EFFECTS OF DANMARKS NATIONALBANK'S INTERVENTIONS IN THE FOREIGN EXCHANGE MARKET

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INTRODUCTION AND SUMMARY

Danmarks Nationalbank's interventions in the foreign exchange market play an important role in the implementation of Denmark's monetary policy, which is designed to maintain a fixed exchange rate of the Danish krone against the euro close to its central rate.[1] This takes place within the framework of the European Exchange Rate Mechanism, ERM2. Officially, the krone may fluctuate by up to 2.25 per cent on either side of its central rate, but in practice the fluctuations are much smaller. This reflects that the fixed exchange rate policy enjoys strong credibility among investors and society as a whole, but also that Danmarks Nationalbank takes consistent action in response to fluctuations in the krone rate.

If Danmarks Nationalbank wants to influence the exchange rate of the krone vis-à-vis the euro, this will initially be achieved through intervention in the foreign exchange market, buying or selling Danish kroner against foreign exchange. This will alter the relationship between the supply of and demand for krone-denominated assets and thereby the price of kroner relative to other currencies. Market participants may also see interventions as an indication that Danmarks Nationalbank is prepared to adjust its monetary policy interest rates if the krone rate does not evolve as desired. Interest rate changes are the next step in the monetary policy reaction function.

The pressure on the krone in January and February 2015 was one of the most extensive tests to date of the Danish exchange rate regime. The system passed the test, and in 2016 the situation of the krone has been stable again. After such an episode, it is relevant to examine whether the instruments at Danmarks Nationalbank's disposal for its defence of the fixed exchange rate policy still serve their purpose. The analysis in this article shows that Danmarks Nationalbank's interventions constitute an effective instrument to stabilise the exchange rate. This applies in periods of calm in the foreign exchange market for Danish kroner, but also in periods of considerable pressure on the krone to either appreciate or depreciate against the euro. The strongest effects of intervention were seen during the financial crisis in 2008-09 and during the pressure on the krone in 2015. Those are the episodes in the analysed period with the most pronounced pressure on the krone.

When Danmarks Nationalbank purchases kroner in the market, this typically coincides with private agents selling kroner to their banks. If there is a substantial excess of sales orders for kroner from their customers, banks tend to reduce the price of kroner, while they tend to raise it when there is an excess of purchase orders. Against this background, transactions involving

1 See Spange and Toftdahl (2014) for an introduction to Danish monetary policy. A broader review can be found in Danmarks Nationalbank (2009).

kroner between banks and their customers will impact on the exchange rate. An intervention on the part of Danmarks Nationalbank may therefore be successful even though there are no immediate signs that it has an impact on the krone rate. Alternatively, the purchases and sales of kroner by private agents might have led to an undesirable development in the exchange rate.

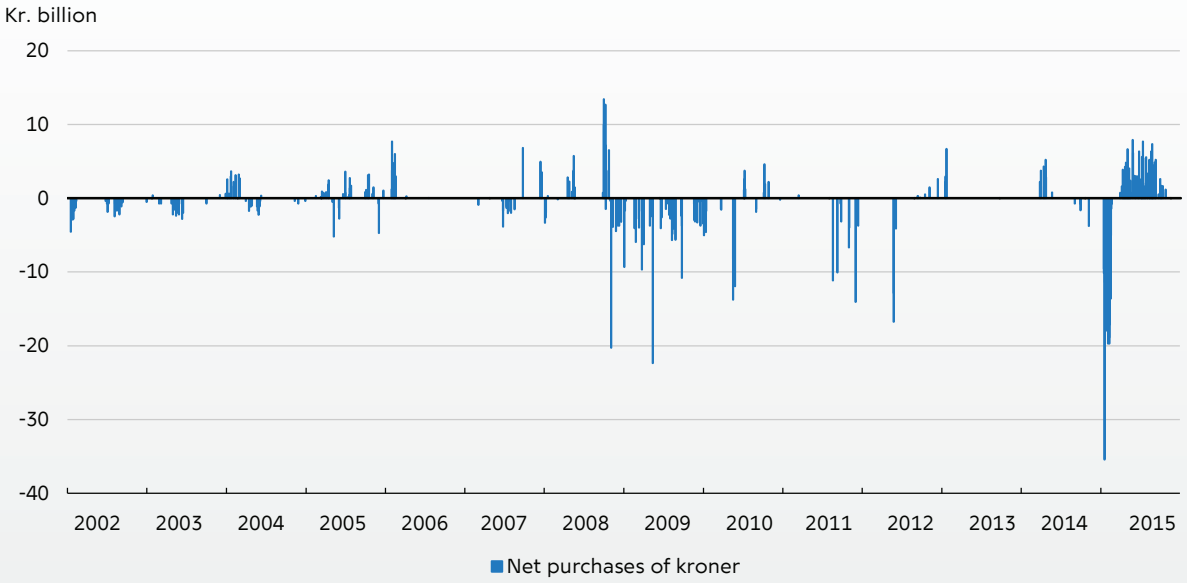
While kroner are traded between banks and their customers on all days, Danmarks Nationalbank is only active in the foreign exchange market on selected days. There are indications of a slightly greater impact on the exchange rate when Danmarks Nationalbank intervenes compared to when private agents trade kroner against foreign exchange. The slightly greater impact of Danmarks Nationalbank's interventions may reflect that market participants see interventions as a sign of a potential, imminent interest rate change.

DANMARKS NATIONALBANK'S MONETARY POLICY REACTION FUNCTION

If Danmarks Nationalbank wants to influence the rate of the krone vis-à-vis the euro, this will initially be achieved through interventions in the foreign exchange market where Danish kroner are bought or sold against foreign exchange. For this purpose, Danmarks Nationalbank holds a considerable foreign exchange reserve. The reserve is mainly placed as collateralised deposits in European banks or invested in euro-denominated government bonds. This reflects the importance of the reserve being liquid and stable in value.

Since January 2002, Danmarks Nationalbank has intervened in the foreign exchange market on 12 per cent of all trading days, cf. Chart 1. On just over half of those days, Danmarks Nationalbank

Danmarks Nationalbank's daily interventions in the foreign exchange market Chart 1



Note: The most recent observation is from 4 November 2015.
Source: Danmarks Nationalbank.

sold kroner against foreign exchange on a net basis, while purchasing kroner net on the remaining intervention days. On days when Danmarks Nationalbank sold kroner, its interventions averaged approximately kr. 3.6 billion, while they averaged approximately kr. 2.5 billion on days of purchases. By comparison, total daily, global turnover in the spot and forward markets for kroner amounted to kr. 80.7 billion in April 2016, while averaging kr. 48.8 billion in April 2007.[2]

The interventions were generally largest in the second half of the period. This may reflect the general increase in turnover in the foreign exchange market for Danish kroner, but also that the years leading up to 2008 were characterised by low volatility in financial markets. The subsequent period has been characterised by greater uncertainty and periods of considerable fluctuations in investors' demand for kroner, which has resulted in larger interventions.

The intervention averages mask considerable differences across individual days and periods. The most substantial interventions took place during the pressure on the krone in January-February 2015. During that period, on a single day net sales of kroner amounted to more than kr. 35 billion. This should be seen in light of the fact that the deposit rate was reduced to -0.75 per cent and that Danmarks Nationalbank favoured interventions over further interest rate reductions, given the low level of interest rates. In general, 2015 was characterised by frequent and substantial interventions, as the strong increase in the size of the reserve during the defence of the krone was gradually reversed. On the other hand, there was a continuous period of more than 14 months up to March 2014, during which Danmarks Nationalbank did not intervene in the foreign exchange market at all.

Interventions in the foreign exchange market are often sufficient to impact the exchange rate of the krone in the desired direction. If this is not the case, Danmarks Nationalbank's next step is to adjust monetary policy interest rates. An interest rate increase will make it more attractive for investors to hold assets denominated in Danish kroner. This increases the demand for kroner, thereby strengthening the krone exchange rate. Investors are familiar with Danmarks Nationalbank's reaction function. Hence, banks will initially often absorb shocks to the demand for kroner from their customers by changing their own foreign exchange positions. This in itself helps keep to the krone stable.

INTERVENTIONS MAY IMPACT THE EXCHANGE RATE VIA SEVERAL CHANNELS

Danmarks Nationalbank's interventions in the foreign exchange market impact the relative supply of Danish kroner available to other market participants. In so far as investors do not consider Danish and foreign assets perfect substitutes, the shift in the relative supply will lead to a shift in relative prices. That is the mechanism behind the *portfolio balance channel.* This channel works whether or not market participants know when and to what extent Danmarks Nationalbank intervenes.

Danmarks Nationalbank's interventions typically coincide with private agents changing, via the banks, the composition of their portfolios across kroner and foreign exchange. When there is a substantial excess of sales orders for kroner from their customers, the banks tend to reduce prices, while they tend to raise them when there is an excess of purchase orders. Against this background, transactions involving Danish kroner between banks and their customers will impact the exchange rate. An intervention by Danmarks Nationalbank may therefore be successful even though there are no immediate signs that it has an impact on the exchange rate of the krone. Instead, the interventions ensure that the relationship between the supply of and the demand for kroner is balanced so that the krone rate remains unchanged. This is also a result of the portfolio balance channel.

The mechanism behind the *signalling channel* is that market participants may see interventions as signals that Danmarks Nationalbank is not satisfied with the trend in the krone rate. The interventions may thus induce market participants to adjust their expectations of future monetary policy rates, thereby impacting the exchange rate. The signalling channel assumes that the interventions are published or somehow become known to market participants.

Although Danmarks Nationalbank does not publish data on its interventions on a daily basis, market participants may sense whether Danmarks

2 Cf. Bank for International Settlements (2016).

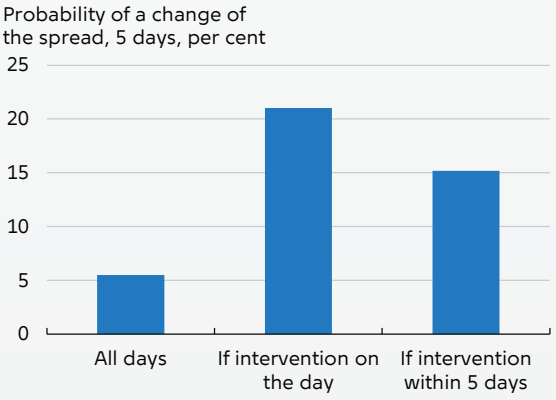
Signal value of Danmarks Nationalbank's interventions

Box 1

Based on data for the period since 2002, the probability on a random day of an announcement of a change in the monetary policy interest rate spread to the euro area within the next five banking days (including the day itself) is approximately 5 per cent. However, a change in the spread is announced within five banking days on 21 per cent of the days when Danmarks Nationalbank intervened in the foreign exchange market on the same day. And in case it intervened on one of the preceding five days (including the day itself), but not necessarily on the day itself, a change in the spread is announced within five banking days in 15 per cent of the cases.

The announcement can be made by Danmarks Nationalbank announcing an interest rate change independently of the ECB, or by the ECB announcing an interest rate change that Danmarks Nationalbank chooses not to match or to match only in part. Most of Danmarks Nationalbank's interest rate changes have taken effect on the day after the announcement, while the ECB's interest rate adjustments have typically taken effect a few days after the day of the announcement.

Intervention and interest rate changes



Note: The bars show the share of days on which the benchmark monetary policy interest rate spread to the euro area is changed within the next five days (including the day itself). The bar on the right includes days when interventions have not necessarily been made on the day itself.
Source: Danmarks Nationalbank.

Purchases and sales of kroner increase the probability that a widening or a narrowing of the monetary policy interest rate spread is announced. Hence, for almost one third of the days when Danmarks Nationalbank sold kroner, a narrowing of the spread was announced within the following five banking days (including the day itself).

However, purchases of kroner only increase the probability that a widening of the spread will be announced within five banking days to approximately 11 per cent. This primarily reflects the period since 2011, when the krone tended to appreciate during periods of uncertainty. Here, only 6 per cent of the purchases of kroner on a given day were followed by a widening of the monetary policy spread. Since April 2015 in particular, purchases of kroner have thus given rise to a gradual reduction of the foreign exchange reserve with no attempts to offset this via interest rate increases.

Nationalbank is active in the foreign exchange market. This is because interventions are conducted with the commercial banks as counterparties. Moreover, market participants follow the banks' net position vis-à-vis Danmarks Nationalbank. Major deviations from Danmarks Nationalbank's liquidity projection, which provides an overview of the expected changes on a daily basis, may also be an indication of intervention.[3]

Historically, the probability of Danmarks Nationalbank changing the monetary policy spread to the euro area has been relatively high in the days immediately after an intervention event, cf. Box 1. Against that background, the signalling channel could be a factor in Denmark. Market participants may thus see Danmarks Nationalbank's interventions as a signal that the current trend in the exchange rate of the krone will not be allowed to continue, thereby triggering a change in interest rates, if necessary. However, the frequency and the size of Danmarks Nationalbank's intervention before adjusting monetary policy rates do not follow a regular pattern, and the level of the krone exchange rate at which Danmarks Nationalbank intervenes also depends on the specific situation.

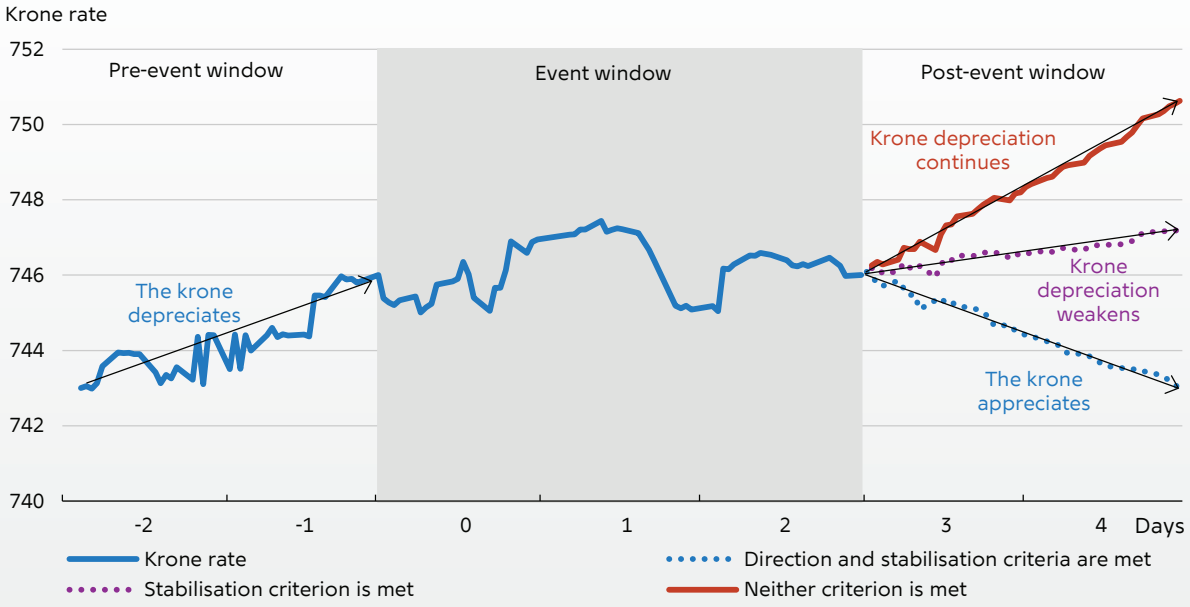
IMPACT OF INTERVENTION EVENTS

In most cases, investor demand for kroner supports a stable exchange rate of the krone without the intervention of Danmarks Nationalbank. Occasionally, intervention in the foreign exchange market will be necessary, however. In some cases, intervening on a single day is sufficient. However, Danmarks Nationalbank is often active in the foreign exchange market several times within a period of a few days. Against that backdrop, this section examines the impact of intervention events.

An intervention event consists of one or more days of interventions pointing in the same direction which are close together in time. Specifically, an event is defined as not containing consecutive days during which Danmarks Nationalbank does *not* intervene in the foreign exchange market. But single days without interventions may occur.

3 See Chapter 2 in Danmarks Nationalbank (2009) for a description of the relationship between Danmarks Nationalbank's interventions in the foreign exchange market and krone liquidity in the banking sector.

Illustration of impact assessment criteria Chart 2



Note: Illustration. The exchange rate is stated in kroner per 100 euro.
Source: Own work.

Two events will always be separated by minimum two days without interventions. Based on this definition, there have been 162 intervention events since 2002, lasting just over three days on average. While 73 events cover just one day of interventions, the longest event lasted more than 28 days in the autumn of 2015. Table 1 summarises the key characteristics of Danmarks Nationalbank's interventions since 2002.

Interventions by Danmarks Nationalbank, 2002-16 Table 1

Average size of intervention[1]	kr. 3.0 billion
Average size of intervention[1], purchases of kroner	kr. 2.5 billion
Average size of intervention[1], sales of kroner	kr. 3.6 billion
Largest intervention on a single day	kr. 35.4 billion
Number of intervention events	162
Average duration, event	3.1 days
Number of events of only one day duration	73
Longest event	28 days

Source: Danmarks Nationalbank.
1. Daily values on days of intervention.

IMPACT ASSESSMENT CRITERIA

Two criteria are defined for assessment of the effect of intervention events, i.e. the *direction criterion* and the *stabilisation criterion*.[4] The direction criterion is met if an event, in which Danmarks Nationalbank sells kroner against foreign exchange, is followed by depreciation of the krone. Likewise, the criterion is met if an intervention event, in which Danmarks Nationalbank buys kroner against foreign exchange, is followed by appreciation of the krone.

The stabilisation criterion is met if an intervention event dampens a current trend in the exchange rate of the krone. For an event where Danmarks Nationalbank buys kroner, this corresponds to the krone depreciating less in the period after the event than it did in the days preceding the event and vice versa for an event entailing sales of kroner. The direction criterion is stricter than the stabilisation criterion. The criteria are illustrated in Chart 2.

4 The method follows Fatum and Hutchison (2003). Andersen (2005) applied the same method to Danmarks Nationalbank's interventions for the period 1999-2004.

The periods before and after the intervention events, i.e. pre- and post-event windows, are determined so that the pre-event window includes the last two days up to the intervention event, while the post-event window includes the two days immediately after the interventions have ceased. The precise definitions of an event and the duration of the pre- and post-event windows are adjusted to match Danmarks Nationalbank's reaction function and comply with Andersen (2005).

CLEAR INDICATIONS OF EFFECT OF INTERVENTION

The stabilisation criterion is met for more than four out of five events, cf. Chart 3 (left). This is true of events involving purchases of kroner on a net basis as well as events involving sales of kroner. The stricter direction criterion is met for around three out of four intervention events.

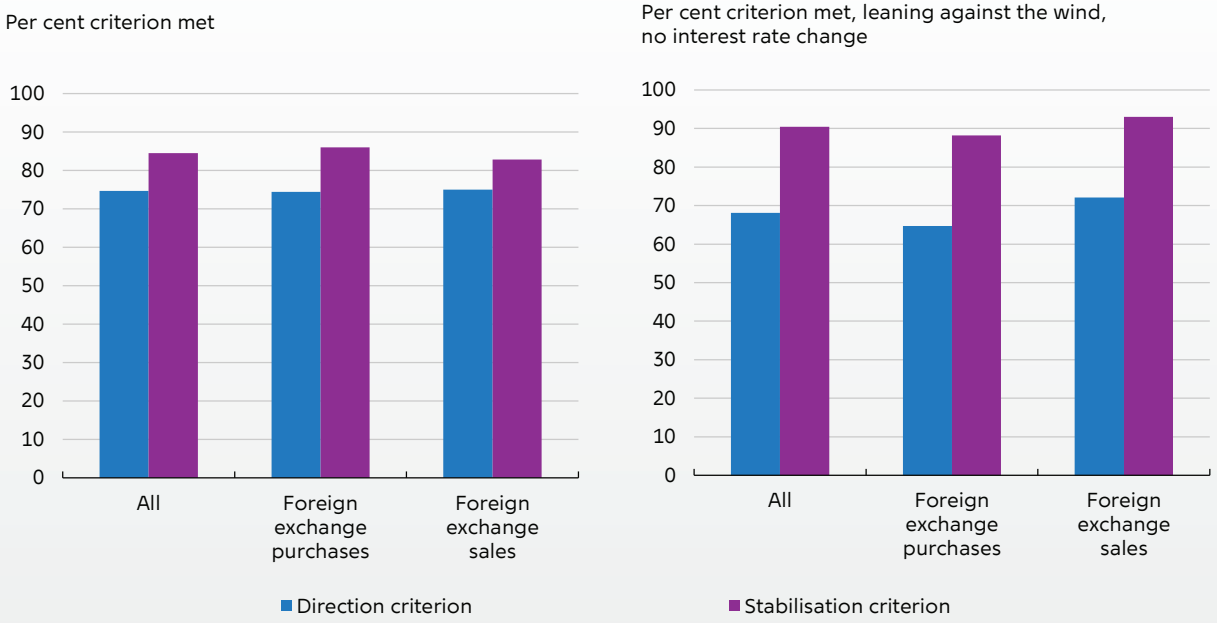
In order to focus on the effect of the events directly aimed at countering undesirable developments in the exchange rate, attention can be centred on events that have been "leaning against the wind". An event involving purchases of kroner against foreign exchange is defined as leaning against the wind if there was an overall weakening of the krone rate in the last two days prior to the intervention. Similarly, an event is leaning against the wind if it involves sales of kroner in response to a strengthening of the exchange rate in the last two days prior to the intervention. A total of 117 events are leaning against the wind.

Some of the intervention events are characterised by Danmarks Nationalbank adjusting its monetary policy interest rates during or immediately before or after the event. For such events, both the interventions and the interest rate changes will have an impact on the krone rate. The relationship between interest rate changes, exchange rates and intervention is discussed in Box 2.

Chart 3 (right) considers only the 94 intervention events that are leaning against the wind, and which do not coincide with or involve an announcement of a change in the monetary policy interest rate spread immediately prior or subsequent to the event. This does not change the conclusions to any significant extent. The direction criterion and the stabilisation criterion are met for 68 per cent and 90 per cent of the events, respectively. There is overwhelming evidence that the high degree to which both criteria are met reflects the effect of the interventions, cf. Box 3.

Effect of intervention events

Chart 3



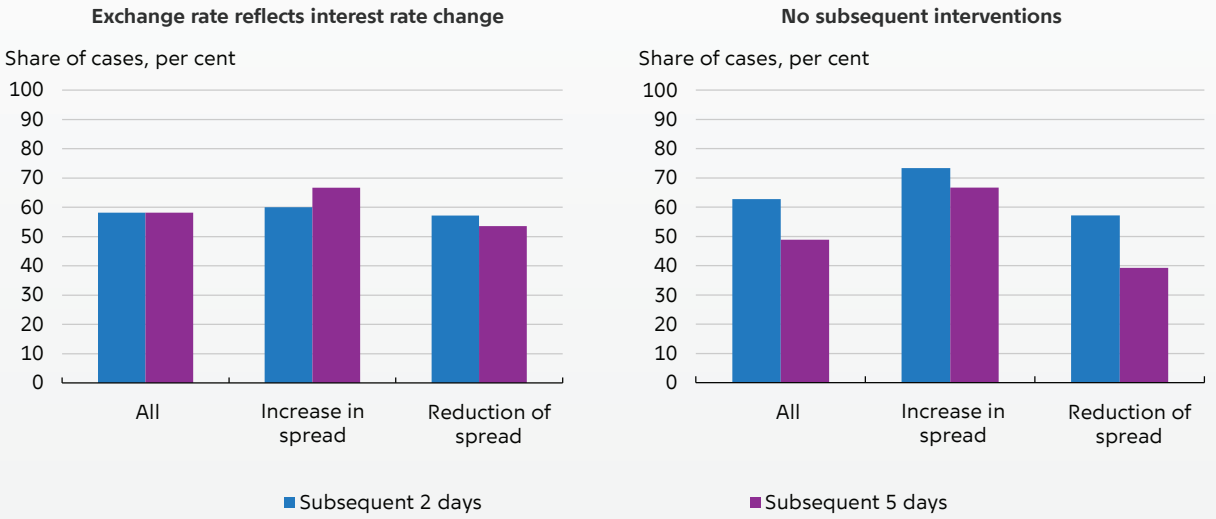
Note: The exchange rate is closing prices at 5 pm Danish time.
Source: Danmarks Nationalbank and Thomson Reuters Datastream.

Interest rate changes, exchange rate and intervention

Box 2

Changes in interest rates is the second step in Danmarks Nationalbank's monetary policy reaction function after intervention in the foreign exchange market. Of the 43 announcements of changes in the monetary policy interest rate spread since 2002, Danmarks Nationalbank intervened in the foreign exchange market within the preceding five days (including the day itself) in 39 cases. There is no strong tendency for the exchange rate of the krone to move in the direction warranted by the change in the monetary policy spread in the days after announcement of the change in the spread, cf. the chart (left).

Impact of interest rate adjustments on the krone rate and interventions



Note: The period is 2002-16.
Source: Danmarks Nationalbank.

An increase in the spread often means that Danmarks Nationalbank can stop intervening in the foreign exchange market, cf. the chart (right). Conversely, announcements of a reduction in the monetary policy interest rate spread have often been followed by sales of kroner within the next five weekdays. This may reflect that the spread is usually reduced in stages. When restoring the foreign exchange reserve after a period of using foreign exchange for intervention purchases in support of the krone, there may be a wish to gradually adjust the interest rate spread to an equilibrium level with no tendencies for strengthening or weakening of the krone.

Furthermore, the spread was reduced in stages in connection with the tendencies for strengthening of the krone in early 2015. This reflected several factors, including that interest rates fell to a level that had not previously been tested. In situations of downward pressure on the krone, on the other hand, the interest rate spread has often been increased markedly so as to cease the pressure immediately, bringing Danmarks Nationalbank's interventions in the foreign exchange market to a close.

Test for effect of interventions

Box 3

The direction criterion and the stabilisation criterion are met for 68 per cent and 90 per cent of the events, respectively. But even without interventions, the development in the krone rate tends to ease off. Based on the period 2002-16 as a whole, the probability that the krone rate will stabilise from one day to the next is 71 per cent, when no account is taken of whether or not intervention is carried out. The probability of the krone rate changing direction from one day to the next, whether or not intervention is carried out, is 51 per cent.

Therefore, a statistical test is conducted to examine whether the observed effects of the events deviate significantly from what could be expected to have happened without intervention. The null hypothesis is that the number of events meeting the criteria follows a binomial distribution with 94 observations and with a 71 per cent probability that the stabilisation criterion is met and a 51 per cent probability that the direction criterion is met.

The test shows that the P value, which indicates the probability that the direction criterion is met for 90 per cent of the 94 events, is only 0.0001 per cent if the interventions had not had any effect. Hence, the observed pattern would be highly unlikely under the assumption that intervening in the foreign exchange market has no effect. Against this background, it can be concluded that the interventions have worked. Similarly, the P value in relation to the direction criterion is only 0.03 per cent. Again, there is overwhelming evidence of the effect of interventions.

INTERVENTIONS AND MARKET MOVEMENTS

Danmarks Nationalbank's interventions in the foreign exchange market are far from being the only driver of krone rate developments. This section therefore specifies and estimates an economic relation taking into account that the exchange rate is also affected by other market participants' purchases and sales of kroner. These market movements are estimated on the basis of daily reports to Danmarks Nationalbank from the largest Danish banks. The method and the data used are described in more detail in Box 4.

DANMARKS NATIONALBANK'S INTERVENTIONS ARE IN RESPONSE TO THE PRIVATE SECTOR'S NET DEMAND FOR KRONER

Danmarks Nationalbank intervenes in the foreign exchange market in response to the current conditions in the foreign exchange market for kroner. The krone rate is dependent on private agents' demand for kroner, e.g. an exporter that has received payment in euro and wishes to exchange it for Danish kroner. Institutional investors such as insurance companies and pension funds also play a key role in terms of demand for kroner, cf. the article *The Pension Sector as a Foreign Exchange Market Participant* in this Monetary Review.

Major cross-border acquisitions may also lead to considerable fluctuations in the demand for kroner. If e.g. a foreign firm acquires a Danish firm, the demand for kroner will often increase up to the settlement of the acquisition, while the previous owners may subsequently choose to reinvest the proceeds in foreign assets. Hence, the acquisition process typically involves several foreign exchange transactions at different times.

Private agents' foreign exchange transactions are typically made through a bank. Initially, a bank customer's purchase of kroner against e.g. euro leads to a shift in the bank's holdings of kroner

Regression model for the krone rate

Box 4

A simple relation is estimated for the percentage change in the krone rate in a given day:

$$\Delta Krone\ rate_t = constant + \beta_1 Interventions_t + \beta_2 Customer\ purchases_t + \varepsilon_t$$

$\Delta Krone\ rate_t$ is the daily percentage change in the krone rate stated as kroner per 100 euro.

$Interventions_t$ indicates Danmarks Nationalbank's net purchases of kroner against foreign exchange on a given day stated in kr. billion. Danmarks Nationalbank's intervention purchases are expected to strengthen the krone rate, corresponding to a negative sign of β_1.

$Customer\ purchases_t$ indicates bank customers' net purchases of kroner against foreign exchange in kr. billion, covering both spot and forward contracts. Customers are residents who are not banks and non-residents (both banks and non-banks). As with Danmarks Nationalbank's intervention purchases of kroner, the krone rate is expected to strengthen when bank customers purchase more kroner, corresponding to a negative sign of β_2.

The constant in the model is not expected to be significantly different from zero, as that will be incompatible with a fixed exchange rate against the euro in the long term.

Data

The data period runs from early 2002 up to and including 24 October 2016. The exchange rate applied is stated at 5 pm Danish time, while Danmarks Nationalbank's interventions typically take place between 9 am and 4 pm. Accordingly, the effect of the interventions made during a particular day is captured in the applied exchange rate.

Bank customers' net purchases of kroner are part of the information on turnover in the foreign exchange market for kroner collected by Danmarks Nationalbank on a daily basis. The statistics for foreign exchange turnover include a number of the largest Danish banks' spot and forward contracts with customers and other currency dealers.

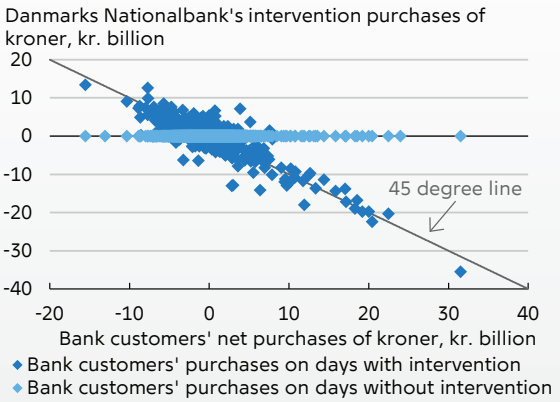
Identification of causal effects

To allow for the fact that Danmarks Nationalbank's interventions respond to the current development in the krone rate, instrument-variable estimation (IV estimation) is performed. The interventions of the preceding five trading days are used as the instrument for the intervention on a given day. The instrument is valid, since the interventions on the preceding days cannot be expected to have a separate effect on the change in the krone rate on that given day. The instrument is relevant, as Danmarks Nationalbank's interventions often take the form of events, meaning that the interventions of the preceding days may to some extent predict intervention purchases on a given day.

Bank customers' purchases of kroner may also be affected by the day's development in the krone rate and thus be partly endogenous. The problem is deemed to be considerably smaller than for Danmarks Nationalbank's interventions, because bank customers' purchases and sales of kroner are a naturally integral part of trade and investments in and out of Denmark. Presumably, any decisions concerning such payment flows depend only to a limited extent on the development in the krone rate on a given day.

Newey-West standard errors are used when estimating the statistical significance of parameter estimates to allow for autocorrelation and heteroscedasticity in the residuals.

Purchases of kroner by Danmarks Nationalbank and bank customers Chart 4



Note: Around 88 per cent of the observations are on the zero line, corresponding to Danmarks Nationalbank having intervened on approximately 12 per cent of all trading days from January 2002 to October 2016.
Source: Danmarks Nationalbank.

and euro. For smaller transactions, the bank will often absorb the associated change in the bank's own foreign exchange exposure at current market prices. This way, the banks themselves contribute to stabilising the krone without the participation of Danmarks Nationalbank. In periods of turmoil in the foreign exchange market for Danish kroner, however, the currency flows may be too strong for the banks to be willing to assume increased foreign exchange exposure without major adjustments to the exchange rates they offer their customers. When there is a substantial excess of purchase orders for kroner, the banks tend to raise prices, while they tend to reduce them when there is an excess of sales orders. This has an impact on the exchange rate.[5]

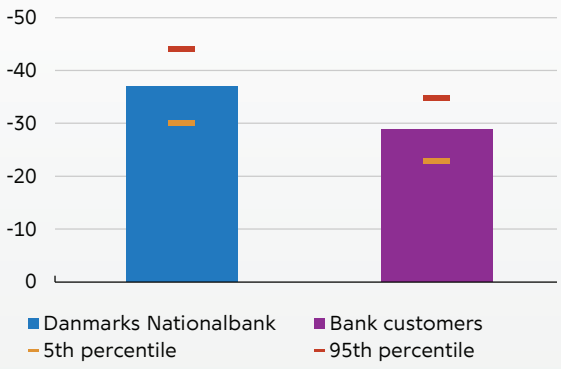
In order to get an unbiased estimate of the effect of Danmarks Nationalbank's interventions, it is vital to allow for bank customers' net purchases of kroner. Danmarks Nationalbank's interventions may thus be effective without necessarily having a visible impact on the krone rate. That would be the case if the interventions counter the effect of the purchases and sales of kroner by the other market participants. Historically, there has been a clear link between Danmarks Nationalbank's interventions and bank customers' purchases of kroner, cf. Chart 4.

The estimated model is based on the assumption that bank customers initiate the realised trades in kroner. The banks, on the other hand, are assumed not to actively initiate net purchases or sales of kroner themselves, but to meet the demand from their customers. Accordingly, in the model market participants' demand for kroner is expressed by bank customers' net purchases of kroner, while the banks' own demand for kroner is not included in the model.

ESTIMATION OF THE EFFECT OF DANMARKS NATIONALBANK'S INTERVENTIONS ON THE KRONE RATE

According to the analysis, intervention in the foreign exchange market by Danmarks Nationalbank to purchase Danish kroner causes the krone to strengthen. For the entire period 2002-16, total purchases of kroner for kr. 1 billion will strengthen the exchange rate of the krone against the euro by approximately 0.005 per cent. This means that the krone rate measured in kroner per 100 euro is strengthened by just under kr. 0.40 when intervention purchases are made for kr. 10 billion, cf. Chart 5. The effect is statistically significant.

Estimated effect of purchases and sales of kroner against foreign exchange, 2002-16 Chart 5

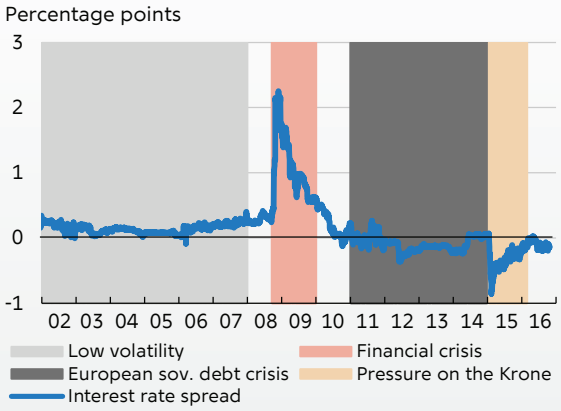


Note: Reverse scale. Negative values correspond to a strengthening of the krone. The chart illustrates the impact on the krone rate of krone purchases in the amount of kr. 10 billion, measured at the central rate of kr. 746.038 per 100 euro. See Box 4 for model specification. The 5th and 95th percentiles span a 90 per cent confidence interval for the estimates.
Source: Own calculations.

5 It is a well-known finding in the literature that a significant relationship exists between order flows and exchange rate changes, cf. e.g. Lyons (2001).

The estimated effect on the krone rate from bank customers' purchases of kroner is slightly lower than the estimated effect of Danmarks Nationalbank's interventions. While bank customers' purchases and sales of kroner only impact the exchange rate through their impact on the relative supply of and demand for kroner (the portfolio balance channel), Danmarks Nationalbank's interventions may also have the effect of market participants seeing them as signalling a potentially imminent interest rate change.[6] Hence, the slightly higher estimated effect of Danmarks Nationalbank's interventions compared to the effect of bank customers' purchases is an indication that the interventions work through *both* the signalling and the portfolio balance channels. For the period as a whole, the portfolio balance channel seems to have been the most significant channel, however.

Changing conditions in the foreign exchange market for kroner Chart 6



Note: The interest rate spread shown is the spread between the 1-month CITA and EONIA swap rates.
Source: Thomson Reuters Datastream and Danmarks Nationalbank.

THE EFFECTS OF EXCHANGE RATE FLUCTUATIONS VARY OVER TIME

There are no indications that the rising turnover in the foreign exchange market for kroner has generally reduced the effect of Danmarks Nationalbank's interventions. This may reflect that conditions in the foreign exchange market for Danish kroner have fluctuated considerably over the past 15 years. The krone has been stable for long periods of time. For example, this was the case for most of the time up to 2008, when the spread between money market interest rates in Denmark and in the euro area was very stable around 10-20 basis points, cf. Chart 6.

Against the backdrop of the financial crisis in the autumn of 2008, there was a considerable outflow of kroner. In response to this, Danmarks Nationalbank made intervention purchases in the foreign exchange market for just under kr. 65 billion in September and October 2008, while the money market spread briefly widened as a result of unilateral Danish monetary policy interest rate increases.

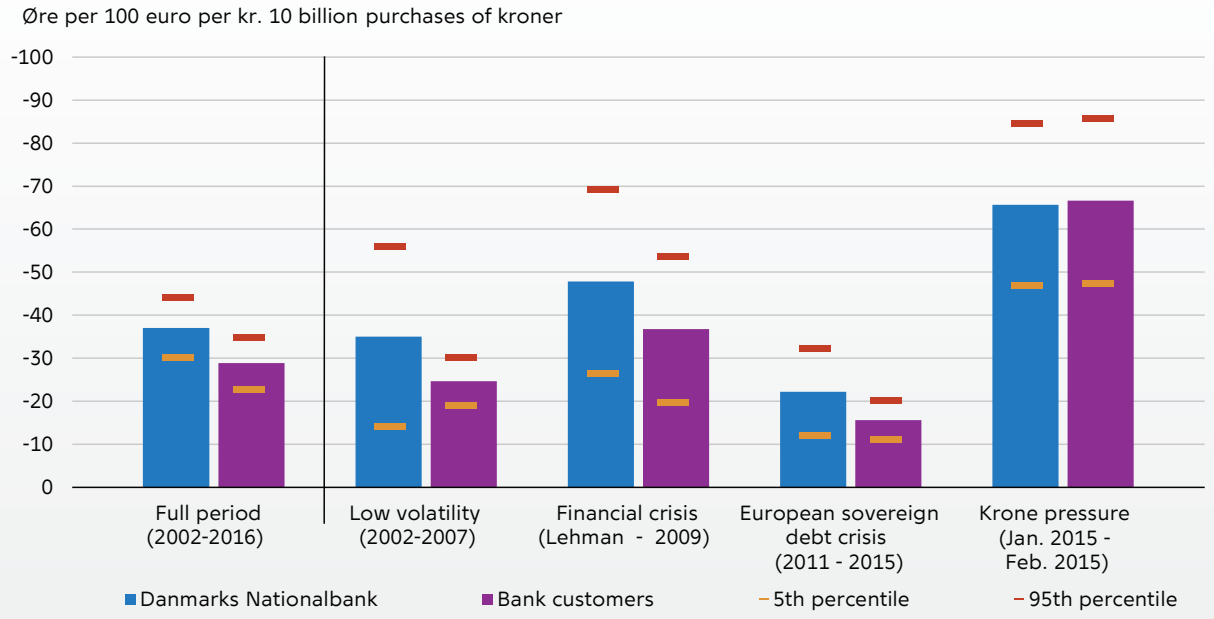
As Denmark has become a creditor nation holding substantial net external assets, turbulence in the foreign exchange market has tended to result in a strengthening of the krone and a negative spread to money market interest rates in the euro area. For example, this was the case in 2012, when the krone gained status as a safe haven currency during the sovereign debt crisis in a number of euro area member states, cf. Jørgensen et al. (2013). Most recently, there were very large inflows of capital in January-February 2015. During both episodes, Danmarks Nationalbank sold kroner. With sales totalling kr. 275 billion in January-February 2015, this intervention is Danmarks Nationalbank's largest within such a short period.[7]

In order to assess the effect of interventions under the varying conditions in the foreign exchange market for kroner, the relation in Box 4 is estimated on four sub-periods. The basic message is that Danmarks Nationalbank's interventions were effective in all sub-periods, cf. Chart 7. The smallest effect was seen in the period 2011-14, while the strongest effects were seen during the financial crisis in 2008-09 and in early 2015. This may reflect that the latter episodes were characterised by considerable, one-sided foreign exchange flows. In such cases, the banks' risk

6 It cannot be ruled out that the lower estimate of the effect of bank customers' purchases of kroner is partly attributable to the fact that those purchases are not completely exogenous in the model, thus creating an endogeneity bias.

7 See Danmarks Nationalbank (2015) for an overview of the pressure on the krone in January-February 2015.

Effect on the krone rate of net purchases of kroner in the foreign exchange market Chart 7



Note: Reverse scale. The chart illustrates the impact on the krone rate of krone purchases in the amount of kr. 10 billion, measured at the central rate of kr. 746.038 per 100 euro. See Box 4 for model specification. The 5th and 95th percentiles span a 90 per cent confidence interval for the estimates.
Source: Own calculations.

appetite and capacity will typically be insufficient to absorb the fluctuations in their customers' demand for kroner, and the banks will be more inclined to adjust the exchange rates they offer their customers.

In the period during the pressure on the krone in January-February 2015 and the subsequent reversal there is no difference between the estimated effects of Danmarks Nationalbank's and bank customers' purchases of kroner in the foreign exchange market. The reason may be that, during this period, Danmarks Nationalbank declared itself willing to intervene for unlimited amounts, whereas changes in interest rates played a minor role. Against that background, investors could not interpret the interventions as a signal of imminent interest rate changes.

INCLUSION OF OTHER VARIABLES

Although the effect of Danmarks Nationalbank's interventions and bank customers' net purchases of kroner are both very pronounced, the estimated regression model only explains a limited part of the total fluctuations in the krone rate. This reflects that the krone rate also depends on a large number of factors that are not included in the model, such as the spread between money market interest rates in Denmark and the euro area. Neither the money market spread nor other potentially relevant variables are significant in the regression analysis, cf. Box 5. This may reflect the method used.

Other factors affecting the exchange rate

Box 5

The exchange rate of the krone vis-à-vis the euro is potentially affected by a large number of factors in addition to Danmarks Nationalbank's interventions and bank customers' purchases of kroner. These include, inter alia, the difference between money market interest rates in Denmark and the euro area. Widening of the spread between money market interest rates in Denmark and the euro area must be expected to increase the inflow of foreign exchange and contribute to strengthening the krone rate.

Changes in the short-term money market interest rate spread are not significant when added to the estimated relation. This is true whether the difference between the 1-month or 3-month CITA and EONIA swap rates or implied interest rate spreads from FX swaps are used. The reason for the lack of statistical significance may be that e.g. narrower interest rate spreads – whether due to changes in monetary policy interest rates or changed expectations thereof – are more likely to reduce bank customers' demand for kroner. Hence, the effect of the money market interest rates is indirectly included in the model via customers' purchases of kroner.

In a credible fixed exchange rate regime such as Denmark's, the level of the krone rate may affect the change in the krone rate. If, for example, the krone is at a relatively strong level within the fluctuation band, the probability of a weakening towards the central rate is greater than the probability of a strengthening. Such underlying movement towards an equilibrium exchange rate does not appear as significant when estimating the relation on a daily basis.

In recent years – e.g. in view of increasing net foreign assets – Denmark has experienced periods of pressure towards a strengthening of the krone and a negative spread to money market interest rates in the euro area. The Danish krone may have gained status as a safe haven currency which investors will turn to in periods of considerable uncertainty in the financial markets, cf. Jørgensen et al. (2013). Based on this, it has also been examined whether changes in the financial market risk outlook expressed by changes in the VIX index may contribute to explaining the daily fluctuations in the krone rate. The effect is not statistically significant.

RESULTS ARE PREDOMINANTLY IN LINE WITH PREVIOUS STUDIES

The effect of Danmarks Nationalbank's interventions on the krone rate has been examined in several previous analyses.[8] The results of the previous analyses of interventions are not fully comparable with the results in this article as they are based on different models, estimation methods, data periods and frequencies. Overall, the different studies find that, in a stable foreign exchange market, the interventions impact the krone rate in the anticipated direction.

Hansen and Storgaard (2005) assess that while the effect on the krone rate of Danmarks Nationalbank's interventions are more or less in accordance with the effect from portfolio flows to and from Denmark, the findings of this analysis indicate that Danmarks Nationalbank's interventions have a greater effect.

8 Andersen (2005), Hansen and Storgaard (2005), Beier and Storgaard (2006), Abildgren (2008), Fatum and Pedersen (2009) and Jørgensen et al. (2013).

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