 21\%$, and if the return of the foreign asset is riskless, then it must be given by $r_2^* = 1.44$ to match the foreign long-term rate of $i_{02}^* = (1 + i_{01}^*)(1 + i_{12}^*) - 1 =$ 44%.

In the baseline environment, we assume that the foreign asset return is known at t = 0, as well as the future domestic and foreign interest rates. We will relax these assumptions for the variables marked with blue circles in Figure 4 when considering various extensions.

In our example, the Swedish asset manager then invests *SEK* 10 in the foreign asset, with a known long-term return of $\tilde{r}_2^* = USD$ 1.44. To do so, she must first purchase dollar in the spot market at the exchange rate S_0 . While the asset return in dollar is known, the future exchange rate is not, and therefore the asset manager does not know how much *SEK* the investment will generate. Thus, she faces FX risk.

⁷ In practice, deviations from the CIP can occur (see, for example, Borio et al. 2016). Through the lens of our model, we can capture deviations from the CIP by manipulating the insurance premia τ_{01} , τ_{12} , τ_{02} . ⁸ Risk aversion is one reason why the spot price of a foreign currency can deviate from the prevailing forward rate.



Figure 4. Foreign asset return, spot exchange rates and interest rates

Note. The spot exchange rates \tilde{S}_1 and \tilde{S}_2 in red are stochastic and their realization is not known at t = 0. In the baseline example variables marked with blue circles are assumed to be risk-free and known at t = 0.

2.2.1 The long-term FX hedging strategy

One way to protect the asset manager from FX risk is to enter a long-term hedging arrangement. Figure 5 illustrates schematically how this works. After the Swedish asset manager places her investment of *SEK* 10 in the foreign asset, which requires her to purchase US dollar in the spot market at the rate S_0 , she engages in a long-term forward contract with the BANK at t = 0. The forward contract stipulates a promise by the AM to deliver *USD* 1.44 at t = 2, which is the anticipated payoff from the foreign asset, and to receive $F_{02} \times USD$ 1.44 from the BANK. Provided that covered interest parity holds, the payment received by the AM is *SEK* 12.1, which is the same return as investing *SEK* 10 in the domestic asset at the interest rate $i_{02} = 21\%$.⁹

In effect, the exchange rate risk associated with the foreign asset return is fully eliminated. Figure 5 also shows that the AM pays an insurance premium at t = 0 to the BANK. Since we assume in the baseline that the insurance premium (τ_{02}) charged by the BANK is zero, the long-term FX hedging assures that the rate of return on the foreign asset is identical to that on an investment in the domestic credit market.

⁹ The return in SEK from the foreign asset return must satisfy $F_{02} \times USD \ 1.44 = (1 + i_{02})/(1 + i_{02}^*) \times S_0 \times USD \ 1.44 = SEK \ 12.1.$



Figure 5. The long-term FX hedging arrangement

Note. The forward contract spans from t = 0 to t = 2. The Swedish asset manager (AM) promises to deliver USD 1.44 at t = 2 in return for SEK 12.1 from the protection seller (BANK).

2.2.2 The short-term FX hedging strategy

An alternative to the long-term hedging arrangement is to enter two short-term hedging arrangements. This is illustrated in Figure 6. The first forward contract signed at t = 0 foresees a promise by the Swedish asset manager to deliver USD x to the protection seller in exchange for $F_{01} \times USD x$ at t = 1. The second forward contract signed at t = 1 foresees a promise by the AM to deliver $USD \ 1.44$ to the BANK in exchange for $F_{12} \times USD \ 1.44$ at t = 2. For each forward contract, an insurance premium may have to be paid (τ_{01}, τ_{12}) , but we assume for the baseline that insurance premia are zero.

We will discuss the optimally chosen amount x of the first forward contract in more detail below. In essence, the optimal x minimizes payoff risk by tailoring hedging gains and losses to the desired levels, taking into account expected future interest rates.

This concludes the discussion of the model framework. We now use this framework to analyze how the long- and short-term FX hedging strategies perform in different risk scenarios. We discuss, in turn: risk originating from movements in the foreign exchange rate (FX risk); risk from movements in the price of the foreign asset (price risk); risk related to FX market distress; risk related to the need to sell the asset and to unwind the FX hedge in advance; risk related to the counterparty in the FX hedging arrangement; and, finally, risk of increased inflation in the domestic economy. Throughout, our aim is to address two questions: *How does the performance of short-and long-term FX hedging strategies differ? Under what conditions will the two strategies lead to the same outcome?*



Figure 6. The short-term FX hedging arrangements

Note. The first forward contract spans from t = 0 to t = 1. The Swedish asset manager (AM) promises to deliver USD x at t = 1 in return for $F_{01} \times USD x$ from the protection seller (BANK). The second forward contract spans from t = 1 to t = 2 and AM promises to deliver $USD \ 1.44$ at t = 2 in return for $F_{12} \times USD \ 1.44$.

3 FX hedging strategies under different types of risk

This section considers how different hedging strategies perform under six different risk categories: FX risk, asset price risk, FX market distress, premature liquidation risk, counterparty risk and inflation risk.

3.1 FX risk

We begin by discussing risk originating from movements in the exchange rate, building on the baseline environment described above. The attractiveness of FX hedging depends in general on what types of risk the investor faces. If most of the risk is due to movements in the exchange rate, for instance if the investment return in foreign currency is easy to predict, then the case for FX hedging is most pervasive. This is typically the case for highly rated fixed-income investments. Conversely, an asset manager investing in foreign currency denominated equity may have little incentive to seek a FX hedge since the risk associated with the equity exposure is likely to dwarf the currency risk.¹⁰

We first abstract from asset return risk, that is, we consider the simpler baseline model with riskless asset cash flows, $\tilde{r}_2^* = r_2^* = 1.44$ and $\tilde{r}_2 = r_2 = 1.21$. Section 3.1.1 focuses on shocks to spot exchange rates and switches off interest rate risk. In this scenario, a long-term FX hedging strategy and a carefully calibrated short-term FX hedging strategy can lead to identical outcomes. We discuss limitations to the result and present in Section 3.1.2 what happens when we introduce interest rate risk as one of the drivers of exchange rate risk. Thereafter, Section 3.1.3 introduces asset return risk.

3.1.1 Shocks to the spot exchange rates without interest rate risk

In our first comparison of FX hedging strategies, we assume that there is neither domestic, nor foreign interest rate risk, that is, the domestic and foreign one-period interest rates are known and equal to 10% and 20%, respectively ($\tilde{i}_{12} = i_{12} = 10\%$ and $\tilde{i}_{12}^* = i_{12}^* = 20\%$). As in the baseline example, this means that the two-period interest rates are $i_{02} = 21\%$ and $i_{02}^* = 44\%$, respectively.

Since the domestic interest rate is below the foreign interest rate, the *SEK* is on average expected to appreciate against the *USD*. But the exact realization of the future exchange rate can be both stronger or weaker than in period 0. We will consider an environment where it is equally likely that the exchange rate will appreciate or depreciate, with shocks equal to +1 or -1. Assuming that covered interest parity (CIP) holds, the forward exchange rate at t = 0 is 9.17 *SEK/USD* (derived as $F_{01} = (1 + i_{01})/(1 + i_{01}^*) \times S_0$), which equals the expected t = 1 spot rate, that is, $E[\tilde{S}_1] = F_{01}$. Given the symmetric shocks of +1 or -1, the actual spot exchange rate is either $S_1 = 10.17$ *SEK/USD* or $S_1 = 8.17$ *SEK/USD* with probability one-half each, as illustrated in Figure 7.

The CIP then also demands that the implied forward exchange rate at t = 1 depends on the realized spot exchange rate: $\tilde{F}_{12} = (1 + i_{12})/(1 + i_{12}^*) \times \tilde{S}_1 SEK/USD$. Given that the future exchange rate is either 10.17 or 8.17 with probability one-half each, the implied forward rate is either 9.32 or 7.49 SEK/USD. This equals the expectations about t = 2 spot rates shown in Figure 7. Again, because of the symmetric shocks of +1 or -1, the actual realizations of the t = 2 spot exchange rates differ. Specifically, Figure 7 shows that there are four different possible realizations with probability one-quarter each, which are 10.32, 8.32, 8.49 and 6.49 SEK/USD.

¹⁰ See, for example, Dimson et al. (2012) for a discussion of empirical evidence.



Figure 7. Spot exchange rates and expectations with FX risk only

Note. Prob. stands for probability. Exchange rate shocks in red.

FX hedging strategies

We consider the following investment strategies for the asset manager:

- 1. Long-term: Invest in the foreign asset and seek a long-term FX hedging arrangement.
- 2. **Short-term**: Invest in the foreign asset and seek two short-term FX hedging arrangements (for example from t = 0 to t = 1 and from t = 1 to t = 2).¹¹
- 3. No FX hedge: Invest in the foreign asset without a hedging arrangement.

Strategy: Long-term

Suppose that the Swedish asset manager pursues a long-term FX hedging strategy. We will show that the asset manager can then fully eliminate FX risk in the described environment and achieve a return of 21% for the foreign dollar denominated asset, which equals the return of the domestic asset.

The long-term FX hedging strategy works as follows: At t = 0, the AM sells *SEK* 10 on the FX spot market at the rate $S_0 = 10 \ SEK/USD$ and obtains USD 1, which she invests in the dollar denominated foreign asset. To insure the FX risk, the AM enters a contract with the BANK, where the BANK agrees to deliver $F_{02} \times USD \ r_2^* = (1 + i_{02})/(1 + i_{02}^*) \times S_0 \times USD \ r_2^* = SEK \ 8.40 \times r_2^*$ in exchange for $USD \ r_2^*$ at t = 2. At t = 0, the foreign asset payoff is realized and the forward contract is settled.

As a result, the AM's rate of return at t = 2 for the domestic investment is

¹¹ The two FX hedges may be provided either by two different protection sellers or by the same protection seller who agrees to roll over the hedge.

$$r_2 - 1 \equiv \frac{SEK r_2 - SEK 10}{SEK 10} = 21\%$$

and the rate of return for the foreign investment is

$$R^{LT} \equiv \frac{F_{02} \times USD \ r_2^* - S_0 \ USD}{S_0 \ USD} = 21\%,$$

where the gross rate of return is computed as the forward rate times the foreign asset return in USD divided by the initial investment of SEK 10. Subtracting one gives the net rate of return of 21%.

Due to the assumption of no-arbitrage, the returns on the domestic and the foreign investment are identical. Moreover, the AM is *fully insured* against both an appreciation or depreciation of the krona relative to the t = 0 expectation given by $E[\tilde{S}_2] = 8.40 \ SEK/USD$; the realization of the spot exchange rates at t = 1,2 does not matter.

Strategy: Short-term

Next, suppose that the Swedish asset manager pursues a short-term FX hedging strategy, and enters a one-period hedging arrangement at t = 0 and then a second arrangement at t = 1.¹² We will show that the asset manager can fully eliminate FX risk in the described environment if the first FX hedge is calibrated to the right amount. In this case, the expected return of the foreign dollar denominated asset is always identical at 21%.

The short-term FX hedging strategy works as follows: At t = 0, the AM sells *SEK* 10 on the FX spot market at the rate $S_0 = 10 SEK/USD$ and obtains *USD* 1, which is invested in the dollar denominated foreign asset. To insure the AM's FX risk; the BANK agrees to deliver $F_{01} \times USD x = \frac{1+i_{01}}{1+i_{01}^*} \times S_0 \times USD x = SEK 9.17 \times x$ in exchange for *USD* x at t = 1. At the beginning of t = 1, the realization of the spot exchange rate becomes known. It is either $S_1 = 10.17 SEK/USD$ or $S_1 = 8.17 SEK/USD$. We start with the former case.

First, the AM has to deliver USD x to the counterparty of the first forward contract and receives SEK 9.17 × x, meaning that she faces a hedging loss of SEK x, as the true exchange rate is 10.17 SEK/USD. Second, the AM seeks a new FX hedge with another BANK, which involves a promise to deliver USD r_2^* at t = 2 to the BANK in exchange for $F_{12} \times USD r_2^* = (1 + i_{12})/(1 + i_{12}^*) \times 10.17 SEK/USD \times USD r_2^* =$ SEK 13.42. The hedging loss necessitates that the AM borrows SEK x domestically at the interest rate $i_{12} = 10\%$ in order to meet the t = 1 payment obligation from the first forward contract. At t = 2, the foreign asset payoff is realized, the second forward contract is settled and the debt is repaid with interest.

¹² The protection seller may be the same or a different BANK. We discuss the case when the new protection seller is another BANK. The outcome is identical if the same BANK is used for a roll-over of the forward contract, which requires to account for hedging gains and losses, as to make the BANK indifferent about whether or not to roll over the forward contract.

This time the result differs. If $S_1 = 10.17 SEK/USD$, the AM's rate of return on the foreign investment at t = 2 is

$$R_A^{ST}(x) \equiv \frac{F_{12} \times USD \, r_2^* - S_0 \, USD - (1 + i_{12}) \times SEK \, x}{S_0 \, USD} = 34.2\% - \frac{(1 + i_{12}) \times SEK \, x}{SEK \, 10}.$$

Similar to before we compute the gross rate of return as the forward rate times the foreign asset return in *USD* divided by the initial investment of *SEK* 10. However, we now also need to correct for the t = 2 value of the hedging loss. Note that the outcome of the short-term FX hedging strategy is *only identical* to the outcome of the long-term FX hedging strategy if the first FX hedge is over the amount x = 1.2, that is, *the discounted* t = 2 *return of the foreign asset*. Formally, $R_A^{ST}(x = 1.2) = 21\%$. The intuition for this result is that the lower cost for the second FX hedging contract has to be exactly off-set by the hedging loss.

We next look at the case where the realization of the spot exchange rate is $S_1 = 8.17 SEK/USD$. At t = 1 the AM seeks to roll over the expiring forward contract. First, the AM has to deliver USD x to the counterparty of the first forward contract and receives $SEK 9.17 \times x$, meaning that she faces a hedging gain of SEK x. The AM seeks a new FX hedge with another BANK, which involves a promise to deliver $USD r_2^*$ at t = 2 to the BANK in exchange for $F_{12} \times USD r_2^* = SEK 10.78$.

The AM's rate of return on the foreign investment at t = 2 then is

 $R_B^{ST}(x) \equiv \frac{F_{12} \times USD \, r_2^* - S_0 USD + (1+i_{12}) \times SEK \, x}{S_0 \, USD} = 7.8\% + \frac{(1+i_{12}) \times SEK \, x}{SEK \, 10}$

Relative to the previous case, the cost for the second FX hedging contract is higher, which shows up as a reduction in the first term. However, we now have to account for a hedging gain in the second term. Again the outcome of the short-term FX hedging strategy is *only identical* to the outcome of the long-term hedging strategy if x = 1.2.

In sum, we find that the asset manager's payoff is constant (that is, the payoff variance is zero) if x = 1.2. Otherwise, the payoff variance is positive.

Strategy: No hedge

Now suppose that the Swedish asset manager pursues no FX hedging. It can be shown that in the described environment the expected return is the same as for the previous strategies, that is, $E[\tilde{R}^N] = 21\%$. However, the payoffs under the different exchange rate realizations are associated with substantial risk.

Specifically, without FX hedging, the return on the foreign investment at t = 2 depends on which of the four equally likely realizations of the spot exchange rate S_2 prevails (recall Figure 7).

We have now set the stage to address some of our questions and to identify variations in the economic environment that help us to gain additional insights.

Can the FX risk be fully eliminated under the short-term FX hedging strategy?

Yes, as shown above, the short-term FX hedging strategy can replicate the outcome of the long-term FX hedging strategy in the described environment. This is, however, only the case if the first forward contract targets the discounted cash-flow of the foreign currency denominated asset, that is, if x = 1.2. A wrongly calibrated first forward contract yields *the same expected return* of 21% as the long-run strategy, *but exposes* the Swedish asset manager to some risk. To see this, suppose that the first forward contract targets the non-discounted cash-flow of the foreign asset, that is, if x = 1.44, then the short-term FX hedging strategy has a risky return of $R_A^{ST} = 18.36\%$ with probability one-half and $R_B^{ST} = 23.64\%$ with probability one-half.

Importantly, the short-term hedging strategy is associated with gains or losses. These gains or losses occur because the FX hedge becomes either cheaper if the Swedish krona appreciates or more expensive if it depreciates. Only if x = 1.2 will the gains and losses exactly offset the variability in the cost of the second FX hedging contract. As a result, the first forward contract needs to be carefully calibrated.

What are the challenges in calibrating the first forward contract?

In our simple example, not only the cash-flow is known, but also the future foreign interest rate. In practice, both variables are likely to be uncertain. In fact, we show in Section 3.1.2 that the equivalence result breaks down if we consider a scenario with interest rate risk. Specifically, we show that discounting with the expected future foreign interest rate inevitably generates payoff variability, making the short-term FX hedging strategy risky.

Why is it that short-term FX hedging arrangements are used much more frequently in practice?

One aspect that can draw a wedge between the outcomes of the long- and short-term FX hedging strategies is related to the insurance premia. Specifically, the comparison of the two strategies is influenced by insurance premia if $\tau_{01} + \tau_{12} \neq \tau_{02}$. Consistent with the prevalent use of short-term FX hedging strategies, it is possible that longer-term hedges are, at least for certain maturities, more expensive due to a less liquid market. In fact, market surveys reveal that the most liquid segment of the FX swap market is typically concentrated over maturities of a few months. For the Swedish krona, the outstanding nominal amounts of FX swaps with maturities over 6 months are very small compared to shorter maturities, as illustrated in Figure 2. It is an interesting empirical question to understand how much of this outcome can be explained by demand and supply factors.

Investors may also choose to use short-term hedging strategies if demand and supply are more misaligned for longer maturities. Specifically, supply shortages for longer maturities can imply that the short-term FX strategy has a more favorable expected return. Formally, this can be captured in our model as $\tau_{01} + \tau_{12} < \tau_{02}$. Conceptually, there are a number of possible reasons for such a scenario. Important aspects have to do with institutional and regulatory factors. From the perspective of domestic banks, who are the dominant counterparties for Swedish asset managers, there is a desire to align the duration of the offered FX swaps with their desired FX funding profile. If their own funding costs in foreign currency are more favorable at shorter maturities, banks will have an incentive to offer better terms to Swedish asset managers for short-term FX hedging arrangements with similar durations.

Another aspect that can draw a wedge between the outcomes of the long- and shortterm FX hedging strategies is related to risk aversion. While risk aversion tends to favor long-term hedging strategies, it can interact with other factors that may induce asset managers to favor short-term FX hedging arrangements. These include the risk of over- and under-hedging, which we discuss in detail in Section 3.1.3, considerations that have to do with flexibility, which we discuss in Sections 3.4 and 3.5, and considerations related to domestic inflation risk, which we discuss in Section 3.6.

3.1.2 Shocks to the spot exchange rates and to the foreign interest rate

Next, we examine the role of uncertainty about foreign interest rates, which is one of the determinants of exchange rate risk. In the previous analysis, we modeled interest rates as deterministic variables and exchange rates as stochastic variables that are driven by a symmetric exogenous shock. Now we add a stochastic foreign interest rate, which is also driven by a symmetric exogenous shock. Specifically, we consider the following modified environment.

As before, the spot exchange rates at t = 1, 2 are assumed to be equally likely to strengthen or weaken by one unit. In contrast to Section 3.1.1, the foreign interest rate \tilde{t}_{12}^* is now stochastic and becomes known at the beginning of t = 1. Consequently, the interest rate differential is now an additional driver of the spot exchange rate at t = 2 and of forward rates at t = 1.

We continue to assume that the short-term foreign interest rate in period t = 0 is given by $i_{01}^* = 20\%$. But the realization of the future short-term interest rate is equally likely to be $i_{12}^* = 18\%$ or $i_{12}^* = 22\%$, with an expected value of $E[\tilde{i}_{12}^*] = 20\%$. The long-term interest rate is unchanged at $i_{02}^* = 44\%$, and we assume that the domestic interest rates are unaltered with $i_{01} = i_{12} = 10\%$ and $i_{02} = 21\%$.

Assuming that CIP holds, the spot rate and implied forward exchange rate at t = 0 remain $S_0 = 10 SEK/USD$ and $F_{01} = 9.17 SEK/USD$. The implied forward exchange rate at t = 1 depends on both the realized spot exchange rate at t = 1 (which is either 10.17 or 8.17) and the realized short-term foreign interest rate (either 18% or 22%). As the forward rate at t = 1 is stochastic and given by $\tilde{F}_{12} = (1 + i_{12})/(1 + \tilde{i}_{12}^*) \times \tilde{S}_1$, there are four possible realizations: 9.48, 9.17, 7.62, or 7.37 SEK/USD, each of which occurs with equal probability of one-quarter. Figure 8 shows how the environment is modified at dates t = 1,2. We can see that there are eight possible realizations with probability one-eights each, which are 10.48, 8.48, 10.17, 8.17, 8.62, 6.62, 8.37 and 6.37 SEK/USD.

As in Section 3.1.1, the Swedish krona is expected to appreciate due to the interest rate differential, but the actual realization of the spot exchange rate can be either stronger or weaker than the expected value. We discuss the outcomes of the two FX hedging strategies in turn.



Figure 8. Spot exchange rates, foreign interest rate risk and expectations with FX and foreign interest rate risk

Note. Prob. stands for probability. Exchange rate shocks in red; foreign interest rate shocks in blue.

Strategy: Long-term

If the Swedish asset manager pursues a long-term FX hedging strategy, the analysis of Section 3.1.1 is unchanged. The long-term FX hedging strategy allows the asset manager to fully insure against either a depreciation or an appreciation of the Swedish krona. The spot exchange rate and the foreign interest rate realized at t = 1 do not matter since the contracting at t = 0 is based on the known (non-stochastic) long-term foreign interest rate $i_{02}^* = 0.44$ as in Section 3.1.1.

Strategy: Short-term

Next, suppose that the Swedish asset manager pursues a short-term FX hedging strategy. We then find that the strategy now delivers a risky payoff. The expected return is with 21% identical, but in contrast to Section 3.1.1, the hedging gains and losses are not fully offset.

As before, the AM sells *SEK* 10 at t = 0 on the FX spot market at the rate $S_0 = 10 SEK/USD$ and obtains USD 1, which is invested in the dollar denominated foreign asset. To insure the AM's FX risk; the BANK agrees to deliver $F_{01} \times USD x = (1 + i_{01})/(1 + i_{01}^*) \times S_0 \times USD x = 9.17 SEK/USD \times USD x$ in exchange for USD x at t = 1. At the beginning of t = 1, the realization of the spot exchange rate and the foreign interest rate become known. As shown in Figure 8, we have to consider four different combinations of spot exchange rate and foreign interest rate realizations. Otherwise, the analysis is identical to Section 3.1.1 and we provide the derivations in Appendix A.

For the case where $S_1 = 10.17 SEK/USD$ and $i_{12}^* = 18\%$, the AM's rate of return on the foreign investment at t = 2 is $R_A^{STi} = 36.51\% - 1.1 \times SEK x/(S_0 USD)$, for the

case $S_1 = 10.17 SEK/USD$ and $i_{12}^* = 22\%$, it is $R_B^{STi} = 32.05\% - 1.1 \times SEK x/(S_0 USD)$, for the case $S_1 = 8.17 SEK/USD$ and $i_{12}^* = 18\%$, it is $R_C^{STi} = 9.67\% + 1.1 \times SEK x/(S_0 USD)$, and for the case $S_1 = 8.17 SEK/USD$ and $i_{12}^* = 22\%$, it is $R_D^{STi} = 6.08\% + 1.1 \times SEK x/(S_0 USD)$.

Notably the expected return from the foreign currency denominated asset is still at 21%. However, different to Section 3.1.1, the short-term FX hedging strategy now delivers a volatile payoff. This is true even if the first FX hedging arrangement is tailored to the discounted cash-flow using the expected interest rate, that is, if x = 1.2, which leads to a small, but positive, payoff variance. In fact, exposure to some risk cannot be avoided. The reason is that the realized interest rate inevitably differs from the expected interest rate used to discount the future cash flow. Hence, the investment return is not fully hedged.¹³

What happens if short-term FX hedging is taken to the extreme, that is, if the asset manager engages in short-term FX hedging arrangements with an ultra-short duration?

From the discussion of our baseline model in Section 3.1.1, we know that the shortand long-term FX hedging strategies can deliver identical outcomes as long as we do not introduce additional elements such as interest rate risk. As a result, even FX hedging arrangements with an ultra-short duration, in some special cases, can yield the same outcome as a long-term FX hedging arrangement. However, this result is a special case and does not generalize.

The environment with foreign interest rate risk in Section 3.1.2 is a case in point. When adding additional periods, we can get an idea of the effect of shortening the duration of the FX hedges. Intuitively, a shorter duration exposes the asset manager to more risk of the type described above. Consequently, the short-term hedging strategy becomes increasingly less favorable when compared to the long-term strategy. In the extreme, when the duration of the short-term hedge becomes ultrashort, then the outcome of the short-term strategy starts to resemble more and more the outcome without any hedging at all. See Appendix B for a formal discussion.

3.1.3 Over- and under-hedging FX risk

So far, we have shown that a long-term currency hedge can perform very well in eliminating FX risk. This result changes when we introduce asset return risk. Specifically, we have so far assumed that the foreign asset return \tilde{r}_2^* is constant. We next consider a modified environment with a stochastic foreign asset return.

¹³ It is worth mentioning that from a theoretical viewpoint an ideal environment with complete markets would allow the asset manager to eliminate any risk even if using a short-term FX hedging strategy. This is because the asset manager could in such an ideal world construct a self-financing trading strategy that has a cash-flow identical to the long-term FX hedging arrangement. In practice, this outcome is, however, difficult to achieve. Even when instruments for the insurance of interest rate risk are available, it is arguably challenging to accomplish a full elimination of risk with short-term hedging strategies if the exchange rate and interest rate risks are intertwined, as it is the case in the environment we considered.

If the payoff in foreign currency is variable and uncertain, then the asset manager is unable to construct a hedge that fully eliminates the FX risk. Faced with such a scenario, the manager forms expectations about the payoffs and seeks FX risk protection accordingly. We find that in such an environment the asset manager will inevitably do some degree of over- or under-hedging from an ex-post perspective. If the asset manager receives new information over time which allows her to form better expectations about the payoffs, the strategy to roll over short-term FX hedges has the potential benefit that it can be more easily adjusted at each roll-over date to reduce the extend of over- or under-hedging.

To see this formally, consider a modification to the baseline model from Section 3.1.1. Specifically, we now assume that the asset manager receives information about the stochastic foreign asset return \tilde{r}_2^* at t = 1, which reveals that the payoff will be higher or lower than the expected value. Specifically, the foreign asset return realizations are $r_2^* = 1.44 + \Gamma$ or $r_2^* = 1.44 - \Gamma$ with equal probability, where $0 < \Gamma < 1.44$.

To be precise, we define another time the actions for the long- and short-term FX hedging strategies for the context of risky foreign asset returns and label these strategies with a star * superscript to account for the modification.

- 1. **Long-term***: Invest in the foreign asset and seek a long-term FX hedging arrangement that does not leave room for adjustments to reduce over- and under-hedging.
- Short-term*: Invest in the foreign asset and seek two short-term FX hedging arrangements that allow for adjustments after one period to reduce overand under-hedging. Moreover, use the domestic credit market for gains and losses from the currency hedges.

Note that the AM could, in principle, under the strategy Long-term^{*}, seek additional short-term FX hedges after new information comes in, so as to make adjustments for the period from t = 1 to t = 2. For brevity, we abstract from this possibility and discuss after the analysis why this assumption is plausible.

Strategy: Long-term*

Suppose that the Swedish asset manager pursues a long-term FX hedging strategy. We show that the long-term FX hedging strategy does not allow the AM to fully insure against a depreciation or an appreciation of the Swedish krona anymore. Specifically, the rate of return of the AM on the foreign asset is

$$\widetilde{R}^{LT*} \equiv \begin{cases} 21\% + \frac{\widetilde{S}_2}{S_0} \times \Gamma & \text{with probability } 1/2 \\ \\ 21\% - \frac{\widetilde{S}_2}{S_0} \times \Gamma & \text{with probability } 1/2 \end{cases}$$

where \tilde{S}_2 has four equally likely outcomes shown in Figure 7. Evidently, the rate of return is not constant anymore and depends on the realization of the asset return and

its interaction with the realization of the spot exchange rate at t = 2. As a result, the AM is either over- or under-hedged.

Strategy: Short-term*

Next, suppose that the Swedish asset manager pursues a short-term FX hedging strategy. We find that the short-term FX hedging strategy is typically superior if the realizations of the foreign asset return deviate a lot from its expected value (that is, if Γ is large), because it allows the Swedish asset manager to reduce risk relative to the long-term FX hedging strategy. The analysis of the asset manager's rate of return follows the same steps as before and derivations can be found in Appendix C. When comparing the short- and long-term FX hedging strategies, the average rate of return is identical and stands at 21%, but the return variability differs.

If $S_2 \approx S_1$, then the risks associated with both strategies are quite similar. Instead, if there is additional exchange rate risk between dates t = 1 and t = 2, as it is the case in our model, then the short-term strategy is typically superior if Γ is large. Analyzing the payoff variances associated with the two strategies reveals that the return variability associated with over- or under-hedging is higher for both, the larger is Γ . However, the effect is stronger for the long-term FX hedging strategy.

The critical insight is that the rolling FX hedge can be more effective in absorbing risk if better information about the returns of the dollar investment arrives over time. Whenever this aspect is important, for example if the asset return risk is high and if the asset manager expects to learn about it over time, then the short-term FX strategy is preferable.

One qualification is important to keep in mind. As mentioned earlier, the asset manager pursuing a long-term FX hedging strategy may seek additional short-term hedges for the period from t = 1 to t = 2 after receiving new information at the beginning of t = 1. There are, however, various practical reasons suggesting that the long-term FX hedging strategy is more difficult to adjust than the short-term strategy. First, the additional hedging arrangements are likely to involve additional costs that make the strategy Long-term* less favorable. Second, the unhedged returns are fairly small relative to the amounts rolled over under the strategy Short-term*, which can make it harder to obtain insurance at reasonable terms for additional FX hedges under the strategy Long-term*.

In practice, the model in Section 3.1.3 best captures a scenario where the underlying foreign currency denominated asset carries substantial risk, as it is the case for lower rated corporate bonds or equity. Instead, the benchmark in Section 3.1.1 best captures a scenario where the foreign asset is a riskless zero coupon bond, meaning that the future payoff in foreign currency is certain.

3.2 Price risk

We next discuss another type of risk, namely risk about the price of the foreign currency denominated asset at t = 1 and its effect if losses associated with the shortterm FX hedging strategy need to be funded by asset sales. For this purpose, we consider a slightly modified environment where we introduce asset-side adjustments to highlight the key insights.

Suppose that the Swedish asset manager pursues a short-term FX hedging strategy as in Section 3.1.1 with the difference that losses from the first period FX hedge are not funded by borrowing, but by selling a fraction of the foreign currency denominated asset at the price p_1^* . This modified strategy may, for instance, be justified by the asset manager's inability to borrow or to sell other assets at t = 1.

How do asset-side adjustments affect the outcome of the short-term FX hedging strategy?

We find that the liquidation price of the foreign currency denominated asset plays an important role for the outcomes. While a buy-and-hold investor (who owns the asset until maturity and uses a long-term FX hedging strategy) is unaffected by changes in the asset price over the duration of the hedging contract, this does not hold for an investor who uses a short-term hedging strategy.¹⁴ Specifically, a depressed liquidation price results in a higher hedging loss due to costly asset liquidation. For the short-term FX hedging strategy, the associated risks remain unhedged. Consequently, short-term FX hedging exposes the AM to a combination of FX risk and price risk.¹⁵

How may such a situation arise? In practice, the foreign asset price may fluctuate over time due to changing liquidity conditions in the market at the point in time when the short-term FX hedge has to be rolled over or due to other factors such as adverse selection problems. Moreover, the asset price no-arbitrage condition may not always hold, which can give rise to deviations from the outcome described in Section 3.1.1.

3.3 Foreign exchange market distress

A third type of risk is foreign exchange market distress, which crystallizes as a challenge to roll over short-term FX hedges. This section is concerned with situations of financial market stress that can occur during a financial crisis episode or because of a large shock such as the COVID-19 pandemic. We are particularly interested in "insurance premium variability", which in our context refers to the FX hedging costs of Swedish asset managers, and in "market access risk", which is a more extreme manifestation of a spike in FX hedging costs that essentially renders the FX hedging market dysfunctional. Arguably, the type of events we have in mind are rare. Nevertheless, they are important and can have significant repercussions in the financial system.¹⁶

Both insurance premium variability and market access risk have important negative implications for the roll-over of short-term FX hedges. We use a slightly modified setting to highlight the key insights. Specifically, consider a version of the environment used in Section 3.1.1 where the asset manager only gets access to FX

¹⁴ A buy-and-hold investor who does not hedge the FX risk is not exposed to price risk, but fully exposed to FX risk.

¹⁵ See Appendix D for a numerical example.

¹⁶ See Avdjiev et al. (2020) and Sveriges Riksbank (2020a,b) for a discussion of the financial market turmoil and FX markets in spring 2020 following the outbreak of the COVID-19 pandemic.

hedging instruments at the intermediate date t = 1 with probability q, where 0 < q < 1. What we have in mind with this modelling tool is to capture major market dislocations during a financial crisis that temporarily impair the functioning of the FX market, thereby disrupting the roll-over of short-term FX hedges.

The outcome of the long-term FX hedging strategy is by definition unaffected by this disruption, but the outcome of the short-term FX hedging strategy is affected as follows. At the beginning of t = 1, the realization of the spot exchange rate becomes known. With probability 1 - q, everything is identical to the short-term FX hedging strategy described in Section 3.1.1. With probability q, there is the FX market distress scenario. If the spot exchange rate is $S_1 = 10.17 SEK/USD$, the Swedish asset manager faces a situation where she cannot roll over the FX hedge. As a result, her rate of return is now risky and given by $(SEK 10.32 \times 1.44 - SEK 10 - SEK 1.2 \times 1.1)/SEK 10 = 35.4\%$ or $(SEK 8.32 \times 1.44 - SEK 10 - SEK 1.2 \times 1.1)/SEK 10 = 6.6\%$ with probability one-half each. A similar result arises if the spot exchange rate is $S_1 = 8.17 SEK/USD$. For this case, we can derive her rate of return as 35.4% or 6.6% with probability one-half each.

Interestingly, the expected rate of return is 21% as before. However, the asset manager's payoff now has a positive variance. Notably, the payoff variance increases in the magnitude of unhedged FX risks, which are positively associated with q, the probability of the FX market being dysfunctional.

Next, we consider a variant of the baseline model where the insurance premium is positive and potentially time-varying.¹⁷ It shows that time-varying premia drive a wedge between the outcomes of the short- and long-term FX hedging strategies. An interesting case in point is a setting where the future premium is stochastic while the expected insurance premium payments are unaltered, that is, $\tilde{\tau}_{12}$ is stochastic with $\tau_{02} = \tau_{01} + E[\tilde{\tau}_{12}]$. In this scenario, the long-term hedging strategy is more effective not only in insuring against the previously discussed risks, but it also shields from fluctuations in the insurance premium. In practice, a source of such fluctuations could be a moderate degree of FX market distress at t = 1 that does not make the market dysfunctional, but merely causes a spike in hedging costs. Another relevant factor could be changes in the market power held by the small number of banks who act as the key sellers of FX risk protection.

Taken together, the roll-over of short-term FX hedges exposes the Swedish asset manager to both market access risk and insurance premium variability. While the average return of the Swedish asset manager may be unaltered, the possibility of FX market distress creates additional return volatility because of unhedged FX risks between dates t = 1 and t = 2.

¹⁷ In Section 3.1.1, we assumed that $\tau_{01} = \tau_{12} = \tau_{02} = 0$. With a positive insurance premium, it evidently matters how the long-term premium τ_{02} relates to the short-term premia τ_{01} and τ_{12} . Only if $\tau_{02} = \tau_{01} + \tau_{12}$ do the results in Section 3.1 continue to hold.

3.4 Premature liquidation risk

In this section, we discuss the fourth risk category. While the previous three risk categories pointed to advantages of long-term FX hedging strategies, premature liquidation risk shows that short-term hedging arrangements offer some "flexibility" that can in certain scenarios be beneficial.

While some asset managers such as insurance companies are often buy-and-hold investors, there is a possibility that they may have to meet unexpected outflows and, therefore, need to sell a foreign currency denominated asset earlier than originally planned, that is, before it matures. In the context of our model, the FX risk may be fully eliminated with the help of a long-term hedging arrangement if the expected duration of the asset is perfectly matched with the duration of the currency hedge (see Section 3.1.1). This is, however, only true if the asset is held for the expected duration. Instead, if it is liquidated prematurely, then the investor has to unwind the long-term FX hedge, which can prove to be costly. In this scenario, the short-term FX hedging strategy can be advantageous, as it suffices not to roll over the FX hedge.

We can identify two relevant scenarios where the flexibility of the short-term FX hedging strategy has advantages. First, there may be additional insurance costs that arise from unwinding the long-term FX hedge, that is, if $\tau_{12} > 0$, which do not arise for the short-term FX hedging strategy. Second, the need to prematurely liquidate the foreign asset may be positively correlated with a foreign currency appreciation. In Appendix E, we formally compare the outcomes of the two FX hedging strategies for this scenario. We find that the expected return of the long-term FX hedging strategy can fall short of the expected return of the short-term strategy.

3.5 Counterparty risk

Next, we discuss the fifth risk category. Similar to Section 3.4, we find that also in an environment with counterparty risk short-term hedging arrangements offer some "flexibility" that can in certain scenarios be beneficial. Counterparty risk materializes when the seller of FX risk protection is for some reason unable to deliver on her promise. As a result, the forward contract signed at t = 0 may become worthless, leaving the Swedish asset manager fully exposed to FX risk. Short-term FX hedging contracts may help to mitigate this type of counterparty risk. More specifically, a short-term hedging arrangement can enable the asset manager to insure a substantial part of the FX risk, while allowing for a switch of counterparties at the roll-over stage (that is, at t = 1) if negative information about the current counterparties comes in. Differently, long-term FX hedging does not allow for this option.

The potential advantage of the short-term FX hedging arrangements being more flexible when unfavorable information about the counterparty comes in needs to be qualified. This is because it is common for the parties of a hedging arrangement to exchange collateral.¹⁸ Notwithstanding, collateralization only works well if margin

¹⁸ Major parties in the FX swap market exchange collateral in accordance with the so-called 'Credit Support Annex' (CSA) agreements. The CSA agreements are voluntary add-on agreements to the standard agreements to which operators undertake through membership of the International Swaps and Derivatives

calls can be met adequately to ensure that changes in the valuation of the collateral and changes in the counterparty risk are taken into account. As a result, a higher residual counterparty risk is likely to remain for long-term FX hedging arrangements relative to short-term FX hedging arrangements; especially when it comes to extreme market stress scenarios like a financial crisis. The same logic applies to credit default swaps, which could be used to hedge the counterparty risk.

3.6 Inflation risk

Finally, we examine the role of domestic inflation risk. In the previous analysis, the domestic and foreign interest rates reflect the real return in the respective currency. However, inflation and monetary policy are, in practice, important determinants of exchange rate developments, which tend to gradually restore relative purchasing power parity in the medium- to long-term (Dornbusch 1976; Taylor and Taylor 2004). At the same time, exchange rate movements also affect domestic inflation, especially in a small open economy like Sweden (Corbo and Di Casola 2020).¹⁹

To incorporate inflation risk in our stylized conceptual framework, we model inflation and exchange rates as exogenously determined stochastic variables and analyze implications for FX hedging. Specifically, we construct an example where we modify the baseline model by allowing for stochastic domestic inflation, $\tilde{\pi}_{01}$, $\tilde{\pi}_{12}$ and $\tilde{\pi}_{02}$, while fixing foreign inflation to zero, that is, $\pi_{01}^* = \pi_{12}^* = \pi_{02}^* = 0$. We denote real and nominal interest rates with the superscripts 'r' and 'n', respectively. Moreover, we assume that the expected real return of investing in the domestic and foreign credit market is identical to the baseline model; formally $i_{02}^r = E[(1 + i_{02}^n)/(1 + \tilde{\pi}_{02})] - 1 = 21\%$ and $i_{02}^{r*} = E[(1 + i_{02}^n)/(1 + \tilde{\pi}_{02}^*)] - 1 = 44\%$.

We assume that domestic inflation is either high or low and that it becomes publicly know at the beginning of date t = 1. Specifically, suppose that inflation risk is independently distributed with the shock hitting the economy between t = 0 and t =1 so that domestic inflation is $i_{01}^n = 10\%$ in the first period with probability one-half and $i_{01}^n = -8.33\%$ otherwise. In the second period, domestic inflation is assumed to be zero so that the real interest rate in the first period is $i_{01}^r = 0\%$ with probability one-half and $i_{01}^r = 20\%$ otherwise, with the expected domestic real interest rate given by $E[\tilde{i}_{01}^r] = 10\%$ as in the baseline model in Section 3.1.1.

When analyzing the outcomes of the long-term and short-term FX hedging strategies in the modified environment with inflation risk, we find that the long-term FX hedging strategy is no longer able to fully eliminate FX risk. In fact, it performs considerably worse than the short-term FX hedging strategy if uninsurable domestic inflation risk is an important factor. The intuition for this result is that the long-term FX hedging

Association (ISDA). All major banks in Sweden, for example, are members of ISDA, as are all the large insurance companies.

¹⁹ Empirically, exchange rates are impossible to forecast in the short-term, as document by Meese and Rogoff (1983), who show for major exchange rates that a random walk outperforms various time series and structural models of exchange rates (for a recent study of the Swedish krona see Askestad et al. 2019).

strategy goes *long in domestic inflation risk*. This effect matters more, the higher the exposure to uninsurable domestic inflation risk. Appendix F offers a formal analysis.

4 Discussion

In Sections 3.1–3.6, we have analyzed the outcomes of short- and long-term FX hedging strategies in different environments that allowed us to focus attention on six risk categories: FX risk, asset price risk, FX market distress, premature liquidation risk, counterparty risk and inflation risk. Based on our findings, we summarize in Table 2 potential advantages and disadvantages associated with the different strategies.

Generally, the outcomes associated with short- and long-term FX hedging strategies are not identical and depend on the nature of uncertainty and the informational environment. The overall picture is nuanced and a key take-away from this article is to carefully consider what types of risk are relevant for different types of asset managers and for the different asset classes they invest in.

As illustrated in Figure 1, Swedish insurance companies and pension funds have a substantial share of their investments in foreign currency denominated assets. They may seek protection against exchange rate risk because of risk management considerations or for other reasons, such as regulatory requirements. Figure 2 shows that Swedish insurance companies and pension funds primarily use FX hedging contracts with short durations (most frequently 3-4 months). Given the longer duration of the foreign currency denominated investments, a duration mismatch emerges which requires the short-term FX hedges to be repeatedly rolled over.

Based on our theoretical framework, a roll-over of short-term FX hedges can have benefits by reducing the risk of over- and under-hedging and by providing more flexibility in case of premature asset liquidation and new information about counterparty risk. Moreover, a short-term FX hedging strategy can help to reduce exposure to uninsurable domestic inflation risk. Notwithstanding, long-term FX hedging arrangements have clear advantages, especially in periods of financial distress when market functioning is impaired. While short-term FX hedging strategies create refinancing risks, long-term FX hedging strategies effectively shield against such risks.

It is an interesting empirical question to understand how much of the FX swap market concentration on maturities below half a year can be explained by demand and supply factors. In practice, Swedish insurance companies and asset managers are likely to carefully trade off the different risks, as well as the price and non-price attributes associated with different contracts. Still, it is possible that market failures stemming from financial frictions or market concentration create a wedge between the privately optimal and the social optimal choice of the appropriate FX hedging products. While it is beyond the scope of this article to draw normative implications, there are important aspects related to our analysis that deserve consideration.

Risk category	Long-term FX hedge	Roll-over of short-term FX hedges	No FX hedge
(1) FX risk.	FX risk is fully eliminated to the extent that the future returns on the USD asset are known or can be insured; otherwise there can be some over- or under- hedging.	In some cases, all/most FX risk can be eliminated. FX hedges need to be carefully calibrated. It is difficult to hedge FX risk associated with foreign interest rate risk. Flexibility benefit: If the USD asset returns are uncertain, the short-term FX hedge can reduce risk, as it can be more easily tailored in response to incoming information.	Full exposure to FX risk.
(2) Price risk (i.e., changes in the USD asset price over investment duration).	No exposure to FX risk and to price risk for buy-and-hold investors (i.e., if USD asset is held until maturity).	If losses from short-term FX hedges are funded with asset-side adjustments, then an exposure to unhedged asset price risk arises (e.g. due to time- varying market liquidity or other factors).	No exposure to price risk for buy- and-hold investors; full exposure to FX risk.
(3) FX market distress (e.g. FX hedges cannot be rolled over at certain times).	No exposure to future FX market distress if there is no need to sell USD asset.	Exposure to market access / refinancing risk and to insurance premium variability (e.g. higher hedging costs when rolling over in times of financial distress).	No exposure to short-term market distress if there is no need to sell the USD asset; full exposure to FX risk.
(4) Premature asset liquidation risk / transaction date uncertainty (i.e., asset sale prior to expected investment duration).	Exposure to the risk of a costly unwinding of the long-term FX hedge if there is a need to sell USD asset.	Flexibility benefit: Limited exposure— especially if the next roll- over date of the short-term FX hedge is near the date of the unexpected premature asset liquidation.	Full exposure to FX risk also when USD asset is liquidated prematurely.
(5) Counterparty risk (i.e., default of the insurer; possibly in conjunction with an impairment of the collateral value).	Exposure to the same counterparty for FX hedging during the full investment duration.	Flexibility benefit: Possibility to limit exposure by changing counterparties at the next roll-over date in case of negative information about existing counterparty.	No exposure to counterparty risk; full exposure to FX risk.
(6) Risk of a high domestic inflation.	Long-term FX hedging has the disadvantage that it goes long in domestic inflation risk.	Short-term FX hedging offers the possibility to limit exposure to domestic inflation risk.	No exposure to domestic inflation risk; full exposure to FX risk.

Table 2. A comparison of long- and short-term FX hedging strategies

First, the repercussions of individual FX hedging strategies are primarily felt in periods of financial distress. Consequently, an "over-reliance" on short-term FX hedges can pose a negative externality by creating additional market congestion in periods of financial distress. In practice, Swedish asset managers cannot rely on having market access at all times. Empirically, a typical crisis scenario features an appreciation of the dollar and at the same time a rise in the cost of FX risk protection. While long-term FX hedging arrangements are shielded against such a scenario, asset managers relying on short-term FX hedging arrangements experience a spike in the costs to roll over their FX hedges, as well as a further shortening of the duration of their hedges.

Second, a substantial part of the funding of Swedish banks is short-term and in foreign currency (see Bertsch and Molin 2016). At the same time, Swedish banks play a dominant role as sellers of FX risk protection to Swedish asset managers. Consequently, a stronger reliance on more short-term FX risk protection can have a disadvantageous financial stability effect in that it translates into a further increase in the short-term foreign currency funding reliance of Swedish banks.

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APPENDIX A – Derivations for the model with FX and foreign interest rate risk

This Appendix complements the discussion in Section 3.1.2. We first consider the case where $S_1 = 10.17 \ SEK/USD$ and $i_{12}^* = 0.18$. As before, the AM seeks to roll over the expiring FX forward contract at t = 1. The protection seller may be the same BANK or a different BANK.²⁰ The payments associated with the first contract are settled and the AM faces a hedging loss of SEK x. She seeks a new FX hedge, which involves a promise to deliver $USD \ r_2^*$ at t = 2 in exchange for $SEK \ 9.48 \times 1.44$. The hedging loss necessitates that the AM borrows $SEK \ x$ domestically at the interest rate $i_{12} = 0.1$. The AM's rate of return on the foreign investment at t = 2 is

$$R_{A}^{STi} \equiv \frac{9.48 \frac{SEK}{USD} \times USD \ 1.44 - S_{0} \ USD - (1 + i_{12}) \times SEK \ x}{S_{0} \ USD} = 36.51\% - \frac{\frac{S_{0} \ USD}{1.1 \times SEK \ x}}{S_{0} \ USD}.$$

Similar to before, we compute the gross rate of return as the forward rate times the foreign asset return in *USD* divided by the initial investment of *SEK* 10. Differently, however, the forward rate at t = 1 now depends on the realization of the foreign interest rate. Again, we need to correct for the t = 2 value of the hedging loss.

We next look at the case where $S_1 = 10.17 SEK/USD$ and $i_{12}^* = 0.22$. Different to before, the new FX hedge now involves a promise to deliver $USD r_2^*$ at t = 2 in exchange for $SEK 9.17 \times 1.44$. The AM's rate of return on the foreign investment is

$$R_B^{STi} \equiv 32.05\% - \frac{1.1 \times SEK x}{S_0 USD}.$$

Similarly, we can derive the AM's rate of return on the foreign investment for the case where $S_1 = 8.17 SEK/USD$ and $i_{12}^* = 0.18$ as

$$R_C^{STi} \equiv 9.67\% + \frac{1.1 \times SEK x}{S_0 USD}$$

and for the case where $S_1=8.17\frac{SEK}{USD}$ and $i^*_{12}=0.22$ as

$$R_D^{STi} \equiv 6.08\% + \frac{1.1 \times SEK x}{S_0 USD}$$

The payoff variance for x = 1.2 is given by

$$Var^{STi}(x = 1.2) = \frac{\binom{(23.31\% - 21\%)^2 + (18.84\% - 21\%)^2}{+(22.87\% - 21\%)^2 + (19.28\% - 21\%)^2}{4} = 7 * 10^{-6}.$$

²⁰ Without loss of generality, we focus on the case where the new protection seller is a different BANK. See discussion in Appendix A for the environment of Section 3.1.1.
APPENDIX B – Shortening the duration of FX hedges

This Appendix complements Section 3.1.2 by providing a formal discussion of potential implications when shortening the duration of FX hedging arrangements. We simplify the environment in Section 3.1.2 by setting expected domestic and foreign interest rates to zero. Formally, let $i_{01} = i_{12} = i_{02} = 0$ and let the foreign interest rate process be given by $i_{01}^* = i_{02}^* = 0 = r_2^*$ and

$$\tilde{\iota}_{12}^* = \begin{cases} -\varepsilon & \text{with probability } 1/2 \\ +\varepsilon & \text{with probability } 1/2 \end{cases}$$

with $E[1 + \tilde{\iota}_{12}^*] = 1$.

Assuming the CIP holds, the spot and implied forward rates at t = 0 are $S_0 = F_{01} = 10 SEK/USD$. The t = 0 expectation about the t = 1 spot exchange rate is $E[\tilde{S}_1] = S_0$. We consider a generalized version of the environment in Section 3.1.2 with $\Delta \ge 0$

$$\tilde{S}_{1} = \begin{cases} (10 + \Delta) \frac{SEK}{USD} & \text{with probability } 1/2 \\ (10 - \Delta) \frac{SEK}{USD} & \text{with probability } 1/2. \end{cases}$$

Assuming the CIP holds, expectations about implied forward exchange rates at t = 1 are now also influenced by the realization of $\tilde{\iota}_{12}^*$ and \tilde{F}_{12} can be derived as

$$\tilde{F}_{12} = \begin{cases} \frac{10 + \Delta}{1 - \varepsilon} \frac{SEK}{USD} & \text{with probability } 1/4 \\ \frac{10 + \Delta}{1 + \varepsilon} \frac{SEK}{USD} & \text{with probability } 1/4 \\ \frac{10 - \Delta}{1 - \varepsilon} \frac{SEK}{USD} & \text{with probability } 1/4 \\ \frac{10 - \Delta}{1 + \varepsilon} \frac{SEK}{USD} & \text{with probability } 1/4. \end{cases}$$

The expectations about t = 2 spot exchange rates are $E[\tilde{S}_2|S_1 = (10 + \Delta) SEK/USD, i_{12}^* = -\varepsilon] = (10 + \Delta)/(1 - \varepsilon) SEK/USD$, etc. and the actual realizations are

$$\tilde{S}_{2} = \begin{cases} \left(\frac{10 + \Delta}{1 - \varepsilon} + \Delta\right) \frac{SEK}{USD} & \text{with probability 1/8} \\ \left(\frac{10 + \Delta}{1 - \varepsilon} - \Delta\right) \frac{SEK}{USD} & \text{with probability 1/8} \\ etc. \end{cases}$$

A comparison with the payoff variance for short-term hedging yields for all $\varepsilon > 0$ that

$$Var^{N}(\Delta,\varepsilon) > Var^{STi}(\Delta,\varepsilon)$$

$$= \frac{\left(\frac{(10-\Delta)\varepsilon}{1-\varepsilon} - 0\%\right)^{2} + \left(\frac{-(10+\Delta)\varepsilon}{1+\varepsilon}}{10}\right)^{2} + \left(\frac{-(10+\Delta)\varepsilon}{1-\varepsilon}}{10}\right)^{2} + \left(\frac{-(10-\Delta)\varepsilon}{1+\varepsilon}}{10}\right)^{2}$$

Consistent with Section 3.1.1, we can see that absent interest rate risk, that is, if $\varepsilon \rightarrow 0$, the short-term FX hedging strategy eliminates all risk. For $\Delta = 1$ and $\varepsilon = 0.02$ as in Section 3.1.2 we have that $Var^{N}(1,0.02) = 0.0204 > Var^{STi}(1,0.02) = 0.0004$.

Notably, the short-term FX hedging strategy does just as badly as the no FX hedging strategy if $\Delta \rightarrow 0$ and $\varepsilon > 0$. Formally, $Var^{STi}(\Delta, \varepsilon) \rightarrow Var^{N}(\Delta, \varepsilon) > 0$ if $\Delta \rightarrow 0$. As a numerical example, consider the case where $\Delta = 0.5$ and $\varepsilon = 0.1$, where $Var^{N}(0.5, 0.1) = 0.01538 > Var^{STi}(0.5, 0.1) = 0.0103$.

We next study a modification of our model with an additional third period which also features interest rate risk and with implied forward exchange rates at t = 2 given by the eight possible combinations in

$$F_{23} = \frac{1}{1 \mp \varepsilon} \left(\frac{10 \mp \Delta}{1 - \varepsilon} \mp \Delta \right) \frac{SEK}{USD}$$

which occur with equal probability of one-eighths.

For $\Delta = 1$ and $\varepsilon = 0.02$, the payoff variance for the no FX hedging strategy is now given by $Var^{N}(0.02) = 0.0313$ and the payoff variance of the short-term FX hedging strategy is $Var^{STi}(0.02) = 0.0009$. Evidently, the short-term FX hedging strategy becomes more similar to the no FX hedging strategy when adding additional periods in this fashion. This effect shows up more prominently for a higher values of ε and smaller values of Δ . To see this, consider again the numerical example where $\Delta = 0.5$ and $\varepsilon = 0.1$. Now $Var^{N}(0.5, 0.1) = 0.03582 > Var^{STi}(0.5, 0.1) = 0.0277$.

APPENDIX C – Derivations for over- and under-hedging

This Appendix complements the discussion in Section 3.1.3. As before, the Swedish AM sells *SEK* 10 at t = 0 on the FX spot market at the rate $S_0 = 10 SEK/USD$ and obtains *USD* 1, which is invested in the dollar denominated foreign asset. To insure the AM's FX risk; the BANK agrees to deliver *SEK* 9.17 × x in exchange for *USD* x at t = 1.

We first look at the case when $S_1 = 10.17 SEK/USD$ and $r_2^* + \Gamma$. At t = 1, the asset manager seeks to roll over the expiring forward contract. The hedging loss of SEK x is funded at the interest rate $i_{12} = 0.1$. Moreover, the AM seeks a new protection which involves a promise to deliver USD $r_2^* + \Gamma$ at t = 2 to the BANK in exchange for SEK 9.32 * $(r_2^* + \Gamma)$. Taken together, the rate of return of the AM is

$$R_{1A}^{ST*} \equiv \frac{SEK\ 9.32 \times (r_2^* + \Gamma) - SEK\ 10 - SEK\ 1.1 \times x}{SEK\ 10}.$$

Next, we look at the case when $S_1 = 8.17 SEK/USD$ and $r_2^* + \Gamma$. Now there is a hedging gain and the rate of return of the AM is

$$R_{1B}^{ST*} \equiv \frac{SEK \ 7.49 \times (r_2^* + \Gamma) - SEK \ 10 + SEK \ 1.1 \times x}{SEK \ 10}.$$

The third case is characterized by $S_1 = 10.17 SEK/USD$ and $r_2^* - \Gamma$. The rate of return of the AM is

$$R_{2A}^{ST*} \equiv \frac{SEK\ 9.32 \times (r_2^* - \Gamma) - SEK\ 10 - SEK\ 1.1 \times x}{SEK\ 10}$$

Finally, the fourth case is characterized by $S_1 = 8.17 SEK/USD$ and $r_2^* - \Gamma$, and the rate of return of the AM is

$$R_{2B}^{ST*} \equiv \frac{SEK\ 7.49 \times (r_2^* - \Gamma) - SEK\ 10 + SEK\ 1.1 \times x}{SEK\ 10}.$$

The respective payoff variances associated with the two strategies are

$$Var^{LT*}(\Gamma) \equiv \frac{\left(\frac{10.32}{10} \times \Gamma\right)^2 + \left(\frac{8.32}{10} \times \Gamma\right)^2 + \left(\frac{8.49}{10} \times \Gamma\right)^2 + \left(\frac{6.49}{10} \times \Gamma\right)^2}{4}$$
$$> Var^{ST*}(x = 1.2; \Gamma) = \frac{\left(\frac{9.32}{10} \times \Gamma\right)^2 + \left(\frac{7.49}{10} \times \Gamma\right)^2 + \left(\frac{9.32}{10} \times \Gamma\right)^2 + \left(\frac{7.49}{10} \times \Gamma\right)^2}{4}$$

Analyzing the variance terms reveals that, for both strategies, the return variability associated with over- or under-hedging is higher, the higher Γ . However, the effect is stronger for the long-term FX hedging strategy, meaning that the differential payoff variance, $Var^{LT*}(\Gamma) - Var^{ST*}(x = 1.2, \Gamma)$, increases in Γ .

APPENDIX D – Derivations for price risk

This Appendix complements the discussion in Section 3.2. As before, the AM sells *SEK* 10 at t = 0 on the FX spot market at the rate $S_0 = 10 SEK/USD$ and obtains *USD* 1, which is invested in the dollar denominated foreign asset. To insure the FX risk; the BANK agrees to deliver *SEK* 9.17 × x in exchange for *USD* x at t = 1.

We first consider the case when $S_1 = 10.17 SEK/USD$. The AM has to deliver USD xand receives $SEK 9.17 \times x$. Since the AM lost from the appreciation of the dollar, a fraction of the foreign asset has to be liquidated, which we denote as l > 0. Moreover, the AM seeks a new FX risk protection, which involves a promise to deliver $USD (1 - l) \times x$ at t = 2 to the BANK in exchange for $F_{12} \times (1 - l) \times USD r_2^* =$ $SEK 9.32 \times (1 - l) \times r_2^*$ where l can be derived as $l = x/(p_1^* \times 9.32)$.

The rate of return of the AM at t = 2 is

$$R_{A}^{STl} \equiv \frac{SEK \frac{p_{1}^{*} \times 9.32 - x}{p_{1}^{*}} \times r_{2}^{*} - SEK \ 10}{SEK \ 10}.$$

The foreign asset is fairly priced, that is, its return at t = 1 corresponds to the interest rate in the credit market, if $p_1^* = 1.31$. In this case, the AM can achieve a return of 21% and fully eliminate risk as in Section 3.1.1 by calibrating the first forward

contract in the same way, that is, x = 1.2. The reason is that the implicit funding cost $r_2^*/p_1^* - 1 = 0.1$ equals the domestic interest rate $i_{12} = 0.1$.

Instead, if the foreign asset is not fairly priced and trades at a price lower than $p_1^* = 1.31$, then the AM strictly prefers the domestic credit market (if accessible). Conversely, if the price is higher than $p_1^* = 1.31$, then the AM strictly prefers to sell the asset over borrowing in the domestic credit market.

We next consider the case when $S_1 = 8.17 SEK/USD$. This time the AM enjoys a hedging gain and there is no need to sell a fraction of the foreign asset. If the asset price is lower than $p_1^* = 1.31$, the asset manager has no incentive to sell the asset and the outcome is the same as in Section 3.1.1.

Taken together, the main insight is that the liquidation price of the foreign currency denominated asset plays an important role for the outcomes. While a buy-and-hold investor (who owns the asset until maturity and uses a long-term FX hedging strategy) is unaffected by changes in the asset price over the duration of the hedging contract,²¹ this does not hold for an investor who uses a short-term hedging strategy. Specifically, a depressed liquidation price, for example $p_1^* < 1.31$, results in a higher hedging loss due to costly asset liquidation. For the short-term FX hedging strategy, the associated risks remain unhedged.

To illustrate this point numerically, consider the outcome when the t = 1 asset price is $p_1^* = 1$, for example due to an adverse selection problem. In this situation, the asset manager suffers from an appreciation of the dollar. Hence, the rate of return of the AM at t = 2 falls short of the return achieved by the short-term FX hedging strategy in Section 3.1.1 since

$$R_A^{STl}(x = 1.2) = 16.92\% < R_A^{ST}(x = 1.2) = 21\%.$$

In sum, short-term hedging exposes the AM to a combination of FX risk and price risk.

APPENDIX E – Derivations for premature liquidation risk

This Appendix complements Section 3.4 by providing a formal discussion of potential implications of premature liquidation risk.

To make the argument, consider a modification to the baseline model where the AM has a need to liquidate the dollar investment at t = 1 with probability q', where 0 < q' < 1. We discuss the outcome below using a modification of the environment in Section 3.1.1. As before, the AM can choose among three investment strategies.

We find that the strategy not to hedge FX risk performs poorly also in our modified environment and is associated with a considerably higher payoff variance than the short- and long-term FX hedging strategies. Moreover, we find that the outcomes of the short- and long-term FX hedging strategies can differ at the presence of

²¹ A buy-and-hold investor who does not hedge the FX risk is not exposed to price risk, but fully exposed to FX risk.

premature asset liquidation risk. For the example with $p_1^* = 1.2$, and with a zero FX insurance premium, the two strategies deliver outcomes identical to those in Section 3.1.1. For $p_1^* \neq 1.2$, both strategies deliver risky payoffs. Notably, the expected return of the short- and long-term FX hedging strategy is equal. But the return is lower than 21% if $p_1^* < 1.2$ and larger than 21% if $p_1^* > 1.2$.

Next, we consider a variant of the previous model where the liquidation need and the foreign currency appreciation are perfectly correlated, with $\Pr\{S_1 = 10.17 | q' = 1\} = 1$ and $\Pr\{q' = 1 | S_1 = 10.17\} = q'' > 0$. Moreover, assume the foreign currency denominated asset has to be liquidated at a depressed price of $p_1^* = 1$. We discuss the outcomes of the long- and short-term FX hedging strategies in turn.

Strategy: Long-term

Everything remains the same if the spot exchange rate realization at t = 1 is $S_1 = 8.17$. Instead, if $S_1 = 10.17$, then the rate of return of the AM is $(11.19 \times p_1^* - 11.32)/10$. For $p_1^* = 1$ and q'' = 1, the ex-ante return can be derived as

$$R^{LT**}(q''=1) = \frac{21\% + (1-q'') \times 21\% + q'' \times \frac{11.19 \times p_1^* - 11.32}{10}}{2} = 9.85\%.$$

Strategy: Short-term

Again, everything stays the same if the spot exchange rate realization at t = 1 is $S_1 = 8.17$. Instead, if $S_1 = 10.17$, then the rate of return is $(4.53 + (p_1^* - r_2^*) \times 11.19)/10$. For $p_1^* = 1$ and q'' = 1, the ex-ante return can be derived as

$$R^{ST**}(q''=1) = \frac{23.64\% + (1-q'') \times 18.36\% + q'' \times \frac{4.53 + (p_1^* - r_2^*) \times 11.19}{10}}{2} = 13.79\%.$$

To conclude, the short-term FX hedging strategy may deliver a better-than-expected return if the asset manager considers it to be likely that the long-term asset needs premature liquidation with a risk that the cost of the unwinding of the long-term FX hedging arrangement cannot be covered.

APPENDIX F – Derivations for inflation risk

This Appendix complements Section 3.6 by providing a formal discussion of the environment with stochastic domestic inflation. We analyze the outcomes of the long-and short-term FX hedging strategies in turn.

Strategy: Long-term

Observe that the two-period forward rate at t = 0 remains the same as in Section 3.1.1, since $F_{02} = S_0 \times E[1 + i_{02}^r]/(1 + i_{02}^*) = 8.40 SEK/USD$. The AM's expected rate of return at t=2 is also the same as in Section 3.1.1, that is, $E[\tilde{R}^{LT,r}] = 21\%$, but now payoffs vary across states due to the domestic inflation risk, which induces a mean-preserving spread. With probability one-half, the rate of return is given by $R^{LT,r} = 1.21/1.1 - 1 = 10\%$ and otherwise by $R^{LT,r} = 1.21/0.9167 - 1 = 32\%$.

Strategy: Short-term

Also, the one period forward rate at t = 0 remains the same as in Section 3.1.1, since $F_{01} = S_0 \times E[1 + \tilde{\iota}_{01}^r]/(1 + \tilde{\iota}_{01}^*) = 9.17 SEK/USD$. The same is true for the t = 1 spot rates and one-period forward rates. While the AM's expected rate of return at t = 2 remains the same, that is, $E[\tilde{R}^{ST,r}] = 21\%$, we now have four cases to consider. We first look at the case where the spot exchange rate is $S_1 = 10.17 SEK/USD$ and a domestic inflation of 10%, where the rate of return is

$$R_A^{ST,r}(x) = 31.10\% - \frac{(1+i_{12}) \times \frac{x}{1+i_{12}^*}}{10(1+\pi_{02,1})},$$

with $\pi_{02,1} = 10\%$ and $R_A^{ST,r}(1.2) = 21.10\%$. Instead, if the domestic inflation is -8.33% then the rate of return can be derived as

$$R_B^{ST,r}(x) = 37.32\% - \frac{(1+i_{12}) \times \frac{x}{1+i_{12}^*}}{10(1+\pi_{02,2})}$$

with $\pi_{02,2} = -8.33\%$ and $R_B^{ST,r}(1.2) = 25.32\%$. Using the same logic, we look at the case where the realization of the spot exchange rate is $S_1 = 8.17 \ SEK/USD$. Now the rate of return is $R_C^{ST,r}(1.2) = 17.14\%$ if the domestic inflation is 10% and $R_D^{ST,r}(1.2) = 20.57\%$ if the domestic inflation is -8.33%.

Taken together, the results with domestic inflation risk differ drastically from our baseline model in Section 3.1.1. Both, the long- and short-term FX hedging strategies now deliver a risky payoff. Moreover, we can see that the introduction of domestic inflation risk is particularly harmful for the long-term FX hedging strategy, which now performs considerably worse than the short-term strategy.



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SVERIGES RIKSBANK Telephone +46 8 787 00 00 registratorn@riksbank.se www.riksbank.se