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# Was the Krone a Safe Haven during the Sovereign Debt Crisis?

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## **INTRODUCTION AND SUMMARY**

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The term "safe haven" is often used about assets that can protect investors from losses during financial turmoil. If the value of an asset increases in connection with financial turmoil, this is a sign that it is a safe haven. A safe haven is often associated with an inflow of capital.

Danish assets have been mentioned as a safe haven in relation to the sovereign debt crisis in parts of the euro area. During the sovereign debt crisis, demand for Danish government securities and mortgage bonds was high. Foreign investors' holdings increased, and the yields on Danish government securities fell to historically low levels, while yields rose for peripheral euro area member states.

The krone strengthened against the euro in the period from July 2011 to July 2012, when the sovereign debt crisis peaked. To counter the strengthening tendency of the krone, Danmarks Nationalbank intervened by selling kroner against foreign exchange for considerable amounts and reduced its interest rates, both unilaterally and in step with the European Central Bank, ECB, so that Danmarks Nationalbank's rate of interest on certificates of deposit became negative.

The strengthening of the krone coincided with increased volatility in the financial markets. This relationship was particularly strong in the period from July 2011 to July 2012, even if the impact of currency flows and Danmarks Nationalbank's interest-rate decisions and intervention in the foreign-exchange market is taken into account. In other words, the increased uncertainty had an effect on the exchange rate beyond that stemming from currency flows.

The development in the krone exchange rate against the euro during the sovereign debt crisis was unusual compared with previous times of financial turmoil. Since the introduction of the fixed-exchange-rate policy in the early 1980s, there has typically been a tendency for the krone to weaken relative to its anchor currency, i.e. the euro and before 1999 the D-mark, in periods of financial turmoil. Most recently, this was

seen during the financial crisis in 2008, when the krone came under pressure, as did other small currencies.

The situation during the sovereign debt crisis was extraordinary. On account of Denmark's fixed-exchange-rate policy, some investors saw the krone as an opportunity to hedge the risk of a break-up of the euro. The perception was that in such a scenario the krone would strengthen and would be pegged to the strong part of the euro with German participation, given that it had previously been pegged to the D-mark. This was particularly notable in the market for currency options between kroner and euro, where there was an increased interest in options giving the holder the right to buy kroner against euro at a predetermined exchange rate. In many cases, the krone rate in these options exceeded the strong margin of the fluctuation band in ERM 2.

All in all, the analysis in this article indicates that the krone was a safe haven relative to the euro at the height of the sovereign debt crisis from July 2011 to July 2012.

## **SAFE HAVEN INDICATORS**

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The term "safe haven" is often used about assets that can protect investors from losses during financial turmoil. There is no clear definition of a safe haven. The term is typically used in periods of financial turmoil, during which asset prices in countries seen as safe havens tend to rise. In this way these investments serve to hedge risks during the financial turmoil. This may give rise to stronger foreign investor interest and thus increased capital inflows in periods of financial turmoil.

The growing volume of literature in this area operates with a number of fundamental characteristics defining a currency as a safe haven, cf. e.g. Habib and Stracca (2011):

1. Investment in the currency hedges increased financial risk.
2. The country issuing the currency has a high credit rating for government issuance.
3. The size and liquidity of the country's financial markets (capital and foreign-exchange markets) make it possible to hedge risks during periods of financial turmoil.
4. The country's financial markets allow free capital flows.

The above properties vary over time and through financial crises, so the status of currencies as safe havens may also change. The narrow definition is that a safe haven currency is generic over time, i.e. it hedges increased financial uncertainty both in "normal" times and during actual financial crises.

There are various indicators of financial turmoil and risk in the financial markets. This article applies the VIX index as an indicator of financial turmoil and risk. The VIX expresses the implied volatility in options on the US S&P 500 stock index. There is a tendency for currencies identified as safe havens to strengthen on days when the VIX rises, cf. Box 1. Grisse

SAFE HAVEN CURRENCIES
Box 1

The Japanese yen, Swiss franc and US dollar are currencies identified as safe havens, cf. Ranaldo and Söderlind (2009), Flatner (2009) and Grisse and Nitschka (2013). A currency does not necessarily display safe haven characteristics vis-à-vis all major currencies. For example, the Swiss franc has generally had safe haven status against the euro, but not against the dollar and the yen, cf. Grisse and Nitschka (2013).

To gain an impression of the relationship between changes in exchange rates and the VIX, daily changes in the VIX index are divided into groups. Group 1 is the 10 per cent of days with the strongest increases in the VIX, while group 10 is the 10 per cent with the strongest declines. For each of the 10 groups, the average return in per cent is calculated for each currency. To facilitate comparison between currencies, the return is normalised with standard deviation of the return.

In the period 1999-2013, the yen and the Swiss franc generally strengthened against the euro in periods of heightened financial risk and weakened when risk declined, cf. Chart 1. This indicates that the yen and the franc were seen as safe havens. The US dollar also tends towards a safe haven status. As regards the Danish krone, it is not possible to gain a clear picture for the period, as the fixed-exchange-rate policy means that it fluctuates with the euro to a large extent.

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CORRELATION BETWEEN CHANGES IN THE VIX AND EXCHANGES RATE AGAINST THE EURO, 1999-2013
Chart 1

| VIX Group              | Krone | Swiss franc | Yen   | Dollar |
|------------------------|-------|-------------|-------|--------|
| 1 (Strongest increase) | -0.05 | 0.30        | 0.25  | 0.05   |
| 2                      | -0.08 | 0.15        | 0.05  | 0.00   |
| 3                      | -0.02 | 0.08        | 0.05  | -0.05  |
| 4                      | 0.05  | 0.05        | -0.05 | -0.02  |
| 5                      | 0.00  | 0.10        | 0.05  | 0.00   |
| 6                      | -0.02 | -0.05       | -0.08 | 0.00   |
| 7                      | 0.00  | -0.05       | -0.05 | -0.02  |
| 8                      | 0.08  | -0.05       | -0.05 | 0.02   |
| 9                      | 0.00  | -0.15       | -0.15 | 0.05   |
| 10 (Strongest decline) | 0.02  | -0.35       | -0.18 | -0.12  |

Note: Daily observations are used, which are divided into 10 groups on the basis of developments in the VIX index. For each group, the average return in per cent is calculated for each currency. This has been standardised by dividing by the standard deviation in the daily returns for each currency. Data for the VIX is lagged by one day due to the time difference between the ECB's fixing of exchange rates and the VIX index.

Source: ECB, Bloomberg and Danmarks Nationalbank.

and Nitschka (2013) argue that the VIX is an expression of the global exchange-rate risk since it has a high correlation with volatility in the foreign-exchange markets.

The Danish krone is a relatively small currency, but as a consequence of the fixed-exchange-rate policy it fluctuates with the euro against third currencies. Investors typically withdraw from small currencies and turn to larger, more liquid currencies in periods of financial turmoil. That was also the case during the financial crisis in 2008.

However, the krone strengthened against the euro in connection with the escalation of the sovereign debt crisis from July 2011 until the ECB's President, Mario Draghi, on 26 July 2012 in a speech announced that, within its mandate, the ECB would do whatever it takes to preserve the euro.<sup>1</sup> This was an extraordinary situation in which investment in kroner, given Denmark's fixed-exchange-rate policy, was seen by some investors as an opportunity to hedge the risk of a break-up of the euro. The perception was that in such a scenario the krone would strengthen and would be pegged to the strong part of the euro with German participation, given that it had previously been pegged to the D-mark. In the market for currency options between kroner and euro this led to an increased interest in options giving the holder the right to buy kroner against euro at a predetermined exchange rate. In many cases, the krone rate in these options exceeded the strong margin of the fluctuation band in ERM 2. There are indications that positions in the currency option market for kroner against euro contributed to the strengthening of the krone, cf. Box 2.

To counter the krone's strengthening tendency, Danmarks Nationalbank in the period from August 2011 to June 2012 intervened by purchasing foreign exchange and selling kroner for kr. 91 billion. Moreover, Danmarks Nationalbank reduced its monetary-policy interest rates on several occasions, both in tandem with the ECB and also unilaterally in order to reduce the interest-rate spread between Denmark and the euro area, cf. Chart 2. In early July 2012, Danmarks Nationalbank followed when the ECB lowered its interest rates, and Danish monetary-policy interest rates became historically low. The rate of interest on certificates of deposit was reduced to -0.20 per cent. The difference between monetary-policy interest rates in Denmark and the euro area remained unchanged.

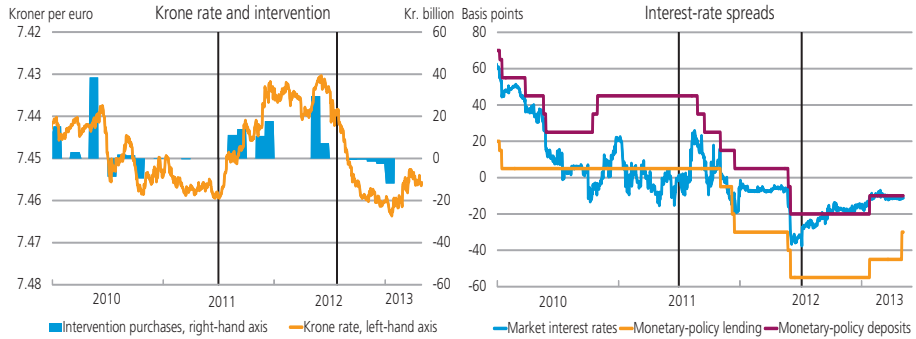
The krone weakened immediately after the introduction of a negative rate of interest on certificates of deposit, which meant that any market

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<sup>1</sup> The markets calmed down further when the ECB in early September 2012 announced a new Outright Monetary Transactions (OMT) programme, which entails that the ECB may purchase government securities from euro area member states in the secondary market under certain conditions.

KRONER EXCHANGE RATE, INTERVENTION AND INTEREST-RATE SPREADS

Chart 2



Note: The vertical lines indicate 1 July 2011 and 26 July 2012, respectively. Intervention purchases are net purchases of foreign exchange against kroner on a monthly basis. Interest-rate spreads are the spreads between interest rates in Denmark and the euro area. Market interest rates are the spread between 1-month CITA and EONIA swap rates.

Source: Reuters and Danmarks Nationalbank.

doubts as to whether Danmarks Nationalbank would actually take this step were eliminated. The subsequent development in the exchange rate of the kroner should be viewed against the backdrop of the situation in the euro area. The kroner weakened as confidence in the management of the sovereign debt crises in a number of European countries improved, partly in response to announcements by ECB President Draghi in late July 2012.

#### OPTIONS FOR DANISH KRONER AGAINST EURO

Box 2

A currency option for kroner against euro gives the holder the right, but not the obligation, to purchase (call option) or sell (put option) euro against kroner at a future date at an agreed price (strike price). The market for options for kroner against euro is normally relatively limited due to Denmark's fixed-exchange-rate policy. In connection with the sovereign debt crisis in the euro area, demand for put options increased. From the 2nd quarter of 2010, when sovereign debt problems in some euro area member states came into focus, options for selling euro against Danish kroner at a price close to the strong ERM 2 fluctuation margin were demanded. On the basis of the prices for such options, it is possible to calculate the option-implied probability that the Danish kroner will exceed the strong margin in ERM 2, i.e. strengthen by more than 2.25 per cent relative to the central rate, cf. Chart 3.

The calculated option-implied probability that the Danish kroner would exceed the strong margin in ERM 2 increased in mid-2010. But it was not until mid-2011, when the sovereign debt crisis escalated, that the implied probability soared. Presumably the increase in the calculated probability is not an expression of market participants' perception of the probability; instead it reflects limited liquidity in the market, with demand for (put) options exceeding the supply. The limited liquidity led to higher volatility. This in turn meant that the value of outstanding options rose, to the advantage of buyers of these options.

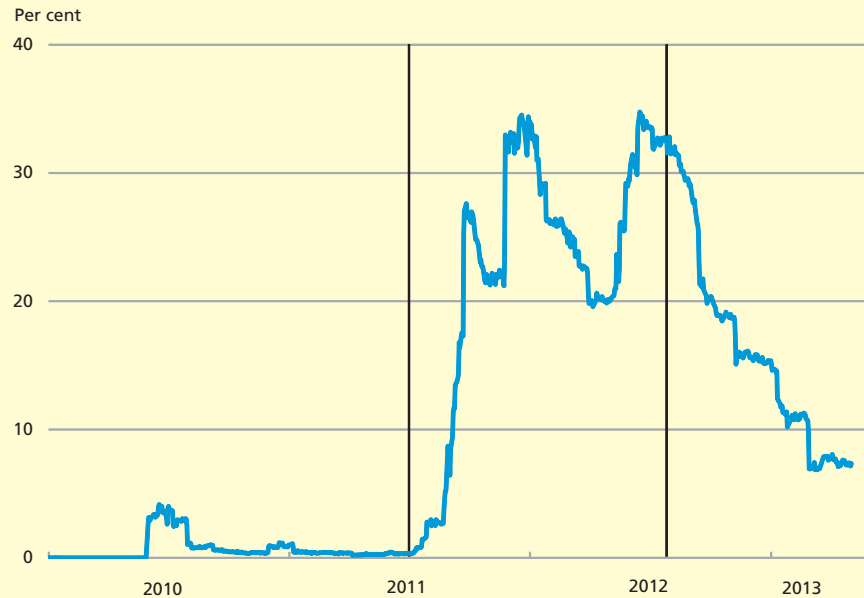
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Box 2

Sellers of the options who wished to hedge the increased liability might have found themselves compelled to buy kroner as the market for opposite options was limited. This amplified the upward pressure on the krone, triggering further purchases of kroner, which had a self-reinforcing effect on the exchange rate. The implied probability that the krone rate will exceed the strong margin has fallen notably since Mario Draghi's speech in July 2012.

OPTION-IMPLIED PROBABILITY THAT THE KRONE WILL EXCEED THE STRONG MARGIN IN ERM 2

Chart 3



Note: Calculated on the basis of implied volatilities for 1-year options and the 1-year forward price for kroner against euro. The implied volatility is found for options with a strike price close to the strong margin in ERM 2 (delta 25). The vertical lines indicate 1 July 2011 and 26 July 2012, respectively.

Source: Nordea Analytics, Danmarks Nationalbank and own calculations.

## CURRENCY FLOWS

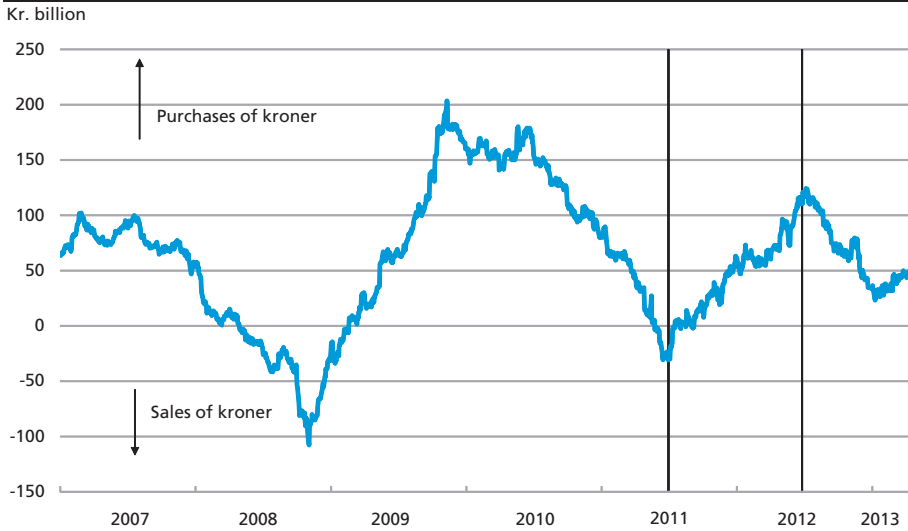
A safe haven is often associated with an inflow of foreign exchange. Statistics of turnover in the foreign-exchange market and the financial account of the balance of payments provide information about foreign exchange flows that has an impact on the krone rate.

### Turnover in the foreign-exchange market

On a daily basis, Danmarks Nationalbank collects information about turnover in the foreign-exchange market for Danish kroner, i.e. a num-

## BANK CUSTOMERS' PURCHASES AND SALES OF KRONER AGAINST FOREIGN EXCHANGE

Chart 4



Note: Net purchases and sales. Daily data. Bank customers include resident non-banks and non-resident banks and non-banks. The vertical lines indicate 1 July 2011 and 26 July 2012, respectively, which was the period when the euro area sovereign debt crisis intensified.

Source: Danmarks Nationalbank.

ber of banks' purchase and sale of foreign exchange against kroner.<sup>1</sup> These currency flows affect the exchange rate. An overweight of purchase orders for Danish kroner normally causes the krone to strengthen.

Bank customers' aggregate purchases of kroner increased from the 2nd half of 2011, cf. Chart 4, which is consistent with a tendency for the krone to strengthen when the euro area sovereign debt crisis peaked. This development was to a large extent driven by pension funds, which purchased kroner against euro forward to hedge their investments in euro.

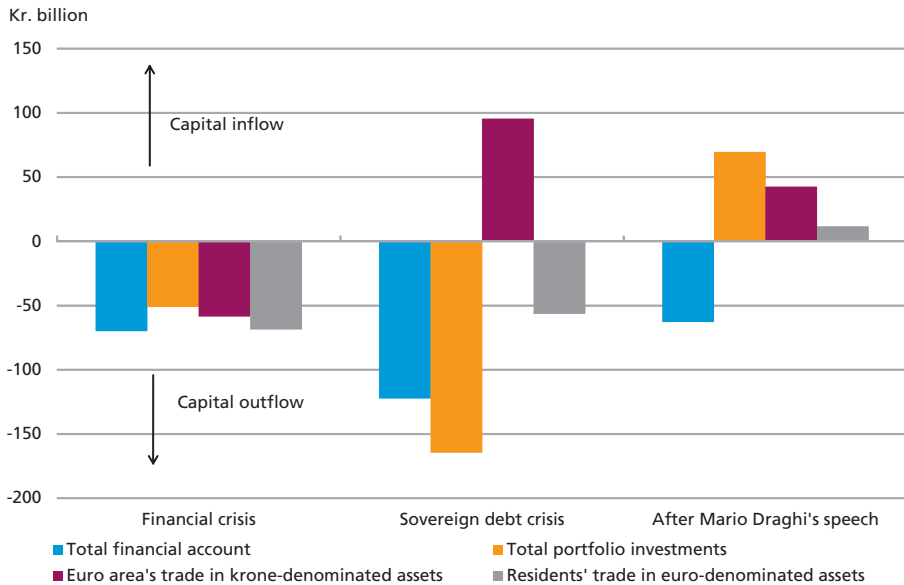
### Capital flows

The balance-of-payments statistics provide information about capital flows on a monthly basis. Capital flows lead to bank customers' purchases and sales of kroner against foreign exchange, thereby affecting the krone rate. In the statistics, capital flows are broken down by investment type, e.g. portfolio investments, and currency. This can provide extra information about how currency flows affect the krone rate.

<sup>1</sup> The statistics for foreign-exchange turnover include the banks' spot and forward contracts with customers and other currency dealers. In connection with foreign-exchange turnover, the trade time of the transaction is applied. Capital flows on the basis of balance-of-payments statistics, transactions are included at the time of payment.

NET CAPITAL INFLOWS AND OUTFLOWS DURING THE FINANCIAL CRISIS, THE SOVEREIGN DEBT CRISIS, AND AFTER THE SOVEREIGN DEBT CRISIS

Chart 5



Note: "Total financial account" denotes the total financial items of the balance of payments excluding Danmarks Nationalbank. "Financial crisis" is the period from August 2007 to December 2008. "Sovereign debt crisis" is the period from July 2011 to July 2012. "After Mario Draghi's speech" is the period from August 2012 to February 2013.

Source: Danmarks Nationalbank.

Overall, the financial account of the balance of payments indicates an aggregate net outflow of capital from Denmark in the period from the 2nd half of 2011 until Draghi's statement in July 2012, cf. Chart 5. This reflects the current-account surplus.

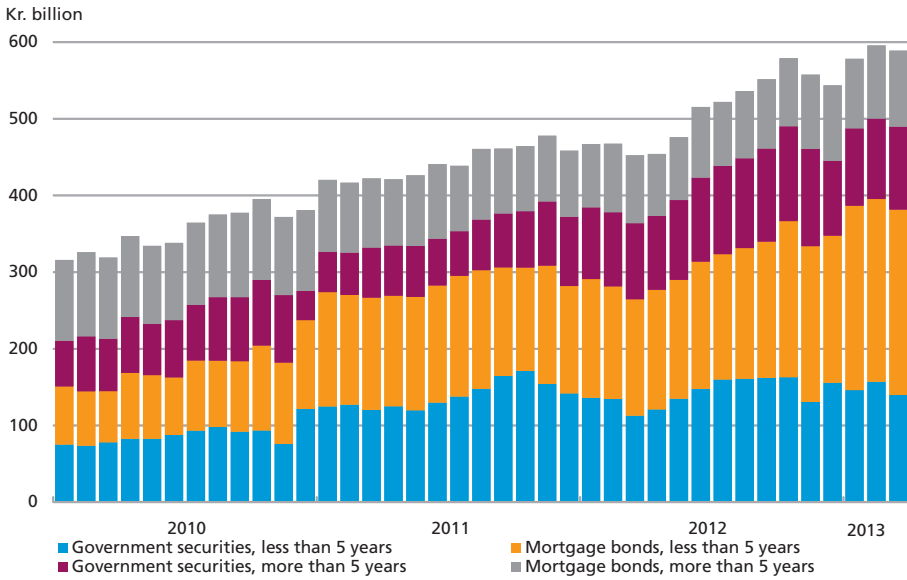
Previous empirical studies have shown that portfolio investments normally have the strongest effect on the exchange rate of the krone, cf. Hansen and Storgaard (2005) and Abildgren (2007). Portfolio investments only affect the krone rate if investors do not hedge the exchange-rate risk.<sup>1</sup> The fixed-exchange rate policy could mean that Danish investors hedge the exchange-rate risk to a lesser extent when purchasing euro-denominated assets than when purchasing assets denominated in other currencies, while investors from the euro area hedge purchases of krone-denominated assets to a lesser extent than investors from the rest of the world. During the sovereign debt crisis in the euro area, domestic residents may have had an increased need to hedge euro exposures, while investors from the euro area may have had a reduced need to hedge investments in krone-denominated assets.

<sup>1</sup> Cf. Danmarks Nationalbank (2009), p. 73.



FOREIGN INVESTORS' HOLDINGS OF GOVERNMENT SECURITIES AND MORTGAGE BONDS IN DANISH KRONER, BROKEN DOWN BY REMAINING MATURITY

Chart 6



Note: Nominal values. Government securities, less than 5 years include T-bills.  
Source: Danmarks Nationalbank.

During the sovereign debt crisis, Danish government securities and mortgage bonds were in strong demand, and foreign investors' holdings increased, cf. Chart 6. Particularly investors from the euro area increased their holdings of krone-denominated bonds. This may have contributed to the strengthening of the krone. On the other hand, Danish residents, particularly pension funds, increased their holdings of euro-denominated issues. But the resultant impact on the krone may have been smaller than usual due to increased exchange-rate hedging.

Overall, portfolio investments led to net capital outflows. Besides domestic residents' purchases of euro-denominated assets, this was to a large extent because Danish banks reduced their financing via dollar issues substantially. At the same time, the banks increased other types of foreign borrowing, which led to capital inflows. Hence, the aggregate impact on the krone rate from borrowing by banks may have been limited.

Foreign investor ownership of Danish bonds has increased in recent years. The number of AAA-rated countries has decreased, which has reduced the supply of high-rated debt securities. Increased uncertainty has boosted demand for government securities with high ratings. Danish government securities have the highest possible credit rating and have therefore been attractive as a safe haven, cf. Danmarks Nationalbank

FOREIGN INVESTORS' DEMAND FOR DANISH SHORT-TERM SECURITIES

Box 3

One of the explanations for the pronounced increase in foreign investors' holdings of Danish short-term government securities and mortgage bonds can be found in the FX swap market for dollars against a number of currencies, including the krone, cf. Mindsted et al. (2012). US money-market funds reduced their lending to non-US banks markedly, and consequently the latter increased their demand for dollar funding via other channels, including FX swaps. This increased the price of dollars via FX swaps.

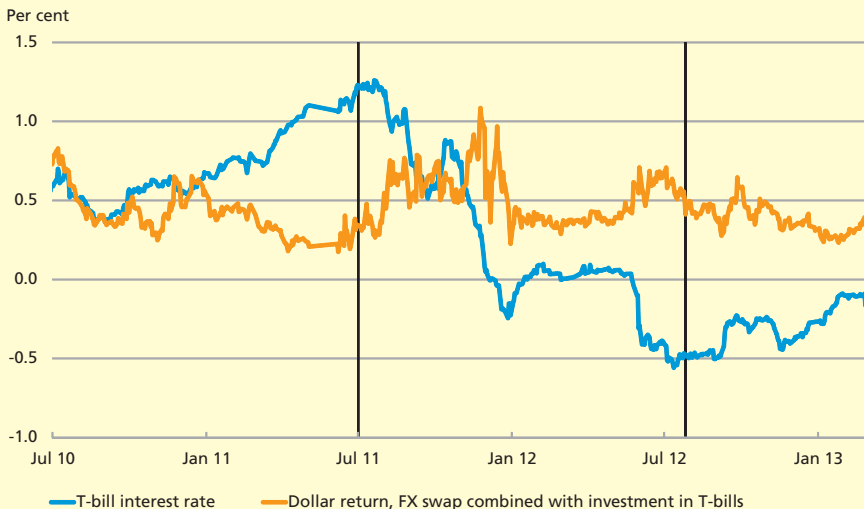
Hence, investors with access to dollars could achieve high returns by lending dollars in FX swaps against Danish kroner. The kroner received in such swaps were invested in e.g. T-bills (or short-term government securities or mortgage bonds or deposits at Danish banks), which contributed to reducing the rate of interest on T-bills, cf. Chart 7.

The dollar return achievable by investors with access to dollar funding from concluding FX swaps and investing in Danish T-bills rose markedly from July 2011, which led to increased foreign interest in Danish short-term securities. The same tendency, albeit to a lesser extent, was seen for FX swaps between euro and kroner.

These transactions were not aimed at hedging financial risk, but rather at reaping the excess return achievable by investors with access to dollars and the opportunity to conclude FX swaps. So this was not a safe haven effect. All the same, the high rating of the Danish economy supported interest in these transactions relative to lower-rated alternatives.

RATE OF INTEREST ON T-BILLS AND DOLLAR RETURN WHEN COMBINING FX SWAPS WITH T-BILL INVESTMENTS

Chart 7



Note: 3-month FX swap between dollars and kroner and 3-month T-bill interest rate. The T-bill interest rate has been estimated by means of interpolation of the rates of interest on outstanding T-bills. The vertical lines indicate 1 July 2011 and 26 July 2012, respectively.  
 Source: Danmarks Nationalbank and Nordea Analytics.

(2013) and Abildgren et al. (2013). The safe haven status has primarily applied to Danish government securities, and the long-term government yield spread between Denmark and Germany has narrowed and even been negative at times. The same tendency, albeit to a lesser extent, has been observed for Danish mortgage bonds. However, foreign investors' increased holdings of short-term Danish issues is to a large extent related to the FX swap market, cf. Box 3.

## IMPACT OF THE SAFE HAVEN STATUS ON THE EXCHANGE RATE OF THE KRONE AGAINST THE EURO

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The correlation between the VIX and the exchange rate of the krone against the euro is a simple indicator of whether the krone has been a safe haven. When the sovereign debt crisis in some euro area member states intensified, the VIX rose and the krone strengthened against the euro, cf. Chart 8.<sup>1</sup>

The correlation analysis does not take into account that the exchange rate of the krone against the euro is affected by a large number of other factors besides market uncertainty expressed by e.g. the VIX. To examine whether uncertainty affects the krone when other factors – such as the interest-rate spread to the euro area, Danmarks Nationalbank's intervention in the foreign-exchange market and currency flows – are taken into account, the development in the krone rate is examined in a regression model. If the parameter for the VIX is statistically significant and shows that the exchange rate strengthens when risk increases, this is taken as an indication that the currency is a safe haven.

Grisse and Nitschka (2013) find that the coefficient on the VIX is significant in regressions explaining the exchange rate of the Swiss franc. Ranaldo and Söderlind (2009) also set up a model in which the exchange rate against the dollar depends on various risk factors, including exchange-rate volatility and the VIX. On the basis of daily data, they find that the VIX is not significant in determining exchange rates, whereas exchange-rate volatility is. Exchange-rate volatility can be measured in several ways. In most cases, realised volatilities are applied.<sup>2</sup> Alternative measures of exchange-rate volatility yield similar results, e.g. the JP Mor-

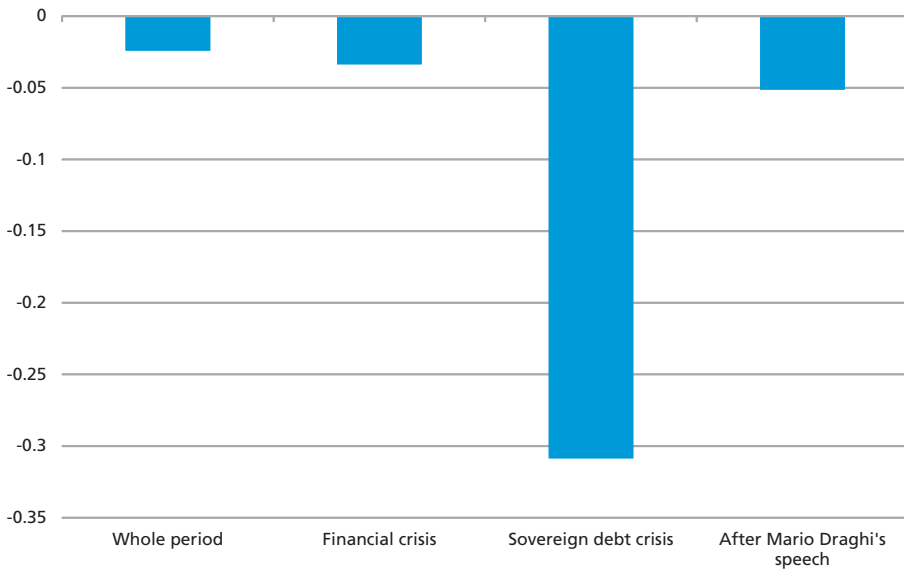
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<sup>1</sup> The financial crisis spans the period from 9 August 2007 to 31 December 2008. If the period is narrowed down so that it starts with the collapse of Lehman Brothers on 15 September 2008, the correlation between the krone rate and the VIX is positive.

<sup>2</sup> The realised exchange-rate volatility on a given day is calculated as the sum of the squared changes in the exchange rate within the day at 5-minute intervals. For a given exchange rate against the dollar, the average of the realised volatilities of other exchange rates against the dollar is included as an explanatory variable. More specifically, the first principal component of the realised volatilities for other currencies is included, but a simple average provides similar results, as the first principal component explains 70 per cent of the variation.

CORRELATION BETWEEN THE VIX AND THE EXCHANGE RATE OF THE KRONA AGAINST THE EURO

Chart 8



Note: Weekly data. Correlation coefficient for weekly changes in the exchange rate of the krone against the euro (kroner per euro) and weekly changes in the VIX. A negative correlation coefficient means that the krone strengthens against the euro when the VIX rises. "Whole period" is the period from the beginning of 1999 until 27 March 2013. "Financial crisis" is the period from 10 August 2007 to 23 December 2008. "Sovereign debt crisis" is the period from 1 July 2011 to 20 July 2012. "After Mario Draghi's speech" is the period from 27 July 2012 to 27 March 2013.

Source: Bloomberg and Danmarks Nationalbank.

gan G7 Volatility Index, which weights implied exchange-rate volatility for currency options on the G7 currencies. Therefore estimations are also performed on the basis of this index instead of the VIX.

Estimations of the explanatory variables' coefficients based on the entire estimation period and of the change in coefficients based on the period when the euro area sovereign debt crisis peaked are performed. In addition, the changes in the coefficients in the period after Mario Draghi's statements in late July 2012 and during the financial crisis are estimated. See Box 4 for a more detailed description of the regression model.

## Results

As expected, the estimates of coefficients for the entire period show that a wider Danish interest-rate spread to the euro area, customer purchases of kroner and Danmarks Nationalbank's intervention to purchase kroner against foreign exchange strengthen the krone against the euro, cf. Table 1. The coefficient on bank customers' purchases of kroner against foreign exchange shows that purchases for kr. 10 billion cause the

## A MODEL FOR THE DEVELOPMENT IN THE KRONE RATE

Box 4

Initially, a model based on weekly data using the ordinary least squares (OLS) method is estimated. The estimated model can be summarised as the following equation:

$\Delta(\text{DKK}/\text{EUR}) =$

$$\beta_0 + \beta_1\Delta(\text{Interest-rate spread}(-1)) + \beta_2\text{Intervention}(-1) + \beta_3(\text{Customers' purchases of kroner against foreign exchange}) + \beta_5\Delta\text{VIX} + \beta_6\Delta(\text{USD}/\text{EUR}) + \beta_{D,0}D + \beta_{D,1}D*\Delta(\text{Interest-rate spread}(-1)) + \beta_{D,2}D*\text{Intervention}(-1) + \beta_{D,3}D*(\text{Customers' purchases of kroner against foreign exchange}) + \beta_{D,5}D*\Delta\text{VIX} + \beta_{D,6}D*\Delta(\text{USD}/\text{EUR}) + \varepsilon$$

$\Delta$  indicates weekly changes in the variable in question, i.e. the value on the last day of the week less the value on the last day of the previous week.

*DKK/EUR* is the exchange rate of the krone against the euro stated as kroner per euro. An increase means that the krone has weakened against the euro. The change in the krone rate is the percentage change.

*Interest-rate spread* is the spread between collateralised 3-month money-market interest rates in Denmark and the euro area. In studies of the exchange rate of the krone against the euro it should be taken into account that, due to the fixed-exchange-rate policy, Danmarks Nationalbank's interest rates, and hence the interest-rate spread between Denmark and the euro area, depend on the development in the krone rate. Technically, this can be solved by applying the interest-rate spread for the preceding period. A wider interest-rate spread is expected to strengthen the krone, i.e. the expected sign is negative. The change is stated as the change of level in percentage points.

*Intervention* is Danmarks Nationalbank's purchases of kroner against foreign exchange in billion kroner within a week. Like the interest-rate spread, Danmarks Nationalbank's intervention depends on the krone rate and therefore it is not exogenous relative to the krone rate. So the preceding week's intervention is included in the estimations (lagged value). Intervention to purchase kroner is expected to strengthen the krone, i.e. the expected sign is negative.

*Customers' purchases of kroner against foreign exchange* are bank customers' net purchases of kroner against foreign exchange within a week. Customers are residents who are not banks and non-residents (both banks and non-banks). The price of foreign exchange is expected to fall, i.e. the krone is expected to strengthen, when currency dealers buy foreign exchange. Consequently, the expected sign is negative.

*VIX* is included as the percentage change. If the krone hedges increased risk, it strengthens when the VIX increases, i.e. the sign is negative.

*USD/EUR* is the exchange rate of the dollar stated as dollars per euro, and the change is the percentage change. This factor can be seen as an expression of the exchange-rate risk linked to the krone beyond fluctuations relative to the euro. Bernhardsen and Røisland (2000) have a similar explanatory variable in their estimation of the development in the exchange rate of the Norwegian krone. Grisse and Nitschka (2013) include the average exchange rate of the Swiss franc vis-à-vis other currencies than the euro as an explanatory variable in a regression of the exchange rate of the franc against the euro. The average exchange rate is seen as a currency-specific risk factor for the Swiss franc. The regression results for the exchange

CONTINUED

Box 4

rate of the Danish krone against the euro are more or less unchanged if the exchange rate of the krone against the dollar or the effective krone rate exclusive of euro is applied instead of the exchange rate of the euro against the dollar.

$D$  is a dummy variable that assumes the value 1 on days in selected periods and zero on other days. The coefficients of these dummy variables indicate the change in the explanatory variables in the period in question.

Newey-West standard errors are used in connection with parameter estimates to allow for autocorrelation and heteroskedasticity in the residuals. Data covers the period from the introduction of the euro at the beginning of 1999 until March 2013.

#### Robustness check

A robustness check has been performed by replacing the VIX by the JP Morgan G7 Volatility Index in the estimations. The results are similar to those achieved with the VIX.

The coefficient on the VIX is not significant if the crisis period is extended to begin in May 2010, when a serious crisis erupted in the market for Greek government securities and spread to other European countries. This also applies if the period after Draghi's speech in late July 2012 is included in the sovereign debt crisis period.

An equivalent analysis can be performed for monthly data that also includes data for portfolio investments. If the estimation in Table 1 is performed for monthly data, there is also a tendency during the debt crisis for the krone to strengthen more than otherwise when the VIX increases, but the dummy coefficient on the VIX is not statistically significant. If portfolio investment data is used instead of currency dealers' purchases of foreign exchange, a statistically significant change in the coefficient on the VIX is generally seen during the sovereign debt crisis.

Data for the VIX and the krone rate are calculated at different times of the day. The krone rate is calculated at 2:15 pm and the VIX later, when the US market closes. Data for the same day is used for the krone rate and the VIX. This means that events relating to e.g. the sovereign debt crisis which have come to the knowledge of market participants during the week before the calculation of the krone rate on the last day of the week may affect the VIX. The VIX may also be affected by events later in the day on the last day of the week, which can cause noise in the relation between the krone rate and the VIX. A robustness check is performed by lagging the VIX by one day, i.e. it is implicitly assumed that the VIX affects the krone rate with a lag. In this case, the coefficient on the change in the VIX during the sovereign debt crisis is not significant, but the sign remains negative and of more or less the same size as previously. If the JP Morgan G7 Volatility Index is applied and lagged by one day, the dummy coefficient is still significantly negative.

Finally, instrument-variable estimations have been performed for the entire period, with the inclusion of all values of the interest-rate spread and intervention. The signs are as expected and the coefficients are generally of more or less the same size as in the OLS regressions.

krone to strengthen by  $10 \cdot 0.00193 = 0.0193$  per cent, corresponding to kr. 0.14 per 100 euro. The coefficient on the VIX is not significant in the estimation covering the entire period, which indicates that for the period overall the krone has not been a safe haven relative to the euro.

At the peak of the euro area sovereign debt crisis, the coefficient on the VIX is statistically significant. During this period, an increase in the VIX caused the krone to strengthen more than it would otherwise have done. The same applies if the JP Morgan G7 Volatility Index is used instead of the VIX. In other words, heightened market volatility tended to strengthen the krone, even if the impact of e.g. currency flows is taken into account.

According to the estimations, the effect of intervention by Danmarks Nationalbank has increased following Mario Draghi's speech in late July 2012. This could indicate that the signal value of the intervention has increased after Danmarks Nationalbank introduced a negative rate of interest on certificates of deposit.<sup>1</sup> The result should also be viewed in the light of increased confidence in the management of the euro area sovereign debt crisis after Mario Draghi's speech.

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<sup>1</sup> The lagged value of the intervention included in the estimation.

ESTIMATION RESULTS FOR THE EFFECT ON CHANGES IN THE KRONE RATE Table 1

|  | Baseline model           | Sovereign debt crisis    | After Mario Draghi's speech | Financial crisis         |
|--|--------------------------|--------------------------|-----------------------------|--------------------------|
| Constant .....   | 0.00123<br>(0.00117)     | 0.00140<br>(0.00121)     | 0.00100<br>(0.00122)        | 0.00152<br>(0.00120)     |
| Interest-rate spread (-1) .....  | -0.05064**<br>(0.02282)  | -0.05227**<br>(0.02317)  | -0.05094**<br>(0.02299)     | -0.03276<br>(0.02327)    |
| VIX .....  | -0.00004<br>(0.00013)    | -0.00001<br>(0.00014)    | -0.00004<br>(0.00014)       | 0.00002<br>(0.00014)     |
| USD/EUR (dollars per euro) .....                                       | 0.00299***<br>(0.00094)  | 0.00307***<br>(0.00099)  | 0.00280***<br>(0.00097)     | 0.00301***<br>(0.00099)  |
| Customers' purchases of kroner against foreign currency .....          | -0.00193***<br>(0.00044) | -0.00191***<br>(0.00048) | -0.00187***<br>(0.00045)    | -0.00214***<br>(0.00044) |
| Intervention purchase of kroner by Danmarks Nationalbank to (-1) ..... | -0.00108**<br>(0.00042)  | -0.00112**<br>(0.00049)  | -0.00107**<br>(0.00043)     | -0.00071*<br>(0.00038)   |
| Change in coefficient  |                          |                          |                             |                          |
| Constant .....   |                          | -0.00363<br>(0.00433)    | 0.00470<br>(0.00337)        | 0.00363<br>(0.00376)     |
| Interest-rate spread (-1) .....  |                          | 0.15337*<br>(0.08397)    | 0.04845<br>(0.09581)        | -0.06034<br>(0.04140)    |
| VIX .....  |                          | -0.00058*<br>(0.00031)   | 0.00005<br>(0.00038)        | -0.00045<br>(0.00034)    |
| USD/EUR (dollars per euro) .....                                       |                          | -0.00351<br>(0.00337)    | 0.00721**<br>(0.00291)      | -0.00333<br>(0.00445)    |
| Customers' purchases of kroner against foreign currency .....          |                          | 0.00032<br>(0.00093)     | -0.00028<br>(0.00079)       | 0.00115<br>(0.00133)     |
| Intervention purchase of kroner by Danmarks Nationalbank (-1) .....    |                          | -0.00003<br>(0.00068)    | -0.00386***<br>(0.00130)    | -0.00093<br>(0.00106)    |
| Adjusted R <sup>2</sup> .....  | 0.10                     | 0.10                     | 0.09                        | 0.11                     |

Note: Weekly data from the beginning of 1999 until March 2013. \*, \*\*, \*\*\* indicate levels of significance of 10, 5 and 1 per cent, respectively. Standard deviations are denoted in parenthesis. "(-1)" after the name of the variable indicates that the variable is lagged by one week. "Baseline model" is the model estimated without dummy variables. "Change in coefficient" shows estimates of the coefficient on Dummy variable\*(Explanatory variable) in the periods selected: "Sovereign debt crisis" (1 July 2011 – 20 July 2012), "After Mario Draghi's speech" (27 July 2012 – 27 March 2013) and "Financial crisis" (10 August 2007 – 23 December 2008). The explanatory variable is weekly changes in the exchange rate of the krone against the euro (kroner per euro) in per cent. An increase in the krone rate indicates weakening of the krone. For a more detailed explanation, see Box 4.



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