Parallels in the exchange rate movements of major currencies

Parallel exchange rate movements of individual currencies can often be seen on the foreign exchange markets. These striking patterns can have a variety of different causes. For example, pegging one currency to another necessarily leads to a co-movement of their exchange rates vis-à-vis a third currency. But co-movement is also often seen between floating exchange rates, brought about, among other things, by spillover effects. Such parallel exchange rate developments stand out particularly after events that lead to pronounced market reactions, for example after the announcement of the Eurosystem's expanded asset purchase programme, the turmoil on the foreign exchange markets in connection with the Turkish lira in the summer of 2018, and after the referendum on the United Kingdom leaving the European Union.

In order to examine whether these illustrative observations represent a systematic pattern, relationships between the exchange rates of major advanced economies are estimated using an econometric model. This identifies three currency blocs whose exchange rates display systematic relationships and even recognises contemporaneous causal relationships between the exchange rates using a machine learning algorithm.

Key determinants for inclusion in the identified currency blocs include the intensity of trade links and financial ties, patterns of trade and expectations regarding economic policy risks. One of these blocs comprises three European currencies (the euro, the Swedish krona and the Norwegian krone), the underlying economies of which are all part of the European Economic Area. A second bloc comprises the Australian dollar, the Canadian dollar and the New Zealand dollar, i.e. currencies of countries that are relatively major commodity exporters. Finally, the approach identifies a bloc comprising the Swiss franc, the US dollar and the Japanese yen. These are safe haven currencies or carry trade financing currencies, which tend to appreciate in times of high financial market stress.

Introduction

Parallels in exchange rate movements can have several causes, …

On the foreign exchange markets, parallels can often be observed in bilateral exchange rate movements. These parallels can have a variety of different causes. However, similar exchange rate movements often indicate that the currency areas concerned have common economic characteristics. For example, similar exchange rate movements can indicate that the respective central banks have the same monetary policy anchor or at least a similar monetary policy orientation. Co-movement of exchange rates often also reflects market participants' expectations and assessments. If, for example, country-specific market turmoil results in a number of other currencies also depreciating, this could be because market participants in these countries regard the risk of contagion effects to be particularly high.

… which makes them more difficult to interpret

Although common exchange rate movements often reflect economic ties or economic policy linkages, the fact that they are observed does not, in itself, provide any indication of the specific cause of such relationships. Precisely because there are so many possible causes, observation must be paired with expert knowledge for a meaningful interpretation.[1] The purpose of this article is therefore to present parallels in the movements of selected exchange rates, identify systematic relationships, and analyse them with theoretical considerations in mind.

The phenomenon of parallel exchange rate movements by way of three examples

Parallel exchange rate responses following the adoption of the Eurosystem's expanded asset purchase programme

Adoption of the APP …

On 22 January 2015, the Governing Council of the ECB adopted the expanded asset purchase programme (APP) in response to a series of negative surprises in the inflation rate and declining inflation expectations in the euro area. It included, among other things, a public sector purchase programme and thus enabled the Eurosystem to greatly increase the volume of its asset purchases from its previous level. Such a monetary policy easing can lead to a depreciation of the euro via a number of channels.[2]

… led to strong reactions on the foreign exchange markets

Indeed, immediately afterwards, there was a sharp depreciation of the euro against a number of major currencies. As the ECB reference rates had already been determined (14:15 CET) by the time the decision on the APP was announced (during a press conference as of 14:30), the earliest visible market reactions were the changes in the reference rates from 22 to 23 January 2015. Measured by the daily rate of change in effective terms, this period saw the second-largest depreciation of the euro ever. However, developments in the effective euro exchange rate do not allow any conclusions to be drawn on co-movements between currencies. For this to be done, it is necessary to examine bilateral or, if necessary, additional effective exchange rates.[3]

1 See Kühl (2010).
2 See Deutsche Bundesbank (2017).
3 Effective exchange rates are not examined in the analyses covered by this article. Such an approach would entail additional difficulties such as the fact that different countries weight partner currencies differently.

The importance of the reference currency in estimating the relationships between bilateral exchange rates

In an econometric estimation of the relationships between bilateral exchange rates, the results depend crucially on the choice of reference currency. A reference currency is the currency to which a bilateral exchange rate refers. For example, in the case of an exchange rate for the euro and the US dollar of US$1.14 per euro, the euro is the reference currency. But the same exchange rate can also be expressed with the US dollar as the reference currency: €0.88 per US dollar. Each of the quotations is the inverse of the other, in this example:

$$1.14\frac{\text{US\$}}{\text{€}} = \frac{1}{0.88\frac{\text{€}}{\text{US\$}}}.$$

If potential parallels are to be drawn between the exchange rate movements of different currencies, it makes sense to express the exchange rates under review in a single reference currency. Only then are exchange rate developments comparable. But this also means that no relationships can be observed for the reference currency itself. Put in more general terms, for $N+1$ different currencies, only the relationships between N bilateral exchange rates can be analysed.[1]

Correlation or regression analysis is often employed to measure the relationships between exchange rates.[2] In the case of a regression analysis, for example, the impact of the rates of change in the exchange rate of one currency pair on the rates of change of another pair are estimated, with the reference currency being the same for all exchange rates under review. However, such an analysis is problematic if the exchange rate of one (or both) of the currency pairs under review is pegged against the reference currency or kept by and large stable by central bank measures. The rate of change used in the analysis would then be at least broadly constant, and the correlation or regression coefficient would contain scarcely any information on possible relationships. In such an instance, it would not be possible to establish, even for the currencies whose possible relationship is to be determined, whether or not they are related by a fixed exchange rate regime.

An appropriate reference currency for these analyses should therefore on no account be firmly pegged to one of the other currencies under review, nor should it be an anchor currency for the other currencies.[3] Ideally, the reference currency should not generally be correlated with other currencies under review.[4] As the correlations vary according to the currencies under review and the observation period, it is not possible to make a general statement about the ideal reference currency that would apply to all analyses. For this reason, completely different reference currencies are

1 Much the same would apply for effective exchange rates if an effective exchange rate were calculated for each currency. The effective exchange rate of currency $N+1$ could be derived from the exchange rates of the N other currencies. One drawback of using effective exchange rates, however, is that the weights on which their calculation is based vary from country to country. As a result, the observed rates of change are comparable to only a limited extent.
2 See Haldane and Hall (1991); Frankel and Wei (1994).
3 The crawling peg exchange rate regime, in which one of the two currencies depreciates against the reference currency by a static percentage in each period, would also cause statistical problems if, for instance, the other currency were pegged against the reference currency. If, in a regression equation, the rates of change in one exchange rate were regressed on the rates of change in the other as normal, the constant in the equation would reflect the exchange rate change trend caused by the central bank. By contrast, the regression coefficient of the rate of change in the exchange rate would not point to any relationship.
4 One way in which this could be assessed is to carry out additional estimations with alternative reference currencies. The literature also provides some suggestions (see, for example, Aloosh and Bekaert (2019) or International Monetary Fund (2019)).

Correlation coefficients for the rates of change of exchange rates based on the euro*

Currency	BGN	CNY	DKK	GBP	USD
BGN	1.00	.	.	.	.
CNY	0.01	1.00	.	.	.
DKK	– 0.01	0.13	1.00	.	.
GBP	0.02	0.41	0.03	1.00	.
USD	0.01	0.92	0.14	0.38	1.00

* The correlation coefficients provide information on the strength of the relationships between daily exchange rates in the period from the start of 2014 to the end of 2018. Currencies: BGN: Bulgarian lev, CNY: Chinese renminbi, DKK: Danish krone, GBP: pound sterling, USD: US dollar.

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Correlation coefficients for the rates of change of exchange rates based on the pound sterling*

Currency	BGN	CNY	DKK	EUR	USD
BGN	1.00	.	.	.	.
CNY	0.58	1.00	.	.	.
DKK	1.00	0.58	1.00	.	.
EUR	1.00	0.58	1.00	1.00	.
USD	0.56	0.94	0.56	0.56	1.00

* The correlation coefficients provide information on the strength of the relationships between daily exchange rates in the period from the start of 2014 to the end of 2018. Currencies: BGN: Bulgarian lev, CNY: Chinese renminbi, DKK: Danish krone, EUR: euro, USD: US dollar.

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often used in various studies in the literature.[5]

A correlation analysis of bilateral exchange rates with two alternative reference currencies clearly illustrates the problem.[6] The above tables show the correlation coefficients between the rates of change in each of the bilateral exchange rates. In the upper table, these are based on rates of change in euro exchange rates, while, in the lower table, they are based on exchange rates in which the pound sterling serves as the reference currency.

The currencies compared with each other here include the Bulgarian lev and the Danish krone. These two currencies are more or less firmly pegged to the euro – the Bulgarian lev via a currency board and the Danish krone as part of Exchange Rate Mechanism II. The exchange rates of these currencies therefore follow a very similar course over time, and the corresponding correlation coefficient should be very high and close to one. However, opting for the euro as the reference currency in the analysis would give rise to the problems described above. Despite the obvious co-movement of the two currencies, the correlation coefficient of -0.01 between them incorrectly suggests that the Bulgarian lev and the Danish krone are not correlated. By contrast, the table shows a high correlation between the US dollar and the Chinese renminbi (0.92). Indeed, the daily fluctuation band of the Chinese renminbi vis-à-vis the US dollar is tight. The pound sterling, too, is slightly correlated with these two currencies (0.38 and 0.41, respectively). The remaining correlation coefficients for the euro exchange rates are small.

Using the pound sterling as the reference currency shows clearer, economically plausible patterns: first, the Bulgarian lev, the Danish krone and the euro are perfectly correlated (1.00), while, second, the table also shows a high correlation between the Chinese renminbi and the US dollar (0.94). As the flexibility of both of these currencies is not restricted versus either the euro or the pound sterling, their correlation coefficient realistically captures their relationship to each other for both reference currencies. The two currency groups are also positively correlated with each other. However, the correlation between the groups, with correlation coefficients of 0.56 and 0.58, is significantly lower than within the groups. Nevertheless, there seems to be a not insig-

5 Instead of individual reference currencies, the literature also considers alternatives such as the currency basket of the International Monetary Fund's (IMF) special drawing rights as a reference (see Frankel and Wei (1993)).
6 The euro foreign exchange reference rates published by the ECB are used for the purpose of this analysis. They are therefore based on daily rates from the start of 2014 to the end of 2018.

nificant relationship between them. This is due in part to the fact that all exchange rates with the pound sterling have a common reference currency which influences the development of all of the exchange rates.

This example illustrates the grave implications that the choice of reference currency may have for the estimation results. Taking the euro as the reference currency completely eliminates the actually very high correlation between the Bulgarian lev and the Danish krone, as both currencies are pegged to the euro. As a result, it erroneously appears that the currencies are not linked. As described above, it is therefore impossible, when using euro exchange rates for the Bulgarian lev and the Danish krone, to differentiate in statistical terms between fixed and floating exchange rate regimes.

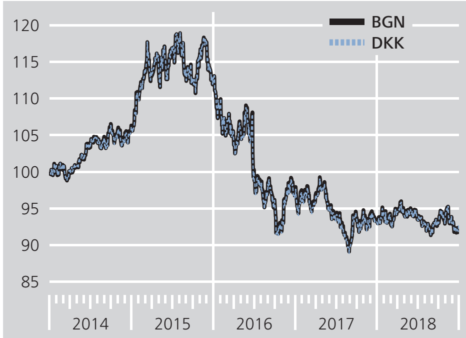
The need to select a reference currency that is, as far as possible, highly flexible against all currencies covered by the analysis is made more difficult by the fact that currencies are, de facto, often not as independent as portrayed by the authorities de jure. Some countries report that their currency is flexible, even though flexibility is in fact limited.[7] An overview of the actual exchange rate regimes of virtually all currencies is published at regular intervals by the IMF in its Annual Report on Exchange Arrangements and Exchange Restrictions.[8,9]

Moreover, some currencies tend to follow similar trends even without monetary policy intervention – in times of heightened financial stress, for example.[10] For the reasons cited above, such relationships should likewise be taken into account when selecting the reference currency.

For a time, use of the Swiss franc as reference currency was very widespread in the econometric analysis of possible relationships between exchange rates. However, the Swiss National Bank introduced a minimum exchange rate against the euro in September 2011, which it then repealed in January 2015. During this period, there were times where the Swiss franc's exchange rate against the euro barely deviated from the aforementioned minimum exchange rate. For that reason, the Swiss franc is, as a rule, no longer a suitable reference currency for this period. Instead, the pound sterling currently appears to be a relatively attractive reference currency. First, the Bank of England does not have an active exchange rate policy. Second, the pound sterling is not an anchor currency for any other currencies.[11] Third, it appears, generally speaking, to be only relatively weakly correlated with other currencies and to be relatively independent, even in times of heightened financial stress.[12]

Bilateral exchange rates of the pound sterling*

Daily rates, 2 January 2014 = 100



Sources: ECB and Bundesbank calculations. * A rise in values indicates an appreciation of the pound sterling. Currency codes: BGN: Bulgarian lev, DKK: Danish krone.

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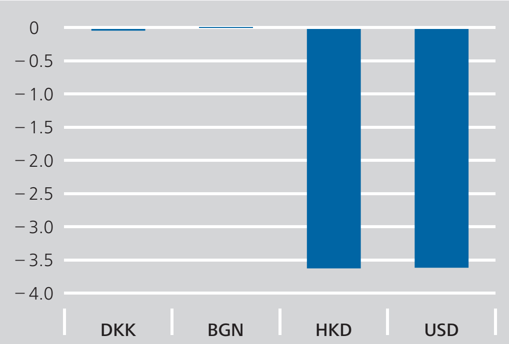
7 See Calvo and Reinhart (2002).
8 See International Monetary Fund (2019).
9 Some central banks, such as the Monetary Authority of Singapore, gear their exchange rate policy towards a basket of several currencies. What tend to be most problematic in statistical terms, however, are fixed exchange rates vis-à-vis individual currencies.
10 See Deutsche Bundesbank (2014).
11 See International Monetary Fund (2019). However, it may well be that some central banks which gear their exchange rate policy towards a basket of currencies also take account of the pound sterling.
12 See Hossfeld and MacDonald (2014) as well as Aloosh and Bekaert (2019).

Rates of change in the euro's exchange rates from 22 January to 23 January 2015*

%



Sources: ECB and Bundesbank calculations. * A negative value indicates a depreciation of the euro. Currency codes: DKK: Danish krone, BGN: Bulgarian lev, HKD: Hong Kong dollar, USD: US dollar.

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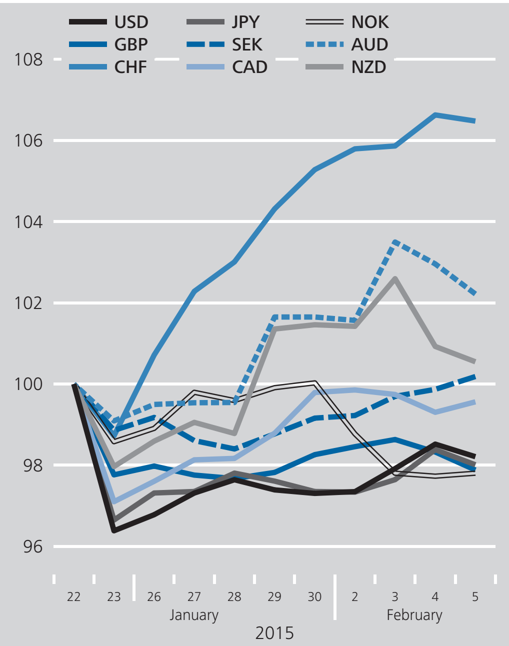
Bilateral euro exchange rates*

Daily rates, 22 January 2015 = 100



Sources: ECB and Bundesbank calculations. * A rise in values indicates an appreciation of the euro. Currency codes: AUD: Australian dollar, CAD: Canadian dollar, CHF: Swiss franc, EUR: euro, GBP: pound sterling, NOK: Norwegian krone, NZD: New Zealand dollar, SEK: Swedish krona, USD: US dollar, JPY: Japanese yen.

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Exchange rate regime decisive factor in exchange rate response

When looking at the response of bilateral euro exchange rates to the adoption of the APP, a distinction should first of all be made between fixed and floating exchange rate regimes. In the case of a fixed exchange rate regime, a central bank will, if necessary, intervene on the foreign exchange market to stabilise the exchange rate of its own currency vis-à-vis an anchor currency. This may, for example, be sensible if there are very close trade links or it may serve to enhance the credibility of the central bank in pursuing a stability-oriented monetary policy.

Fixed exchange rates often lead automatically to parallel developments

Fixed exchange rate regimes regularly directly lead to parallel exchange rate movements. This can also be seen in the response of bilateral euro exchange rates to the adoption of the APP, for example for currencies that are pegged either to the euro or the US dollar. As can be seen in the euro reference exchange rates at that time, there were no marked changes in the euro against the Bulgarian lev or the Danish krone. By contrast, the euro's movements against the US dollar and the Hong Kong dollar were relatively sharp, with the euro depreciating against both currencies by 3.6% the following day. Nevertheless, the movements of both euro exchange rates follow an almost identical pattern. Even over a longer period, the euro exchange rates of the Bulgarian lev and the Danish krone, on the one hand, and of the US dollar and the Hong Kong dollar, on the other hand, remain close to each other. In both cases, the reason for the co-movement of the exchange rates is the way the exchange rates of these currencies are set. While the Eurosystem and the Federal Reserve System allow the exchange rates of their currencies to be freely determined by the supply and demand of foreign exchange, the authorities in Bulgaria and Denmark peg their currencies to the euro and those in Hong Kong peg their currency to the US dollar.[4]

After adoption of APP, co-movement also observable between currencies with floating exchange rates, …

Fixed exchange rate regimes should therefore be noted as a first source of parallel exchange rate developments. Following the adoption of the APP, however, there were also parallels in the exchange rate movements of currencies which are subject to a flexible exchange rate

4 The International Monetary Fund (2019) provides an overview of the exchange rate regimes of almost all countries.

regime. From 22 to 23 January 2015, i.e. immediately following the announcement of the adoption of the APP, the euro depreciated significantly not only against the US dollar, but also against the Japanese yen (-3.4%). Comparatively large losses were also seen against the Canadian dollar (-2.9%), the pound sterling (-2.2%) and the New Zealand dollar (-2.0%). The euro fell less strongly against a group of European currencies comprising the Norwegian krone (-1.4%), the Swiss franc (-1.3%) and the Swedish krona (-1.1%). It depreciated only slightly against the Australian dollar (-0.9%).

… for example between the Australian dollar and New Zealand dollar or between the US dollar and the Japanese yen

The immediate exchange rate response was, for instance, fairly similar in terms of the sharp depreciation of the euro against the US dollar and the Japanese yen. The same is true of the somewhat less pronounced reactions of European currencies. These correlations between the aforementioned euro exchange rates remained largely intact for the remainder of the period under review. For example, in the two weeks following the adoption of the APP, a significant co-movement is observable for the currencies of Australia and New Zealand, despite the initially divergent responses. Furthermore, over this two-week period, the US dollar and the Japanese yen also move virtually in unison. Finally, the sharp appreciation of the euro against the Swiss franc is striking, decoupling the Swiss currency from its co-movement with the Swedish krona and the Norwegian krone.[5] Possible reasons for these parallel exchange rate movements of currencies not subject to a fixed exchange rate regime are discussed below, following the analysis of two further exemplary episodes of exchange rate co-movement.

Parallel exchange rate reactions after the UK referendum on leaving the European Union

On 23 June 2016, a referendum was held in the United Kingdom on whether the country should leave the European Union (EU). A majority of just under 52% of votes cast were in favour of withdrawal. This outcome of the referendum appeared to come as a surprise to many market participants, which can be seen, among other things, from the response on the foreign exchange markets. The pound sterling depreciated very sharply against all other currencies of advanced economies, both on a daily and two-week view.

Massive depreciation of the pound sterling in the wake of the referendum on leaving the EU …

… as an example of co-movement caused by an extraordinary impulse to the reference currency

The exchange rates of all currencies under consideration against the pound sterling followed a rather similar path in the two weeks following the vote. A further reason (besides the exchange rate regime) for the co-movement in exchange rates is even more apparent here than after the adoption of the APP: if the exchange rate of all other currencies is expressed vis-à-vis a single reference currency, such as the pound sterling in this case, parallel movements in exchange rates occur if the reference currency is shaken by an event of such magnitude that it overshadows stimuli from all other currency areas. In this case, it can therefore be assumed that the depreciation of the pound was primarily attributable to the referendum result and not to country-specific events in the other currency areas.

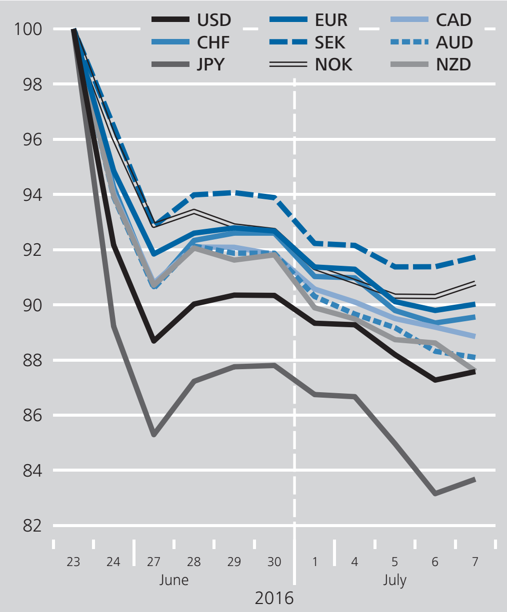
Parallel exchange rate movements as a result of common reassessment of economic outlook

Despite the above-mentioned similarities across all pound sterling exchange rates, differences can also be observed, as co-movement between certain exchange rates is tighter than between others. For example, the pound sterling depreciated less strongly against the European currencies under consideration than against non-European currencies. This implies that non-European currencies not only appreciated against the pound sterling, but also against other European currencies. Market par-

5 The Swiss franc experienced relatively large exchange rate fluctuations in this period. On 15 January 2015, i.e. before the announcement of the APP, the Swiss National Bank suspended the franc's exchange rate floor vis-à-vis the euro, resulting in strong reactions in the foreign exchange markets. This triggered a marked short-term appreciation of the Swiss franc against the euro, followed by a counter-reaction. This can be seen clearly in the chart on p. 22.

Bilateral exchange rates of the pound sterling*

Daily rates, 23 June 2016 = 100



Sources: ECB and Bundesbank calculations. * A rise in values indicates an appreciation of the pound sterling. Currency codes: AUD: Australian dollar, CAD: Canadian dollar, CHF: Swiss franc, EUR: euro, GBP: pound sterling, NOK: Norwegian krone, NZD: New Zealand dollar, SEK: Swedish krona, USD: US dollar, JPY: Japanese yen.

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ticipants clearly assumed that the now expected withdrawal from the EU would weaken not only the British economy, but also the economic development of other European countries, albeit to a lesser extent. The parallel exchange rate developments are therefore a reflection of a similar reassessment of the economic outlook in some countries, in divergence from the assessment of other countries.

Correlations in exchange rate movements seen on a recurring basis

A look at the percentage changes in various pound sterling exchange rates from the day of the referendum on 23 June 2016 to the following day, calculated from the euro reference exchange rates, reveals a further peculiarity. For example, as in the case of the adoption of the APP, exchange rate movements against the Japanese yen (-10.8%) and the US dollar (-7.8%) were particularly pronounced. There were almost identical percentage changes against the Australian dollar (-6.1%), the New Zealand dollar (-6.0%) and the Canadian dollar (-6.0%). The pound sterling also lost slightly more ground against the Swiss franc (-5.7%) than against other European currencies. As mentioned above, the depreciation against European currencies such as the euro (-5.1%), the Norwegian krone (-3.9%) and the Swedish krona (-3.5%) was less marked. These rates show that, in most cases, the currencies with similar exchange rate movements are the same as those following the adoption of the APP. Once again, the Japanese yen and the US dollar exhibit the strongest exchange rate reaction. In addition, parallels are observable between the currencies of commodity exporting countries and between some European currencies. These relationships are also strikingly persistent over time. Parallel exchange rate movements of unpegged currencies are therefore also not necessarily a one-off phenomenon, but can be observed on a recurring basis.

Parallel exchange rate reactions to the Turkish lira's weak streak in the summer of 2018

Strong depreciation of the Turkish lira against the US dollar in the summer of 2018

In the summer of 2018, the Turkish lira fell sharply against the currencies of advanced economies.[6] The appreciation of the world's most important currency, the US dollar, against the Turkish lira was partly attributable to a trade conflict between Turkey and the United States. A number of monetary policy measures were only able to slow the lira's slide temporarily. The US dollar's appreciation against the Turkish lira from 9 to 10 August 2018 (+12%) as well as over the weekend of 10 to 13 August 2018 (a further +14%) was particularly striking, bringing the US currency to a new all-time high against the lira.

6 To analyse these exchange rate movements, the exchange rates used here are expressed against the US dollar as the reference currency. This is because a number of emerging market economies tend to orientate their monetary policy to the US dollar without operating a genuine fixed exchange rate regime. As the US dollar is used as the reference currency, US dollar effects between the exchange rates are masked. At the same time, the links of the observed emerging market currencies to the US dollar are not so strict as to make it impossible to interpret correlations between US dollar-based exchange rates.

Appreciation of the US dollar also against currencies of advanced economies

Such a sharp appreciation in the foreign exchange markets is comparatively rare and therefore drew a lot of attention from market participants. From Thursday, 9 August, to Monday, 13 August 2018, the US dollar also rose against the currencies of most other major economies. The currency appreciation was, however, far smaller than against the Turkish lira: +1.7% against the euro, +1.0% against the pound sterling, +1.9% against the Swedish krona, +0.9% against the Canadian dollar, +1.5% against the Norwegian krone, +2.0% against the Australian dollar, and +1.2% against the New Zealand dollar. The exchange rate remained virtually unchanged against the Swiss franc. The US dollar depreciated only against the Japanese yen.

Co-movement between currencies considered particularly safe

The US dollar therefore gained in value against all observed currencies except for the Swiss franc and the Japanese yen. This is interesting, as the latter two currencies are considered safe haven currencies or carry trade financing currencies and tend to appreciate in times of financial market turmoil.[7] The exchange rate responses at the time thus suggest that uncertainty on the foreign exchange markets increased over these days and the security of safe haven currencies and carry trade financing currencies was sought after (as carry trades became less attractive). A co-movement of exchange rates can therefore also arise if several currencies are considered to be particularly safe in times of crisis. A parallel movement of exchange rates already stood out in the aforementioned examples, at least for the US dollar and the Japanese yen.

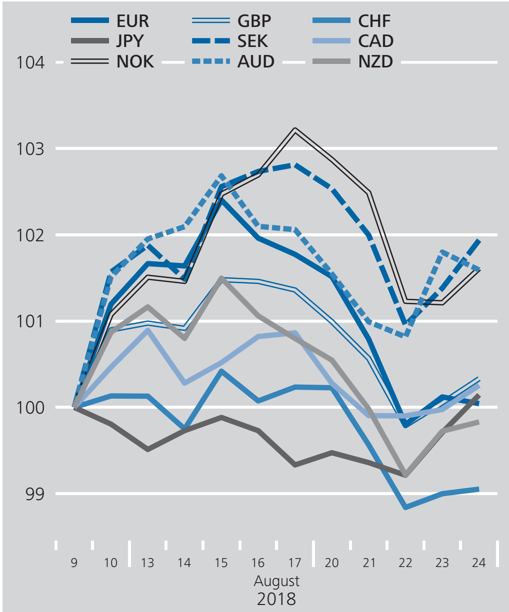
Appreciation of the US dollar also against other emerging market currencies

Ultimately, the question arises as to whether a correlation existed between the Turkish lira and other emerging market currencies during this period. Indeed, between 9 and 13 August 2018, the US dollar not only appreciated against the Turkish lira, it also rose by 6.5% against the South African rand. It also gained markedly against the Brazilian real (+3.1%), the Indian

7 See Deutsche Bundesbank (2014).

Bilateral US dollar exchange rates of currencies of advanced economies*

Daily rates, 9 August 2018 = 100



Sources: ECB and Bundesbank calculations. * A rise in values indicates an appreciation of the US dollar. Currency codes: AUD: Australian dollar, CAD: Canadian dollar, CHF: Swiss franc, EUR: euro, GBP: pound sterling, NOK: Norwegian krone, NZD: New Zealand dollar, SEK: Swedish krona, USD: US dollar, JPY: Japanese yen.

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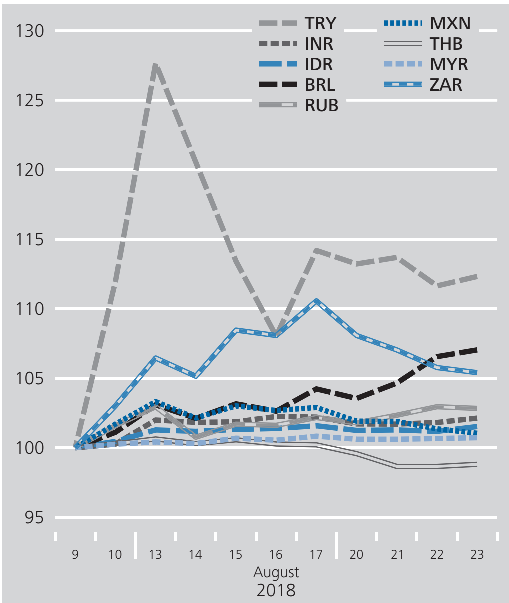
Bilateral US dollar exchange rates of currencies of emerging market economies*

Daily rates, 9 August 2018 = 100



Sources: ECB and Bundesbank calculations. * A rise in values indicates an appreciation of the US dollar. Currency codes: BRL: Brazilian real, INR: Indian rupee, IDR: Indonesian rupiah, MXN: Mexican peso, MYR: Malaysian ringgit, RUB: Russian rouble, THB: Thai baht, TRY: Turkish lira, ZAR: South African rand.

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rupee (+2.0%), the Indonesian rupiah (+1.3%), the Mexican peso (+3.3%) and the Russian rouble (+2.9%).

Spillover of the crisis from Turkey to other emerging market economies?

Looking at subsequent exchange rate developments, the reactions of the South African rand and the Brazilian real were the most pronounced – alongside those of the Turkish lira. The exchange rates of other emerging market economies followed paths that were more in line with those of the advanced economies. The relatively strong appreciation of the US dollar against the rand could indicate that investors may have expected the crisis to spill over from Turkey to South Africa. With regard to such a conclusion, however, it should be noted that country-specific events may also have contributed to the simultaneous depreciation of the South African rand. For example, discussions at the time about expropriations of land in South Africa led to uncertainty among investors, which also weighed on the rand. This example shows that it is very difficult to distinguish between economic developments that happen to occur at the same time and contagion effects as the cause of parallel exchange rate developments.

Empirical analysis of the relationships between exchange rates of advanced economies

Systematic relationships between currencies?

In the above examples, recurring parallel exchange rate movements were identified for some currencies, for example for the US dollar and the Japanese yen. In addition, the exchange rates of some European currencies such as the euro, the Swedish krona and the Norwegian krone followed relatively similar paths. Finally, co-movement in exchange rates was also repeatedly observed for the Australian dollar and the New Zealand dollar.

Analysis of connectedness using empirical methods

The observation of co-movements in these examples arises thus far only from descriptive statistics and is not in itself evidence of systematic relationships. In order to be able to draw any substantive conclusions, it is necessary to estimate connectedness using statistical methodologies.

Analytical framework of the estimation

For analysing issues of this kind, an approach developed by Diebold and Yılmaz (2009, 2014) has become established in the economic literature. It is based on the underlying assumption that there are simultaneous and lagged correlations between economic time series, such as those on exchange rates, and that developments in these time series are driven by unexpected events, known as shocks or innovations. In this analytical framework, there is a strong connectedness between two time series if the innovations of one time series have a relatively high impact on the development of the other time series.[8]

Machine learning methods for estimating causal links

Since then, this general approach has been further enhanced and applied to different economic variables such as bond yields, default risk, and even rates of change in exchange rates. It became clear that it was particularly difficult to determine contemporaneous causal relationships.[9] Bettendorf and Heinlein (2019) show how this can be achieved using machine learning methods.[10]

Estimate for the period from January 2010 to December 2017 confirms the existing assumptions …

This approach was used to estimate the relationships between the rates of change for the currencies of the advanced economies already analysed in the examples. It involved observing the daily rates of change in the exchange rates of the currencies, with the pound sterling as the reference currency.[11] The pound sterling was selected as the reference currency because it displays relatively low correlation with other currencies (see pp. 19 ff.). The picture that

8 This approach is designed to estimate connectedness between the variables. Such connectedness is also identified if the variables systematically move in opposite directions.
9 In this context, causality does not refer to an economic model, meaning that the relationships between the exchange rates cannot be explained using economic reasons. Instead, it should be considered as a purely data-based, statistical concept in this case.
10 See pp. 29 ff.
11 The ECB's euro reference exchange rates for each trading day are used as the data source.

emerges for the analysis period from January 2010 to December 2017 confirms the relationships previously observed in the examples.

… and identifies three blocs with parallel exchange rate movements

The model measures strong connections within a bloc of European currencies (the euro, the Swedish krona and the Norwegian krone). It also identifies a bloc of currencies comprising the Canadian, Australian and New Zealand dollar. The strong co-movement between the exchange rates of these three currencies can be put down to the fact that they represent countries that rely relatively heavily on commodities exports. Finally, the model assigns the Swiss franc, the US dollar and the Japanese yen to a common bloc. Indeed, these currencies do also appear to share common ground. They are used in the financial markets as safe haven currencies or carry trade financing currencies and therefore tend to appreciate during periods of financial market turmoil.

Spillover effects significant in terms of exchange rate variability

Overall, 62.2% of the total variability in the rates of change in the exchange rate can be explained by reasons that are specific to the exchange rate under review.[12] The remaining 37.8% of the total variability, on the other hand, can be attributed to the influence of other exchange rates – spillover effects, in other words.

Estimation results largely consistent with those of other studies

All in all, the empirical model can prove the existence of systematic links between individual exchange rates, which, to a large extent, could already be observed in the examples shown above. The currency blocs identified appear economically plausible and are also consistent with the findings of other studies. Greenwood-Nimmo et al. (2016), for example, find similarly strong relationships between the Australian dollar and the New Zealand dollar, as well as between the European currencies mentioned above. However, their study cannot reach any definite conclusions regarding the contemporaneous direction of causality. Because the study uses the US dollar as the reference currency, the relationships between safe haven currencies and carry trade financing currencies are not clear, either.[13]

Rates of change of various exchange rates after selected events*

	APP decision	Brexit referendum	Turmoil in emerging market economies
Currency	EUR	GBP	USD
CHF	– 1.3	– 5.7	0.1
JPY	– 3.4	– 10.8	– 0.5
SEK	– 1.1	– 3.5	1.9
CAD	– 2.9	– 6.0	0.9
NOK	– 1.4	– 3.9	1.5
AUD	– 0.9	– 6.1	2.0
NZD	– 2.0	– 6.0	1.2
EUR	–	– 5.1	1.7
GBP	– 3.6	–	1.0
USD	– 2.2	– 7.8	–

Sources: ECB and Bundesbank calculations. * The table shows the rates of change for bilateral exchange rates after selected events: decision to adopt the expanded asset purchase programme (APP) (change from 22 to 23 January 2015), euro rates; Brexit referendum (change from 23 to 24 June 2016), pound sterling rates; turmoil in emerging market economies (change from 9 to 13 August 2018), US dollar rates. Currency codes: AUD: Australian dollar, CAD: Canadian dollar, CHF: Swiss franc, EUR: euro, GBP: pound sterling, NOK: Norwegian krone, NZD: New Zealand dollar, SEK: Swedish krona, USD: US dollar, JPY: Japanese yen.

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Causes of parallel exchange rate movements

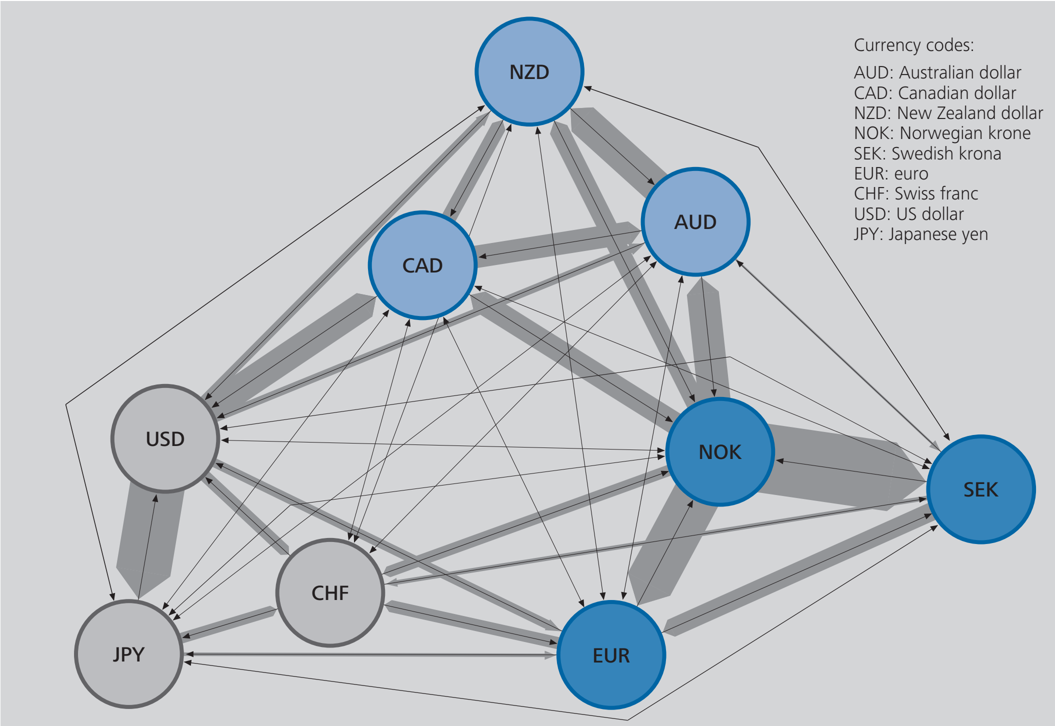
Classifying the economic causes of parallel exchange rate developments

Together with the empirical analysis, the examples above show that it is possible to provide evidence of systematic relationships between the exchange rates of different currencies. Examples of potential economic causes for the parallel movements identified have already been put forward. These causes can be divided into four categories:

12 The term "total variability" refers to the total forecast error variance of the underlying model. A description of the variance decomposition can be found on pp. 29 ff.

13 Greenwood-Nimmo et al. (2016) perform a generalised forecast error variance decomposition. This approach does not allow any conclusions to be drawn about contemporaneous causal effects.

Connectedness between currencies of advanced economies*



* The width of the connecting lines reflects the estimated strength of the connectedness between the currencies. Currency blocs estimated by Bettendorf and Heinlein (2019) are indicated by different background colours.
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A fixed exchange rate regime

– If a country's monetary policy is geared towards stabilising the exchange rate of the domestic currency vis-à-vis a particular anchor currency, the exchange rates of these two currencies expressed in an independent third currency are, naturally, very similar or even identical. This was illustrated by the example above, which showed different exchange rate responses to the Eurosystem's decisions regarding the APP. The US dollar and the Hong Kong dollar – which is pegged to the US dollar – each appreciated against the euro by exactly the same percentage. Parallel exchange rate movements that result from fixed exchange rate regimes are not deemed to be spillover effects because the choice of exchange rate regime – in this case fixing or stabilising rates – is an independent decision taken by each individual country.

– Leaving aside fixed exchange rate regimes, the causes of parallel developments in flexible exchange rates can be assigned to three other categories. For instance, co-movement between exchange rates develops vis-à-vis a reference currency if the currency is hit by a domestic impulse strong enough to overshadow all other disruptive factors stemming from the other currency areas. Again, this phenomenon could be observed in the euro exchange rates in the wake of the adoption of the APP – but particularly after the announcement of the results of the United Kingdom's referendum on withdrawing from the EU. The exchanges rates of many other currencies against the pound sterling showed fairly similar movements for weeks thereafter. Here, too, it is not a spillover effect between exchange rates that is responsible for their co-movement. On the contrary, if there were spillover effects from the reference currency to other currencies, the relationship between the other currencies would tend to weaken.

Major fluctuations in the reference currency

Estimating the causal relationships between bilateral exchange rates using machine learning methods

Relationships between time series can be estimated in various different ways. The current analysis presents an econometric method of estimating relationships between the rates of change of bilateral exchange rates following the approach of Diebold and Yılmaz (2009, 2014), which is established in the economic literature. This method is based on a reduced-form vector autoregression (VAR) model:

$$y_t = \Phi y_{t-1} + \epsilon_t,$$

where y_t represents a vector with observations of all K endogenous variables. In the case at hand, these variables are the rates of change of bilateral exchange rates, defined in relation to a single reference currency. The $(K{\times}K)$ Φ matrix contains regression coefficients that relate to the observations of endogenous variables, lagged by one period (y_{t-1}). The variable ϵ_t denotes the error term that cannot be explained by the model.[1] In the VAR model, therefore, the exchange rates at time t are explained by the rates of the preceding period. The VAR model above can also be expressed in the form

$$y_t = \Theta(L)\epsilon_t$$

(moving average representation), where L is the operator for delayed error terms (lag operator). This is defined by $Ly_t = y_{t-1}$. The lag polynomial is thus given as $\Theta\ (L) = (\mathrm{I} - \Phi\ \ L)^{-1}$,[2] meaning that the exchange rates at time t represent the sum of all previous disturbances.

In structural form, i.e. when the VAR model is transformed in such a way that the u_t error terms (shocks) are uncorrelated, the model is written as

$$y_t = A(L)u_t.$$

Here, $A(L) = \Theta\ (L)B_0^{-1}$ and $u_t = B_0\epsilon_t$, where B_0 in Diebold und Yılmaz (2009) corresponds to the Cholesky decomposition of the covariance matrix of ϵ_t.[3] However, these results are, to a certain extent, arbitrary, as they are dependent on the order of the variables in y_t on account of the Cholesky decomposition.[4]

In the following, the forecast error variance of the observed variables is decomposed into the contributions made by individual shocks.[5] This allows us to determine how strongly the shock to a particular equation of the system impacts upon other exchange rates. Using an appropriate reference currency,[6] these effects can thus be interpreted as spillover effects. The optimal forecast value for y_{t+1} at time t is calculated as $y_{t+1,t} = \Phi y_t$, where the forecast error is $e_{t+1,t} = y_{t+1} - y_{t+1,t} = \mathrm{A}_0 u_{t+1}$.[7] This has the covariance matrix $E(e_{t+1,t}e'_{t+1,t}) = A_0A'_0$, whereby, according to the definition, vari-

1 A constant term and additional lags are dispensed with in order to present the methods as clearly as possible. When estimating the model, the number of lags is determined with the help of the Akaike information criterion.
2 A geometric series is used here to present the time series in the form of an infinite weighted sum of the error terms.
3 In Diebold and Yılmaz (2009), a Cholesky decomposition (see Lütkepohl (2007)) is used to orthogonalise the error terms. However, other appropriate approaches exist, such as the PC algorithm described below.
4 From an economic perspective, a specific order cannot be assumed in the case of a VAR model consisting solely of exchange rates, either.
5 The difference between an observation and a point estimate calculated with the model is known as a forecast error. It can be explained by individual innovations (u_t). As the difference can assume positive or negative values, the forecast error variance is calculated by means of squaring. Breaking this down into the contributions of innovations therefore yields general information about the innovations that are significant to the development of individual variables.
6 See pp. 19 ff.
7 A_0 refers to the contemporaneous element of the lag polynomial $A(L)$, i.e. B_0^{-1}.

ances lie on the diagonals and the off-diagonal entries contain the covariances.

The share of forecast error variance of the j^{th} variables, which is explained by variable k following h periods (forecasting horizon), is the product of

$$\omega_{jk,h} = \frac{\Sigma_{i=0}^{h-1}(c_j' A_i c_k)^2}{\Sigma_{i=0}^{h-1}\Sigma_{k=1}^{K}(c_j' A_i c_k)^2} = \frac{\Sigma_{i=0}^{h-1} a_{jk,i}^2}{\Sigma_{i=0}^{h-1}\Sigma_{k=1}^{K} a_{jk,i}^2},$$

where c_k is the k^{th} column of the identity matrix I_K.

Calculated in this way, the shares of the individual variables as a proportion of the total forecast error variance of other variables can be directly interpreted as spillovers. This clearly demonstrates that both the simultaneous and the lagged relationships between the variables play a role here. However, this approach has the disadvantage that its results are strongly dependent on the underlying structure of contemporaneous exchange rate effects, and therefore the order of exchange rates in vector y_t, on account of the Cholesky decomposition. This means that the estimated connectedness is also influenced by the order of the variables. Contemporaneous causal effects based on such estimates can therefore only be meaningfully interpreted if information about the causal structure between the variables is available a priori. This is, however, generally not the case, especially where financial market variables such as exchange rates are concerned.

In such cases, then, it makes sense to use alternative methods for which the order of the variables is unimportant.[8] Bettendorf and Heinlein (2019) applied such a method to the rates of change of the following currencies' exchange rates[9] against the pound: the Australian dollar (AUD), the Canadian dollar (CAD), the Swiss franc (CHF), the euro (EUR), the Japanese yen (JPY), the Norwegian krone (NOK), the New Zealand dollar (NZD), the Swedish krona (SEK) and the US dollar (USD). The ECB's euro reference exchange rates (daily data) were used as the data source for the period from the start of 2010 to the end of 2017.

The causal structure of the contemporaneous effects is not predetermined in this case; rather, it is estimated with an algorithm featured in the literature on machine learning, namely the PC algorithm, which is now used in many structural VAR analyses (see Kilian and Lütkepohl (2017)).[10] On the basis of (partial) correlation tests, this algorithm seeks to identify the causal structure between the residuals of the reduced form VAR model (ϵ_t).[11] If the causal structure of the residuals has been estimated, the matrix B_0, which depicts the contemporaneous effects, can be defined accordingly.[12] Here, a zero restriction is set if no significant stimulus is simultaneously transmitted from one exchange rate to another. If the algorithm recognises that no relationships exist between a sufficient number of variables,

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8 Diebold and Yılmaz (2014), for instance, use a generalised forecast error variance decomposition. This produces results which are independent of the sequence of the variables in the vector y_t. However, it does not allow any conclusions to be drawn about contemporaneous causal effects.
9 In the present study, rates of change in the exchange rates are approximated by the first differences of the logarithmic exchange rates.
10 The PC algorithm derives its name from those of its developers, Peter Spirtes and Clark Glymour.
11 Owing to the complexity of the algorithm, we forego a description here and refer only to Spirtes et al. (2001).
12 In this context, it is important that the algorithm detects a directed acyclic graph, or in other words, that no bidirectional, undirected or cyclic relationships exist between the residuals. The model would otherwise not be identified. In cases where the PC algorithm can identify no such graphs, it makes sense to subject the reduced form VAR model to a bootstrapping process and to save the results of the PC algorithm for each estimate. The direction of the relationships, which could not be clearly ascertained by the PC algorithm originally, can ultimately be determined by their relative frequency in the bootstrapping process. This approach is based on that of Hoover and Demiralp (2003) and Demiralp et al. (2008).

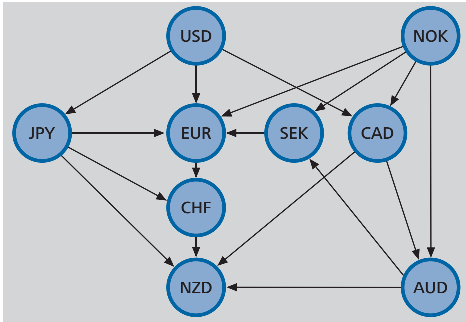
more than the single $(K-1)\times K$ zero restriction necessary to identify the model can be applied to the matrix B_0, making the structural VAR model overidentified. Assuming that the restrictions are correct, this tends to produce a more detailed picture of connectedness.

The algorithm yields the graphs shown on the right. It describes the structure of the contemporaneous effects between the residuals of the estimate (ϵ_t). It can be seen that the US dollar and the Norwegian krone are both relatively independent of each other, and that they affect other currencies at the same time. By contrast, movements in the exchange rates of the Swiss franc and the New Zealand dollar in relation to the pound sterling are largely in response to price movements in other currencies. However, these are only the contemporaneous effects. In order to also take lagged influencing factors into account, a structural VAR model (SVAR model) is estimated using the obtained information on the contemporaneous causal structure of the residuals.[13] The forecast error variance decomposition can also be calculated using the method described above.

The results for a forecast horizon of ten days are presented in the table on p. 32.[14] The analysis suggests that, during the period under review, 37.8% of the total forecast error variance determined using the model for all nine observed exchange rates was explained by foreign shocks, i.e. spillover effects. This share corresponds to the sum of the entries on the off-diagonals divided by the total share of the nine variables (900%).

In light of all the uncertainty surrounding such econometric analyses, it can be said that the results confirm the assessment already derived from an examination of the contemporaneous causalities alone. Over the review period, the US dollar and the

Estimated causal structure of the residuals of the VAR model*



* Currency codes: AUD: Australian dollar, CAD: Canadian dollar, NZD: New Zealand dollar, NOK: Norwegian krone, SEK: Swedish krona, EUR: euro, CHF: Swiss franc, USD: US dollar, JPY: Japanese yen.
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Norwegian krone in particular were relatively independent of influences from abroad, looking at the calculations based on their exchange rates against the pound, but they had a comparatively strong impact on other currencies. The influence of the US dollar on the Japanese yen and the Canadian dollar was particularly strong. The Norwegian krone had a relatively strong influence on considerably more currencies, but chiefly the Swedish krona and the euro. The Swiss franc and the New Zealand dollar, by contrast, barely influenced other currencies. Exchange rate movements of the euro were influenced not only by the US dollar, but also by the Norwegian krone and the Swedish krona. The euro itself influenced, in particular, the Swiss franc, which was probably due to the temporary introduction of a minimum exchange rate against the euro by the Swiss National Bank.

The comparatively strong influence of the Norwegian krone on other currencies is a surprising finding. These spillover effects

13 If the causal structure is known, the model can be estimated on an equation-by-equation basis using the method of least squares.
14 The forecast horizon of ten days is customary in the literature (see, for example, Diebold and Yılmaz (2009, 2014)). Here it is assumed that financial market shocks are processed no later than ten days after the event.

Variance decomposition of forecast errors*

Share (%)

Currency	AUD	CAD	CHF	EUR	NOK	NZD	SEK	USD	JPY	Total
AUD	53.0	16.8	0.1	0.0	24.1	0.0	0.0	5.9	0.1	100.0
CAD	0.1	61.6	0.1	0.1	16.8	0.0	0.0	21.2	0.1	100.0
CHF	0.1	0.0	61.9	9.1	8.4	0.0	3.5	8.9	8.0	100.0
EUR	0.5	0.3	0.1	39.6	36.1	0.0	13.8	6.9	2.7	100.0
NOK	0.4	0.1	0.0	0.0	98.6	0.0	0.2	0.2	0.5	100.0
NZD	24.3	11.2	0.4	0.0	14.5	42.3	0.0	6.6	0.6	100.0
SEK	1.6	0.6	0.0	0.0	52.0	0.0	45.1	0.3	0.5	100.0
USD	0.2	0.1	0.0	0.1	0.2	0.0	0.0	99.3	0.0	100.0
JPY	0.0	0.0	0.0	0.0	0.3	0.0	0.1	41.2	58.4	100.0

* Respective share of the variance of the forecast error of the variables in row j which is explained by shocks to the variables in column k ($\omega_{jk,10}$). All currencies as exchange rates based on the pound sterling. Currency codes: AUD: Australian dollar, CAD: Canadian dollar, CHF: Swiss franc, EUR: euro, NOK: Norwegian krone, NZD: New Zealand dollar, SEK: Swedish krona, USD: US dollar, JPY: Japanese yen.

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could be due to a commodity factor impacting on different currencies. This may also affect currencies that are not classified as commodity currencies. Similarly, the established impact of the Swedish krona on the euro may ultimately be a Norwegian krone-based secondary effect.

The results of the estimation can be used to group the currencies under review into currency blocs with the aid of a cluster analysis. A currency bloc is defined in such a way that it includes only those currencies that are relatively closely connected to each other.[15] In contrast to the approach used in Deutsche Bundesbank (2012), only the relationships estimated from the rates of change in the exchange rates in the model are taken into account.[16] The results suggest that the observed currencies can be divided into three blocs: commodity currencies, comprising the Australian dollar, the Canadian dollar and the New Zealand dollar; a bloc of European currencies, namely the euro, the Norwegian krone and the Swedish krona; and a bloc of safe haven currencies and carry trade financing currencies comprising the Swiss franc, the US dollar and the yen. The distinction between these blocs can also be seen in relation to events which had a significant influence on the pound sterling. While the pound depreciated against all major currencies in the first two weeks following the referendum on the United Kingdom remaining in the European Union, for example, it depreciated by very similar amounts against the currencies within each individual bloc.[17]

This approach is not above criticism.[18] For instance, when examining the results, it must be borne in mind that in the absence of any theoretical specifications, the shocks are identified using empirical tests alone (at a significance level of 10%, in this case). Amongst other things, therefore, there is a risk that the null hypothesis will (erroneously) not be rejected. Consequently, under the null hypothesis, the model is not necessarily correct. Furthermore, Kilian and Lütkepohl (2017) criticise this approach as being ill-suited to revealing economically significant structures. However, this criticism is less relevant to the approach presented here, as only a general exchange

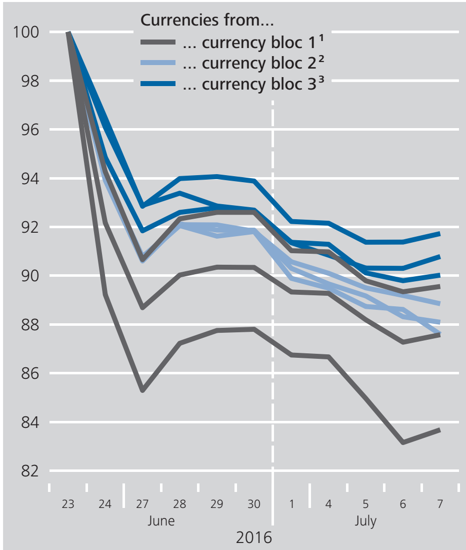
15 The Louvain algorithm created by Blondel et al. (2008), which is commonly used in the literature, and the proposed extension of modularity for directed graphs in Dugué und Perez (2015) were used to achieve this.
16 Alternatively, currency blocs can be obtained from the data on de facto exchange rate regimes provided by the International Monetary Fund; see Deutsche Bundesbank (2012) and Fischer (2016).
17 However, the bloc of safe haven currencies and carry trade financing currencies is an exception in this case.
18 See Kilian and Lütkepohl (2017).

rate-specific shock has to be identified, without it being split into economically interpretable components. This approach merely identifies empirical causalities between the exchange rates without trying to interpret them. Simulations also show that in spite of potential distortions, such relationships are often estimated considerably more accurately than when using the methods hitherto employed.[19]

19 See the Monte Carlo experiments in Bettendorf and Heinlein (2019), which indicate this under equivalent assumptions.

Bilateral exchange rates of the pound sterling by currency bloc*

Daily rates, 23 June 2016 = 100



Sources: ECB and Bundesbank calculations. * A rise in values indicates an appreciation of the pound sterling. **1** Safe haven currencies and carry trade financing currencies: the Swiss franc, the US dollar and the Japanese yen. **2** Commodity currencies: the Australian dollar, the Canadian dollar and the New Zealand dollar. **3** European currencies: the euro, the Norwegian krone and the Swedish krona.

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Coincidences

– Exchange rates also show parallel movements when two currencies happen to be influenced by domestic stimuli which are independent of one another, but cause unidirectional exchange rate movements. It is not usually possible to provide solid evidence of such a phenomenon. However, it is possible that this was the case in the summer of 2018, when the Turkish lira was weakened by trade disputes, inter alia, and the South African rand by uncertainty regarding land ownership. Naturally, there is no question of these cases being attributable to spillover effects.

Spillover effects and similarities

– Spillover effects involve one currency having a real systematic impact on another. Here, the cause of the co-movement may originate in one of the two currency areas in question (spilling over from one to the other). However, it may also stem from events in third countries that spill over to the two currencies being observed. A similar situation occurs when foreign exchange market participants attribute a shared characteristic relating to foreign exchange investments to several currency areas. One example of this would be a currency area whose main characteristic is that it exports commodities. The currencies of these countries would thus tend to respond in similar ways to changes in commodities prices. It is not always possible to separate spillover effects from similarities because the underlying cause of a change in commodities prices, for example, could be attributable to a country-specific event whose economic effects spread to other countries and exchange rates. Spillover effects and similarities are usually the focus of economic, but also academic, interest. This is because they are typically responsible when the exchange rate of a currency shifts vis-à-vis a number of other currencies as a result of external factors.

Spillover effects between exchange rates can be triggered by a variety of economic phenom-

Spillover effects and exchange rate determinants

ena. To be able to explain them, it makes sense to first provide a brief overview of the key factors determining exchange rates. Following on from this, the causes of spillover effects between exchange rates can then be deduced.

Determinants of exchange rate movements: inflation differentials, …

In the medium to long term, differences between price movements in individual countries play an important role in determining exchange rates (purchasing power parity theory). If prices in one country increase comparatively slowly, demand for the goods this country supplies – which are now cheap in relative terms – goes up, as does demand for its currency. The currency in question tends to appreciate. It should be noted, however, that a corresponding adjustment process can take a long time. In the short term, especially where inflation differentials are comparatively low, the opposite effect can often be seen. If a surprisingly low inflation rate is published for a currency area, its currency initially tends to depreciate because market participants then see a greater likelihood of domestic monetary policy being eased.

… interest rate spreads, monetary policy and real income

According to the theory of uncovered interest parity, an unexpected domestic interest rate cut leads, all else being equal, to a depreciation of the local currency because rational investors adjust their portfolios towards investments that promise higher returns.[14] Similar effects on the exchange rate are posited for an expansion of the money supply or quantitative easing of monetary policy. All other things being equal, a rise in domestic real income ultimately increases currency demand, thus leading to an appreciation of the relevant currency.

Market participants' expectations, effects from third countries, and global factors

Of course, in many cases, it is not variations in the actual determinants themselves that lead to an adjustment in the exchange rate. Instead, exchange rates tend to react as soon as indicators lead market participants to change their expectations of the determinants. Moreover, the causes of the changes in the determinants are not necessarily to be found in the observed currency areas themselves. Global risks or changes in third countries, for instance, can also influence these determinants.[15] For example, an increase in global risk perception often sees market participants transfer capital to "safe haven" countries such as the United States or Switzerland. The US dollar and the Swiss franc tend to appreciate as a result of these capital flows.

The following section now presents channels via which unidirectional movements in the above-described determinants of exchange rates, and hence spillover effects, may take place.

Common changes in determinants as a result of international trade, …

One classic transmission channel is the international trade in goods and services. International trade links make it easier for economic cycles to spill over to other countries. Take, for example, an economic crisis that is initially limited to one country and whose effects include a decline in real incomes and lower aggregate demand.[16] Not only would this tend to lead to a depreciation of the domestic currency, but also to a reduction in imports of goods from other countries. As a result, the country's major trading partners would also see a decline in aggregate demand and thus a reduction in income. In turn, the currencies of the countries indirectly affected would also tend to depreciate. In this case, the collective depreciation of the currencies would reflect the intensity of the trade links between the countries involved.

14 Empirical evidence for uncovered interest parity, however, is not very strong (see, for example, Deutsche Bundesbank (2005) or Chinn (2006)). In contrast to the interest rate parity theory, the monetary model of exchange rate determinants argues that rising interest rates increase the propensity to save and reduce demand for currency for transaction purposes. This causes the domestic currency to depreciate.
15 See Bettendorf (2019).
16 According to the monetary model of exchange rate determination, lower real income leads to reduced demand for currency. If the money supply were to stay the same, this would lead to a higher (goods) price level. As a result, the domestic currency depreciates according to the purchasing power parity theory. It should be noted that this model only describes the long term, in which prices are usually assumed to be flexible. Nonetheless, in the short term, too, international investors tend to move their funds away from countries that are starting to show signs of an economic downturn. This then also tends to be accompanied by a depreciation in the short term.

… international financial markets …

The international financial markets represent another transmission channel. For example, if close financial links exist, both domestic and foreign investors will be affected by asset price losses in a particular country. As a consequence, negative wealth effects could unfold in both countries.[17] Lower demand for goods would reduce the gross domestic product of both countries. A historical example of spillover effects via international financial markets is the financial crisis of 2008. Credit defaults in the United States caused both US and foreign banks significant losses. Some of these foreign banks had purchased securitised loans in the United States and were thus directly affected by the credit defaults and asset price losses there. This was among the factors that caused lending to decline in several countries simultaneously and the crisis to spread internationally. Ultimately, the currencies of countries hit harder by the crisis would be expected to depreciate against the currencies of those countries that were less strongly affected. In this example, the degree of international financial interconnectedness plays a crucial role. As a result of the spillover described above, parallel movements would become apparent in the exchange rates of countries that tend to have close financial ties with the country in which the crisis originated.[18]

… or market participants' expectations

Market participants' expectations represent a further transmission channel. These expectations can affect the exchange rates as described above, even if their usual determinants remain unchanged. If said expectations relate to several different currency areas, for example because they are deemed to have shared characteristics, this can lead directly to parallel movements. Generally speaking, expectations can apply to all determining factors such as the interest rate differential, inflation differentials or even common risks (risks for emerging market economies).

Potential transmission channels within the identified currency blocs

The described spillover effects and similarities between currency areas presumably also played a part in the co-movement of the exchange rates within the currency blocs identified. The relatively strong trade and financial links between the euro area and the Scandinavian countries could have an important bearing on the clear connections between the euro, the Norwegian krone and the Swedish krona. These links can transmit changes in the determinants of the exchange rates, thus resulting in parallel movements. A second bloc containing safe haven currencies and carry trade financing currencies consists of the Swiss franc, the Japanese yen and the US dollar. As described above, these countries' currencies are influenced in part by market participants' expectations of global risk, which can lead to parallel movements in their rates. The third bloc comprises the Australian dollar, the Canadian dollar and the New Zealand dollar. The currencies of commodity exporting countries often respond in similar ways because these countries have similar trade patterns.

Conclusion

Parallel exchange rate developments can take place due to a range of factors. If, say, the currency of one country is pegged to that of another as a result of a fixed exchange rate regime, the exchange rates of both currencies vis-à-vis a third currency will, of course, be very similar over time. But even without a fixed regime, systematic relationships between different exchange rates are apparent. Among the major currencies of the advanced economies, an empirical analysis identifies three blocs which show evidence of systematic parallel exchange rate movements since 2010. The mechanisms that bring about such co-movement in flexible exchange rates are many and varied. In the case of the blocs identified in the analysis, however, there are indications that important factors include the intensity of trade links and financial ties, patterns of trade, and expectations regarding economic policy risks.

17 Negative wealth effects ensue if falling asset prices mean that economic agents feel less affluent and therefore scale back their demand for goods.
18 See Borio (2012).

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