René Kallestrup[1]

The volatility of the Icelandic króna

It is often claimed that the Icelandic króna is more volatile than other currencies. This article takes a closer look at this contention and assesses whether it is a reasonable statement. First, the article analyses the historical vari-ability and volatility of the króna and relates it to currencies with similar macroeconomic characteristics. Second, it examines market expectations of future exchange rate fluctuations, with particular emphasis on the evolving Icelandic option market. Third, it focuses on possible reasons for exchange rate volatility. The data period begins in April 2001, after the Icelandic currency was floated, and ends in March 2008. The conclusion is that the aver-age volatility of the Icelandic króna is in the high end among developed market currencies but substantially below that of high-yielding emerging market currencies. On the back of the huge imbalances in the Icelandic economy, above-average volatility of the króna in 2006-2008 is probably not very surprising. That said, in 2008 foreign ex-change volatility has been excessively high. Volatility is likely to remain relatively high during the rebalancing of the economy; however, it is reasonable to expect a reduction in volatility towards some historical average as the economy becomes more balanced, financial uncertainties are reduced, and Icelandic carry trades fade as the policy interest rate is lowered.

Introduction

Foreign exchange volatility has attracted attention since the outset of floating exchange rates. More recently, economists have studied the theoretical and empirical impact of trade openness, financial integra-tion, and other related factors on foreign exchange volatility across countries. Bravo-Ortega et al. (2005) find that open economies tend to have lower real exchange rate volatility.[2] Likewise, Devereux and Lane (2003) find that increased financial linkages between countries tend to be associated with lower exchange rate volatility. On the other hand, a high level of financial openness may also increase foreign exchange rate volatility if net liabilities become very large.[3] Hence, according to econo-metric and theoretical analyses, foreign exchange volatility is dependent on macroeconomic and financial factors, and this makes it interesting to take a closer look at the volatility of the Icelandic króna.

The remainder of this article is organised as follows: the second section focuses on the historical volatility of the króna, the third centres on the Icelandic foreign exchange option market, and the fourth section discusses general determinants of exchange rate volatility. The fifth sec-tion contains conclusions and a summary of points presented. A glos-sary of financial and statistical terms can be found in the appendix.

Chart 1

Trade-weighted foreign exchange trading ranges

Based on average monthly nominal exchange rates[1]
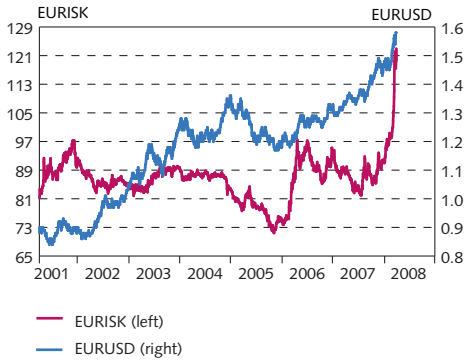Daily data, April 2001 - March 2008
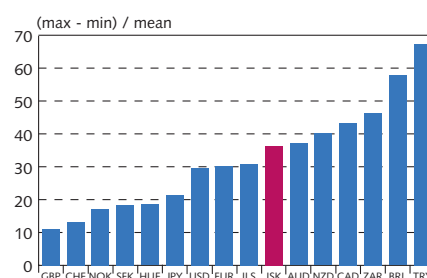
1. GBP: British pound, CHF: Swiss franc, NOK: Norwegian krone, SEK: Swedish krona, HUF: Hungarian forint, JPY: Japanese yen, USD: US dollar, EUR: Euro, ILS: Israeli shekel, ISK: Icelandic króna, AUD: Australian dollar, NZD: New Zealand dollar, CAD: Canadian dollar, ZAR: South African rand, BRL: Brazilian real, TRY: Turkish lira.

*Sources:* Bank of International Settlements (BIS) and author's calculations.

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1. The author is an economist at the Central Bank of Iceland Economics Department. He would like to thank Arnór Sighvatsson, Thórarinn G. Pétursson, Regína Bjarnadóttir, Thorvarður Tjörvi Ólafsson and Ásgeir Daníelsson for their constructive comments. The author alone is responsible for any errors or omissions. The opinions expressed in this article are those of the author and do not necessarily represent the views of the Central Bank of Iceland.

2. Their focus, however, is not on very small open economies, which tend to be less diversi-fied and more prone to idiosyncratic economic shocks and may therefore display higher exchange rate volatility. Devereux and Lane (2003) and Pétursson (2008) find, however, that smaller economies tend to have lower exchange rate volatility, and argue that they are more reluctant to tolerate fluctuations in the nominal exchange rate.

3. Devereux and Lane (2003) find different responses in industrialised and emerging markets countries in their sample period.

Chart 2

Bilateral foreign exchange trading ranges[1]

Daily data April 2001 - March 2008

1. An increase is an appreciation of the euro (base) against the other currency.
Source: Bloomberg.

Chart 3

The Icelandic króna against the euro

Level and daily percentage changes, April 2001 - March 2008
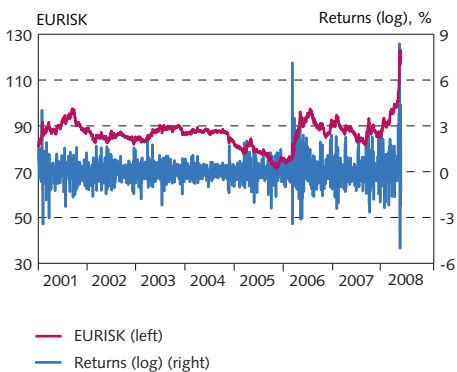
Source: Central Bank of Iceland.

Chart 4

The Icelandic króna against the euro[1]

Daily percentage changes (log returns),
April 2001 - March 2008
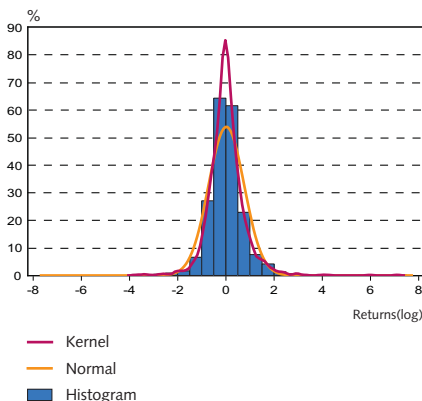
1. ISK per euro.
Source: Bloomberg.

Historical volatility

The Icelandic monetary framework, with an open capital account and independent monetary policy, implies that the exchange rate cannot be fixed against another currency. However, in view of the fact that foreign exchange markets seem to exhibit excess volatility, and given that exchange rates can diverge from fundamentals for lengthy periods, it is interesting to look closer at the behaviour of exchange rate fluctuations (see Gudmundsson, 2008). Relating historical volatility and variability, as well as skewness and kurtosis of the exchange rate, to other countries provides useful insight into this matter. Needless to say, this section concentrates on backward-looking (realised) measures of fluctuation, which ignore market expectations. The data period ranges from April 2001, after the independent floating of the Icelandic currency was introduced, to March 2008. This study uses daily data.

In assessing the uncertainty of the foreign exchange rate, one can approach the issue in different ways. The most popular measure of volatility in financial markets is the standard deviation of log returns.[4] It is possible to examine high-frequency (e.g., daily) or lower-frequency (quarterly or yearly) changes in the exchange rate. Volatilities based on daily returns are more directly related to the cost of hedging currency transactions in the foreign exchange markets via simple (plain vanilla) currency options.[5] Low-frequency changes can be equally important because they are more effective at capturing trend changes (level shifts) in a given currency and can be important for more exotic options. When a significant shift in the level of the currency has occurred, it is often too expensive to purchase financial products securing a reversion to the initial exchange rate.[6] The shift in the level of the currency can be called variability (though other definitions of variability may appear in the literature). Both variability and volatility are very important for consumers, businesses and policy-makers because they may answer completely different questions.

Variability

Chart 1 shows the trading ranges of broad trade-weighted indices since 2001 for a group of different currencies. A currency trading in a narrow range relative to other currencies may increase the predictability for exporters and importers with transactions in a given currency. The trading range of the króna has been wider than that in several European currencies but slightly narrower than that for other so-called commodity currencies, such as the Canadian (CAD), Australian (AUD) and New Zealand (NZD) dollars. Of course, the shift in the level of the currency can be quite data-dependent. Interesting patterns may emerge if one looks at bilateral exchange rates as well. For instance, the variability of

4. Log returns are mathematically defined as $u[i]= \ln(S[i]/S[i\text{-}1])$, where $S[i]$ is the value of the market variable at end of day i.

5. Options are defined as the right to purchase or sell at a given price at a specified point in the future.

6. A discussion of the importance of long-lasting exchange rate changes and the difficulties in hedging against them can be found in Kenen (2002).

the US dollar (USD) against the euro (EUR) has been greater than that of the Icelandic króna against the euro, with declines of 90% and 72% respectively, from the peak to the trough (see Chart 2).
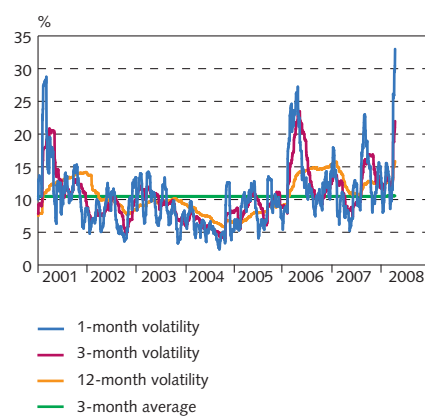
Volatility

When fluctuations in daily returns are large, volatility is said to be high; conversely, when fluctuations in returns are small, volatility is said to be low. While volatility does not necessarily capture periods of rapid and sustained changes in the spot exchange rate, the concept has important implications for hedging via simple options. If the Icelandic króna ends the quarter or year where it started – though it may have moved up and down frequently in the interim – according to quarterly sampling, it will not display any variability, whereas its high-frequency volatility can be relatively high.

Importantly, all uncertainty measures change over time, and focusing on average volatility over the entire sample may only convey a part of the whole story. Economists use different moving volatility windows (e.g. one, three, and twelve months) to show time variation across a sample. For instance, the one-month exchange rate volatility is the standard deviation over a one-month rolling window on the daily exchange rate change; that is, from April 1, 2001, to May 1, 2001; and then from April 2, 2001, to May 2, 2001.[7]

Chart 3 displays the daily fluctuations in the Icelandic króna against the euro, and Chart 4 illustrates the distribution of returns. They show how volatility varies over time, as well as giving indications that daily percentage changes have heavier tails than the normal distribution (a common finding for exchange rate returns). Tail events are more common for depreciation than appreciation (see the section on skewness and kurtosis).[8] Charts 5 and 6 illustrate the volatility of the Icelandic króna and the New Zealand dollar, respectively, against the euro. Volatility clustering is evident in both foreign exchange rates; i.e., periods of persistent high volatility are followed by periods of relatively low volatility. Overall, the average patterns of annualised volatility in the króna and the New Zealand dollar look very similar, but there are some marked differences nonetheless. Chart 7 summarises the one-month EURISK volatility shown in Chart 5. The average one-month volatility, at 10.4%, is driven by the large spikes above 20%, with one-month EURISK volatility fluctuating between 2.5% and 33% (the three-month and twelve-month volatility range is much narrower, however). In the period 2002-2005, the volatility of the króna was notably lower than that of the commodity currencies. However, in 2001 and 2006-2008, daily changes in the króna were greater than those in other developed currencies. Not surprisingly, the floating of the króna

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7. To facilitate the comparison of volatilities for different interval lengths, it is useful to express volatility in annual terms. In order to de-annualise the annual figures, one divides by the square root of trading days (square root of 252 for daily data). Therefore, if the one-year realised annual volatility in EURISK (Icelandic krónur per euro) is 9.5%, this corresponds to approximately 0.6% for daily volatility.

8. The normal distribution is shown with a constant sample mean and standard deviation. Jarque-Bera tests reject the null hypothesis of normality at a 1% significance level.

Chart 5

EURISK volatility using a moving window[1]
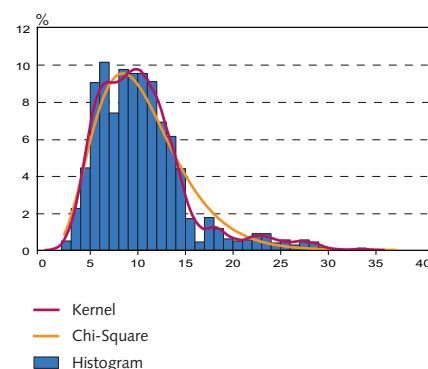Daily data April 2001 - March 2008

1. Volatility in exchange rates is annualised.
Source: Bloomberg.

Chart 6

EURNZD volatility using a moving window[1]
Daily data April 2001 - March 2008
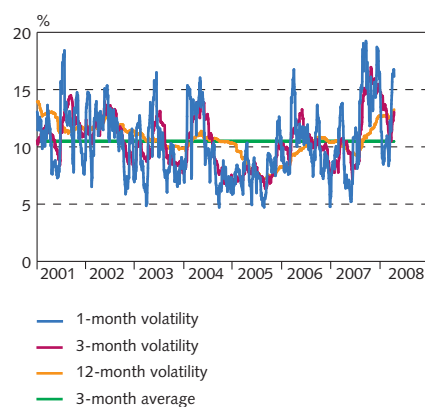
1. Volatility in exchange rates is annualised.
Source: Bloomberg.

Chart 7

1-month foreign exchange volatility (EURISK)
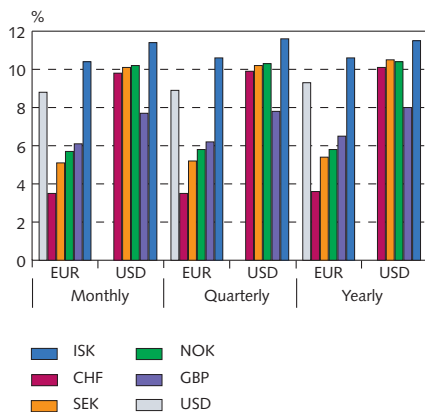April 2001 - March 2008

Sources: Bloomberg and author's estimates.

Chart 8

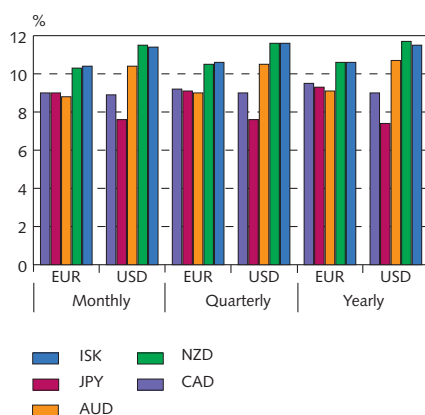Volatility in the ISK and core
European currencies
Average rolling volatility, April 2001 - March 2008

Source: Bloomberg.

Chart 9

Volatility in the ISK and other developed
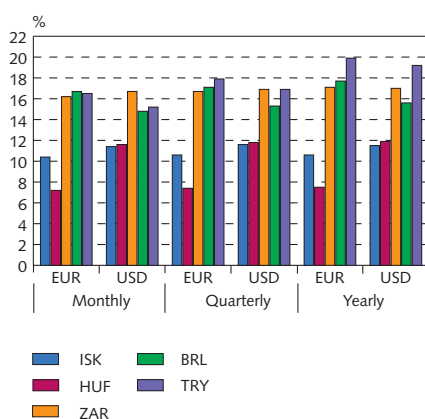market currencies
Average rolling volatility, April 2001 - March 2008

Source: Bloomberg.

Chart 10

Volatility in the ISK and
emerging market currencies
Average rolling volatility, April 2001 - March 2008

Source: Bloomberg.

in 2001 seems to have increased the volatility of the ISK.[9] Likewise, 2006-2008 was a period characterised by idiosyncratic economic and financial shocks, resulting in higher volatility (see the section on volatility drivers). In 2008, the volatility of the Icelandic króna has been excessively high and comparable to unstable periods in floating, high-yielding emerging market currencies.

Table 1 Average historical volatilities, April 2001-March 2008

	Monthly		Quarterly		Yearly	
Developed markets	EUR	USD	EUR	USD	EUR	USD
USD	8.8		8.9		9.3	
CHF	3.5	9.8	3.5	9.9	3.6	10.1
SEK	5.1	10.1	5.2	10.2	5.4	10.5
NOK	5.7	10.2	5.8	10.3	5.8	10.4
GBP	6.1	7.7	6.2	7.8	6.5	8.0
JPY	9.0	8.9	9.2	9.0	9.5	9.0
CAD	9.0	7.6	9.1	7.6	9.3	7.4
AUD	8.8	10.4	9.0	10.5	9.1	10.7
NZD	10.3	11.5	10.5	11.6	10.6	11.7
ISK	10.4	11.4	10.6	11.6	10.6	11.5
ILS	9.8	5.9	9.9	6.0	10.2	5.9
Emerging markets						
HUF	7.2	11.6	7.4	11.8	7.5	11.9
ZAR	16.0	16.7	16.7	16.9	17.1	17.0
BRL	16.7	14.8	17.1	15.3	17.7	15.6
TRY	16.5	15.2	17.9	16.9	19.9	19.2

Note: Based on Bloomberg daily closing prices. EUR and USD are base currencies.
Source: Bloomberg.

Table 1 shows the average volatility of various currencies against the euro and the US dollar, and Charts 8 to 10 give a graphic representation of the same data. Generally speaking, the volatility of the króna has been of similar magnitude, on average, to that of other developed high-yielding currencies, such as the Australian dollar and the New Zealand dollar, but greater than that of the core European currencies like the Swedish krona (SEK), Norwegian krone (NOK), Swiss franc (CHF), and British pound (GBP). The Icelandic króna, however, is much less volatile than high-yielding emerging market currencies such as the Turkish lira (TRY), South African rand (ZAR), and Brazilian real (BRL).

The core European currencies track fluctuations in the euro quite closely, which tends to reduce their volatility against the single currency. For instance, the Swiss franc and the euro co-move against the US dollar. This is partly explained by trade patterns and similar business cycles in the euro area and Switzerland (see European Central Bank (2006) for further discussion of systematic co-moving currencies). Based on volatilities, the Icelandic króna is currently not a "euro currency" because it tracks the dollar and the euro more or less equally (the Australian and New Zealand dollars seem to show similar characteristics). If the Icelandic business cycle followed that of the euro area

9. This is confirmed in an empirical analysis using a GARCH model in Ísberg and Pétursson (2003).

more closely and trade with the euro area were increased, it could be expected that the volatility of the króna against the euro would diminish.

Table 2 Distribution of changes in foreign exchange rates. Average monthly percentage changes divided into intervals, April 2001-March 2008

# OBS	< -7.5%	[-7.5%;-5%]	[5%;7.5%]	> 7.5%
USD	-	-	-	-
EUR	-	-	-	-
CHF	-	-	-	-
SEK	-	-	-	-
NOK	-	-	-	-
GBP	-	-	-	-
JPY	-	-	-	-
CAD	-	-	-	-
AUD	-	-	-	-
NZD	-	2	-	-
ISK	3	2	-	-
ILS	-	1	-	-
HUF	-	1	-	-
ZAR	4	4	4	-
BRL	3	4	3	3
TRY	9	5	3	-

*Note*: Nominal effective exchange rates, 81 observations.

Source: Bank of International Settlements.

Table 2 illustrates the average monthly foreign exchange return distribution of the currencies above. The table shows clearly that large average monthly percentage changes are relatively more common in emerging market currencies. The next section analyses tail events more closely.

Skewness and kurtosis

Skewness reflects the distribution's asymmetry around its mean and thus indicates a deviation from the normal distribution, where skewness is zero. The skewness of EURISK (Icelandic krónur per euro) had a tendency to be positive in 2001, as well as in 2006-2008 (see Chart 11), on the back of the occasional large daily depreciation of the króna, in the range of 2-6%. Among currency investors, this is popularly known as downside risk. Other high-yielding currencies like the New Zealand and Australian dollars exhibit similar tendencies (although to a somewhat lesser degree), and this pattern is widespread among emerging market currencies as well. Significant selling pressures of the currency, combined with low liquidity in the foreign exchange market (see Section 4), resulted in something that resembles a jump in daily data for EURISK in 2006 and 2008.[10] Low-yielding currencies, however, tend to be skewed towards an appreciation, partly reflecting the low and

Chart 11
EURISK and rolling skewness
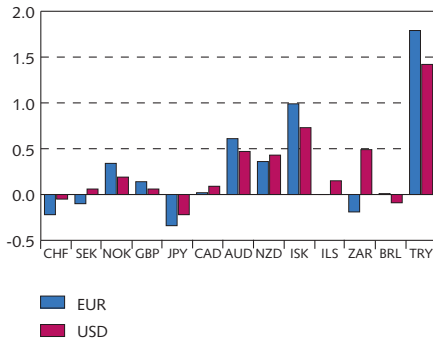Daily data April 2001 - March 2008

— 1-month
— 3-month
— 12-month

Source: Bloomberg.

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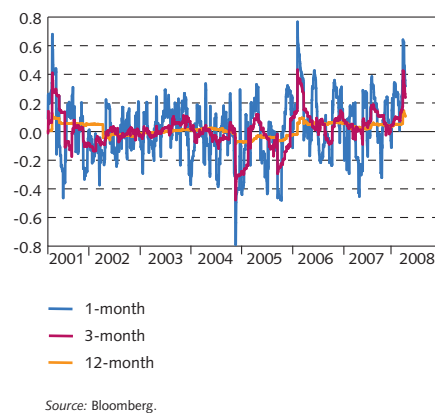
10. A liquid market can be described as a market where large transactions can be executed with small impact on prices; cf. Galati (2000).
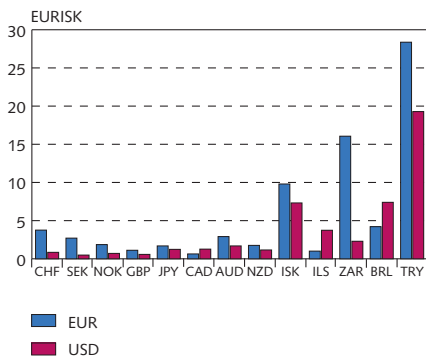
Chart 12

Foreign exchange skewness[1]

Based on daily returns over the entire period
April 2001 - March 2008

EUR

USD

1. EUR and USD are base currencies.
Sources: Bloomberg, author's calculations.
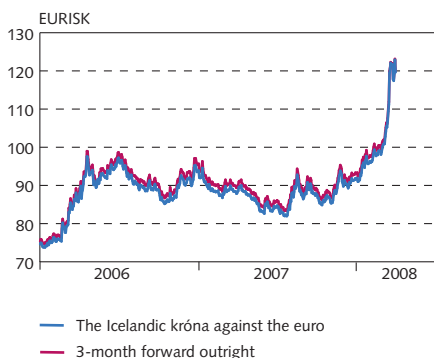
Chart 13

Foreign exchange kurtosis[1]

Based on daily returns over the entire period
April 2001 - March 2008

EUR

USD

1. EUR and USD are base currencies.
Sources: Bloomberg, author's calculations.

Chart 14

Spot and 3-month forward exchange rate contract

Daily data January 2006 - March 2008

—— The Icelandic króna against the euro

—— 3-month forward outright

Sources: Bloomberg, local sources.

stable inflation regime of these countries. Skewness for some currencies is shown in Chart 12.[11]

The negative skew in the króna (positive skew of e.g. EURISK) is closely related to the high level of kurtosis, which is a measure of extreme returns.[12] A high kurtosis is characterised by a high peak near the mean, declining somewhat rapidly and with heavy tails. A kurtosis exceeding three means a higher probability of large positive or negative returns than under the normal distribution. Data on kurtosis in different countries in Chart 13 correlate with those in the skewness chart. The following section discusses financial protection against potential shifts in the currency. The non-technical reader may skip directly to Section 4 without any loss of continuity.

Forwards and options

Hedging currency transactions via the forward exchange rate, where the investor is obligated to buy/sell at a specified price in the future, is very popular due to its simplicity.[13] A forward outright contract enables the investor to neutralise future exchange rate fluctuations by, for example, receiving a currency at a fixed price. According to the covered interest rate parity (CIP), the interest rate differences of any particular maturity between two countries (e.g., the euro area and Iceland) should equal the percentage difference between the forward exchange rate and the spot exchange rate (the so-called forward premium). This no-arbitrage condition should hold – at least approximately – in countries where capital is free to move between bank deposits. Hence, the CIP is used to price forward outright contracts. Foreign currency liquidity shortages and differential country risk premia may result in deviation from the CIP, however (see Box III-1). Chart 14 shows the three-month exchange rate contract, which is characterised by fairly good liquidity (at least before January 2008).[14] Because interest rates are higher in Iceland than in the euro area, the Icelandic króna will be worth fewer units of euro forward than the spot (that is, the króna is traded at a discount).

According to the "forward premium puzzle" in economics, however, the forward exchange rate is not a good indicator of market expectations of the future exchange rate.[15] In fact, high-yielding currencies like the Icelandic króna tend to appreciate, on average, not depreciate. This empirical fact is exploited in the so-called currency carry strategy and has been an argument against selling high-yielding currencies based on forward contracts. That said, some investors tend

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11. Skewness = $(1/N)\Sigma[(x_i-\mu)/\sigma]^3$

12. Kurtosis = $(1/N)\Sigma[(x_i-\mu)/\sigma]^4$

13. Alternatively, the related FX swap can be more flexible.

14. Quoted forward points can be found in one-week, one-month, and 12-month regularly in the foreign exchange market; cf. Bloomberg. Cross-currency basis swaps against the euro and the US dollar are traded regularly on the one-year, 18-month, two-year, and three-year horizon (at least before January 2008).

15. The *uncovered* interest rate parity (UIP) implies that the interest rate difference should reflect the expected depreciation of the high-yielding currency against the low-yielding one. The UIP is different from the CIP in that investors do not cover the exchange rate risk on the forward exchange market.

to overlook the fact that high-yielding currencies have a tendency to depreciate significantly when risk aversion rises in financial markets.[16]
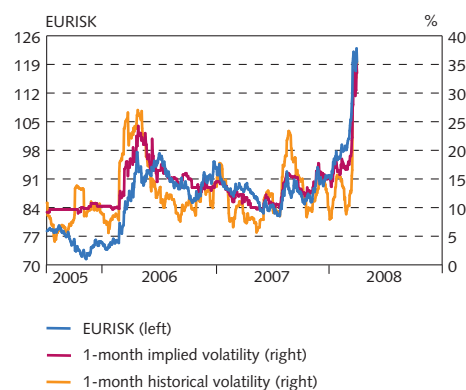
Implied volatility

Further insight into market expectations about future uncertainty can be gained by looking at foreign exchange options. The price of pro-tection – for example, put options, which give the owner the right to sell at a particular price at a specified time in the future – depends on market expectations for future exchange rate volatility, called im-plied volatility. In the market, quoted options on EURISK are available at fixed time-to-maturities: one, three, six and twelve months.[17] For instance, one-month (at-the-money) implied volatility is the market's estimate for realised one-month volatility in one month's time. Chart 15 reveals that implied volatilities tend to follow historical volatilities, but some large differences can be observed as well.[18]

In recent years, (at-the-money) implied volatilities of EURISK have become more liquidly traded; therefore, the main focus is on data since July 2005. This period is characterised by relatively high implied volatility, fluctuating between 9% and 35%. In foreign ex-change markets, implied volatility tends to be higher than the most recent realised volatility in order to compensate volatility sellers for the inherent uncertainty concerning future fluctuations.[19] That said, when implied volatility systematically trades higher than realised volatility, it is typically expensive to purchase an option. Fortunately, new ways to circumvent this are being addressed by so-called countdown options, with the optionality in terms of realised rather than implied volatility. Chart 15 shows a high positive correlation between spot changes and (at-the-money) implied volatility; i.e., a depreciation of the Icelandic króna tends to imply a rise in implied volatility.[20]

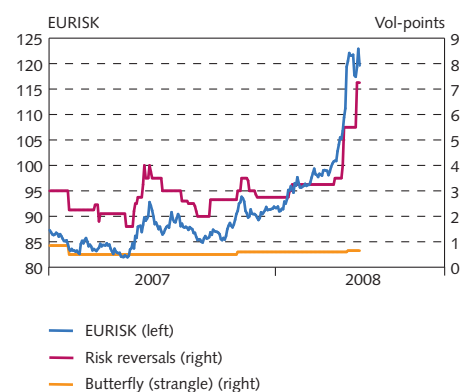## Asymmetry in foreign exchange rates

Foreign exchange option traders use risk reversals – where the investor simultaneously purchases an out-of-the-money call option and sells an out-of-the-money put option – to reflect the expected skewness in the distribution. Chart 16 illustrates the one-month risk reversal for EURISK during May 2007 - March 2008, a period when the market consistently expected a depreciation of the Icelandic króna.[21] The pos-

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16. See Section 4 of this article. Furthermore, Gyntelberg et al. (2007) show that expected carry trade returns do in fact reflect downside risk.

17. The implied volatilities are traded over the counter.

18. According to market convention, currency options are quoted in terms of implied volatil-ity and strike relative to forward prices. The latter is known as the Black-Scholes delta; for example, a 25-delta option has approximately a 25% probability of expiring in the money. The liquid quotes are 25-delta, 10-delta, and at-the-money options corresponding approximately to 50-delta. Implied volatility varies with maturity and strike price, and it is known as the "volatility smile" in volatility/strike space. At-the-money volatility gives the location of the volatility smile, the risk reversal prices indicate the skew, and the strangle prices gives the degree of curvature of the volatility smile.

19. When sudden unexpected changes in the exchange rate occur, realised volatility will have a tendency to surpass implied/traded volatility.

20. This pattern is common in foreign exchange markets, and stochastic volatility models exhibit a correlation between spot and volatility changes. See Carr (2007).

21. 25-delta out-of-the-money EUR calls were trading at 3.25 volatility points higher than a put on January 31, 2008 (according to indicative quotes from Bloomberg).

Chart 15

EURISK implied volatility

Daily data July 2005 - March 2008

- EURISK (left)
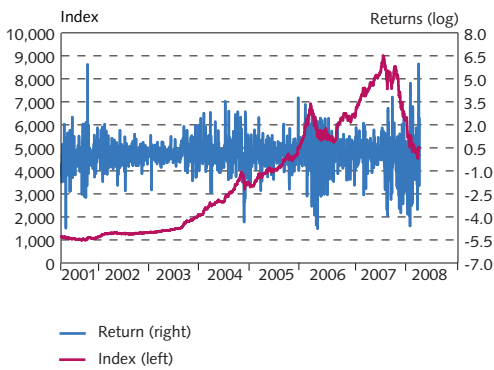- 1-month implied volatility (right)
- 1-month historical volatility (right)

Source: Bloomberg.

Chart 16

Risk reversals and strangles (1M, 25-delta)[1]

Daily data May 2007 - March 2008

- EURISK (left)
- Risk reversals (right)
- Butterfly (strangle) (right)

1. See footnote number 23.
Sources: Bloomberg, investments banks.

Chart 17

1M EURISK risk-neutral probability functions[1]

- January 31, 2008
- March 31, 2008

1. 25-delta risk reversal: 3.25 (7.25), 25-delta butterfly spread: 0.60 (0.65), at-the-money implied volatility (mid): 16.50 (33.5), forward rate: 97.87 (119.8), interest rate: 14.088 (15.36). Volatility smile fitted according to Malz (1997).
Sources: Bloomberg, investment banks, auther's calculations.

Chart 18

Stock market volatility in Iceland

Daily data April 2001 - March 2008

Source: Bloomberg.

Chart 19

EURISK vs. stock market volatility

1-month moving window based on daily returns
Daily data April 2001 - March 2008
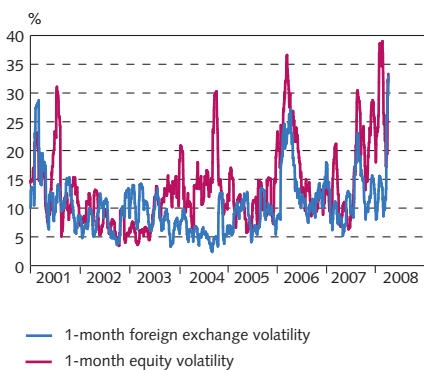
Sources: Bloomberg and author's calculations.

Chart 20

1-month stock market volatility (OMXI15)

April 2001 - March 2008

Source: Bloomberg.

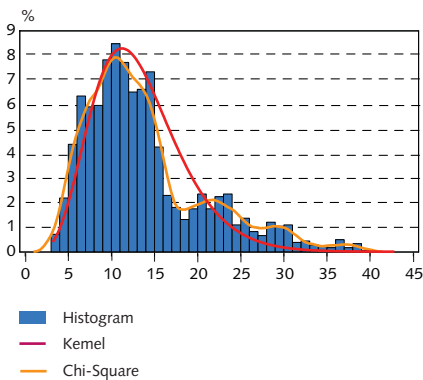itive correlation between spot changes and changes in risk reversals is strong. One could call it a kind of momentum in foreign exchange markets (see, for example, Campa, et al., 1998), as a weaker currency is related to a high probability of a further large future depreciation. One reason for this is that a strong depreciation of the króna indicates that the adjustment costs of a further depreciation could be large (for instance, in anticipation of investors' being forced to sell their long króna exposures, which would not be the case if the currency appreciated).[22]

Investors expecting a large movement in the exchange rate in any direction (excess kurtosis) simultaneously buy an out-of-the-money put and an out-of-the-money call (called a strangle; see Chart 16).[23] Time variation in both risk reversals and strangles is evident, with risk reversals exhibiting a larger standard deviation than strangles.

Risk-neutral foreign exchange distribution

The previous section explains how options, like strangles and risk reversals, provide new information about the expectations of the market's assessment of future exchange rate movements, whereas the forward exchange rate is merely a reflection of the traded interest rate differential and the current spot exchange rate (by the risk premium-adjusted covered interest rate parity). Assuming a smooth "volatility smile" based on actual option prices, one can extract an implied risk-neutral probability density function (PDF) that the market attaches to the future exchange rate. Bahra (1997), Bank of England (2002), Castrén (2005) and Gereben (2002) elaborate on the procedure. Chart 17 illustrates the exchange rate horizontally and the probability vertically, with the area under the curve summing to 100%. It is important to notice that, when a risk premium is present, the forward rate is a biased indicator of market expectations concerning future exchange rates, and the risk-neutral probabilities do not necessarily provide an actual perception of asset price movements held by market participants.[24] In the chart, one spots a skew towards a large appreciation of the euro against the Icelandic króna rather than an equivalent depreciation (due to the non-zero risk reversals).[25]

The accuracy of the PDF depends on the quality of the quoted option prices. If daily quotes on options reflect limited liquidity – which can be the case in the Icelandic market – the implied PDF may become volatile. It is difficult to establish a market price in the tails of potential outcomes, which reflects the diverging perception of the likelihood of

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22. Risk reversals are an indication of non-normally distributed exchange rate returns, and the positive correlation between spot and skewness points out that market participants do not expect a stable, narrow nominal trading range (since, in this case, the correlation would be negative).

23. A 25-delta butterfly spread is defined as the difference between the average implied volatility of a 25-delta call and a 25-delta put and the delta-neutral straddle implied volatility.

24. Hence, the difference between risk-neutral and the actual expected distributions is closely associated with a time-varying risk premium that, for example, compensates risk-averse investors for holding the Icelandic currency. The economics literature indicates that the risk aversion primarily changes the location of the distribution (the mean) and still makes it useful to interpret measures of implied skewness and kurtosis (see, for example, Bliss et al., 2002).

25. Since the mean is equal to the forward rate in a risk-neutral distribution, one cannot interpret it as an indication that appreciation is more likely than depreciation.

large changes in the exchange rate, hedging activity, and expected option order flows. However, the simulations do not seem to show large differences between indicative market quotes and the interpolated smile, suggesting that the derived foreign exchange distribution is fairly accurate.

Volatility drivers

The realised foreign exchange volatility of the króna remains below that in the Icelandic stock market (see Charts 18-20), but the strong co-movement of the two volatilities suggests that they may be driven by common factors. This section examines the level of foreign exchange volatility and the co-movement with macroeconomic factors across countries. Although it is difficult to separate the different factors, it is nonetheless useful to attempt to suggest a plausible causality. The introduction of this article discusses how financial openness seems to co-move negatively with volatility, a pattern that is documented in Chart 21. Other determinants of exchange rate volatility are examined below, using an approach inspired by Cairns et al. (2007). The data period remains from April 2001 to March 2008, and an equally weighted average of the historical volatility against the euro and the US dollar is used.

First, a currency tied to a high net external financing requirement is very dependent on global risk sentiment and changes in country-specific economic and financial factors. Hence Chart 22 reveals a negative relationship between volatility and the average quarterly current account surplus. For instance, when global risk perception increases, investors withdraw from funding large current account deficits, friggering in large foreign exchange depreciations. New Zealand, Australia and Iceland are all developed countries that have had persistent current account deficits.

Second, higher inflation and inflation variability tend to co-move positively with high-frequency exchange rate volatility in the sample appearing in Chart 23. When inflation domestically and abroad is at significantly different levels, the exchange rate is expected to reflect these differentials and show greater volatility, whereas low and stable inflation will require less adjustment. Reverse causality may also appear, however. Pétursson (2008) finds that a more volatile exchange risk premium leads to more volatile inflation rates. According to Pétursson's results, the countries that tend to have a more volatile exchange rate risk premium are very small, open economies and emerging market economies. The perceived risk of holding the currency could be a result of the more volatile nature of these economies, more frequent idiosyncratic shocks, or less developed foreign exchange markets.

Third, speculative currency carry trades are related to risk appetite, which lead to foreign exchange dynamics known as "up the stairs, down in the elevator" (see Plantin et al., 2007). Hence, high-yielding currencies tend to appreciate slowly, followed by a period of large depreciation. This phenomenon explains the consistent downside risk priced in Icelandic foreign exchange options. A high policy interest rate – which is a result of an imbalanced economy and high inflation – attracts short-term foreign capital, making the exchange rate vulnerable

Chart 21

Foreign exchange volatility and financial openness[1]

Average quarterly data, April 2001 - March 2008

Average 3-month FX volatility (equally weighted average of EUR and USD)
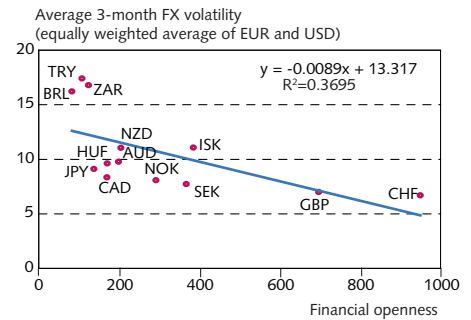
1. Financial openness = (Assets + Liabilities) / GDP, average 2001-2006.
Sources: International Financial Statistics (IMF), OECD.

Chart 22

Foreign exchange volatility and current account

Average quarterly data, April 2001 - March 2008

Average 3-month FX volatility (equally weighted average of EUR and USD)
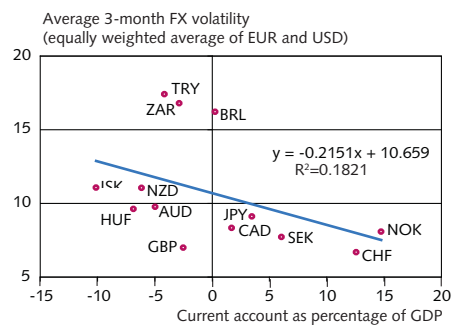
Sources: International Financial Statistics (IMF), OECD.

Chart 23

Foreign exchange and inflation volatility[1]

Average quarterly data, April 2001 - January 2008

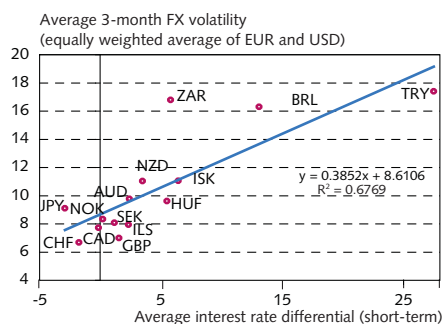Average 3-month FX volatility (equally weighted average of EUR and USD)
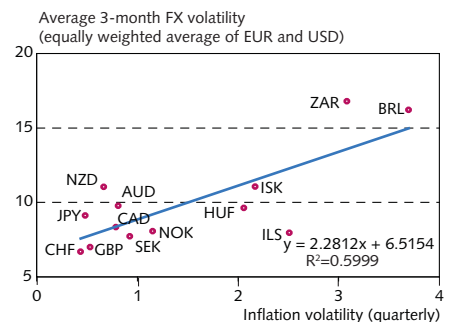
1. Turkey has very high inflation volatility.
Sources: International Financial Statistics (IMF), OECD.

Chart 24

Foreign exchange volatility
and interest-rate differentials

Average quarterly data, April 2001 - March 2008

Average 3-month FX volatility
(equally weighted average of EUR and USD)

$$y = 0.3852x + 8.6106$$
$$R^2 = 0.6769$$

Average interest rate differential (short-term)

Sources: International Financial Statistics (IMF), OECD.

Chart 25

Daily turnover in the Icelandic interbank
FX market and the exchange rate index

Daily data April 2006 - March 2008

- Turnover (right)
- Exchange rate index (left)

Source: Central Bank of Iceland.

to investor sentiment. This relationship is documented in Chart 24. When sentiment deteriorates sharply, a large foreign exchange selling pressure tends to have a greater impact on the Icelandic króna than in more liquid foreign exchange markets (see Chart 25).[26]

Conclusions

In 2006-2008, the volatility of the Icelandic króna has been elevated in the wake of country-specific and global shocks amid large domestic macroeconomic imbalances. These shocks and imbalances lifted the average realised volatility of the Icelandic króna up to the high end among developed market currencies, and the average is now slightly above countries like New Zealand and Australia. However, the average volatility remains substantially below that of other high-yielding emerging market currencies. In 2008, foreign exchange volatility has been extremely elevated. From a policy-maker's perspective, excessive exchange rate volatility is not desirable because it increases the cost of international trade and financial transactions, as well as raising the cost of hedging this risk. In Iceland, foreign exchange volatility is likely to have a greater impact than it would have in a larger country, simply due to the fact that the Icelandic economy is very small and open, it faces a rapid and large asymmetric exchange rate pass-through to general price levels (see Pétursson, 2008), and it has a high degree of domestic financial indexation. In addition, consumers' and businesses' sizable debt in foreign currency makes exchange rate volatility more costly and may reduce the effectiveness of the exchange rate's response to external shocks. Going forward, as domestic imbalances fade and inflation becomes better anchored to the inflation target, the Central Bank will be able to reduce interest rates, which should contribute to lower foreign exchange volatility in the medium term.

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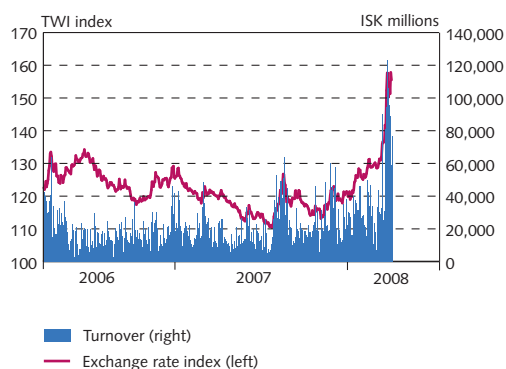
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Appendix: Financial Glossary[27]

At-the-money (ATM): An option whose strike is equal to the currency forward rate.

Call: An option that gives the holder the right (but not the obligation) to buy the underlying asset.

Delta: The ratio of the change in price of an option to the change in price of the underlying asset.

Forward contract: A contract that obligates the holder to buy or sell an asset for a predetermined price at a predetermined future time.

Implied volatility: The expected volatility in an asset's return derived from its option price, maturity date, exercise price, and the riskless rate of return, using an option pricing model such as Black-Scholes.

In-the-money (ITM): An option with non-zero intrinsic value. A call whose strike is below the current spot is ITM. A put whose strike is above the current spot is ITM.

Intrinsic value: The realised difference between spot (S) and strike (X) if exercised now, but no less than zero. Maximum(S-X,0) for a call and maximum(0,X-S) for a put.

Kurtosis: Measures the thickness of the tails of a probability distribution. A fat-tailed distribution has higher-than-normal chances of a big positive or negative realisation.

Mean: The average value of a random variable.

Option: Gives the buyer the right, but not the obligation, to buy or sell an asset at a set price on or before a given date.

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27. Source: http://www.bloomberg.com/invest/glossary and others.

Out-of-the-money (OTM): An option whose intrinsic value is equal to zero. A call whose strike is above the current spot is OTM. A put with strike below the current spot is OTM.

Put: An option granting the right (but not the obligation) to sell the underlying asset.

Realised volatility: While the implied volatility refers to the market's assessment of future volatility, the realised volatility measures what actually happened in the past.

Risk reversal: Simultaneously purchasing an out-of-the-money call option and selling an OTM put option.

Skewness: Negative skewness means there is a greater-than-normal probability of a big negative return. Positive skewness means that there is a greater-than-normal probability of a big positive return.

Standard deviation: The square root of the variance. A measure of dispersion of a set of data from its mean.

Strangle: A strangle is a combination of a call and a put with the same expiry date, but with a different strike price.

Strike price: The price at which the underlying asset may be purchased (in the case of a call) or sold (in the case of a put) by the option holder upon exercise of the option contract.

Variance: The mathematical expectation of the average squared deviations from the mean.

Volatility: A measure of risk based on the standard deviation of the asset return.

Volatility smile: The variation of implied volatility with strike price.