The Phillips curve as an instrument for analysing prices and forecasting inflation in Germany

Since the beginning of the financial crisis in summer 2007, it has become a particularly challenging endeavour to analyse and forecast price developments. In Germany, as in most of the other large industrial countries, the inflation rate fell considerably at first during the Great Recession. Once the economy rebounded, it went up again rather quickly until 2011; in 2012, it went back down noticeably and has remained surprisingly low amidst the positive developments in the labour market.

This article examines whether inflation developments in Germany over the past few years can be understood in the context of the Phillips curve, according to which there should be a positive short to medium-run relationship between the domestic inflation rate and capacity utilisation in the real economy and/or the labour market situation. The impact of the strong fluctuations in crude oil prices and food raw materials on consumer prices since 2007, too, is taken into consideration. The Phillips curve turns out to be quite good at explaining the development of both the headline inflation rate and what is often referred to as the core inflation rate (ie headline inflation excluding energy and food). However, the results suggest that, since 2009, core inflation has been significantly shaped by fluctuations in import prices (excluding energy), whereas headline inflation was predominantly affected by oil prices. Although the determinants of real economic activity, ie capacity utilisation and the labour market situation, have made a positive contribution to the inflation rate excluding energy and food since 2012, their impact is relatively low and, in many cases, not statistically significant. For headline inflation, the contribution made by the determinants of real economic activity, which goes beyond the impact implicitly contained in inflation expectations, was practically negligible according to estimates. In recent years, this is likely to have been attributable, amongst other things, to the fact that the output gap has virtually been closed since 2012.

No substantial change in the Phillips curve relationship is evident in the case of Germany. Merely the impact of external conditions appears to have increased somewhat since 2012. Regarding the forecast accuracy of the Phillips curve, the results are mixed. If it is realistically assumed that the path of the explanatory variables is unknown for the forecasting horizon, it would be possible to retrace the general direction of the core inflation rate since 2008; however, the innumerable Phillips curve forecasts do not always reflect actual price movements. The result for the headline inflation rate is considerably worse and can be attributed to the dominant influence of crude oil prices.

Inflation developments marked by surprises since 2008

Strong fluctuations in the inflation rate since mid-2008

Over the past few years, consumer price inflation in Germany has been marked by abnormally strong fluctuations. Measured in terms of the annual rate of change in the Harmonised Index of Consumer Prices (HICP), it initially increased from just under 2% in 2005 and 2006 to 3.2% in the third quarter of 2008. In the course of the Great Recession and amidst the wild swings in commodity prices, the annual rate of change in HICP fell by more than 3½ percentage points to -0.4% in the third quarter of 2009. In the two years that followed, the inflation rate started picking up again rather swiftly and, at 2.7%, reached its last peak to date in summer 2011. It subsequently went into a steady decline, going as low as -0.1% in the first quarter of 2015, and has remained at a subdued level ever since.

Discrepancy between expected and actual inflation

This development in the inflation rate came as a surprise to most experts. In 2009, the decline in the rate of inflation was underestimated, whereas lower inflation rates had been anticipated for the years between 2010 and 2012. From 2013 to 2015, the inflation rate again fell short of observers' expectations (see the chart on page 33). The majority of these misjudgements can probably be explained by surprising developments in the prices of commodities, as the fluctuations in consumer price inflation were largely attributable to price movements in the crude oil and food markets.

Bundesbank approach to analysing and forecasting price developments

When carrying out analyses and making forecasts relating to consumer prices, the Bundesbank draws on a large and diverse toolkit. Whereas a disaggregated approach[1] is chosen mainly for short to medium-term maturities, model-based approaches tend to be used for medium to longer-term maturities. The (New Keynesian) Phillips curve falls under the latter category. The underestimation of the inflation rate in 2010 to 2012 and the subsequent overestimation could therefore be attributed to structural changes in the Phillips curve, which are reflected, for instance, in a lower impact of overall capacity utilisation on consumer price inflation.[2]

The relationship between inflation and the level of overall capacity utilisation in the context of the New Keynesian Phillips curve[3]

The Phillips curve: basic version and …

Named after the economist A W Phillips,[4] the most basic version of the curve describes the empirical relationship between the general rate of price change and the cyclical position of the real economy. As a rule, this relationship should be positive as employees benefit from improved economic growth through rising wages, which, in turn, encourages businesses to pass at least some of the cost of the wage increases on to consumers in the form of higher prices. In addition, the negotiating power of unions increases during a period of economic upswing as unemployment declines, which likewise tends to add to cost pressures on prices.

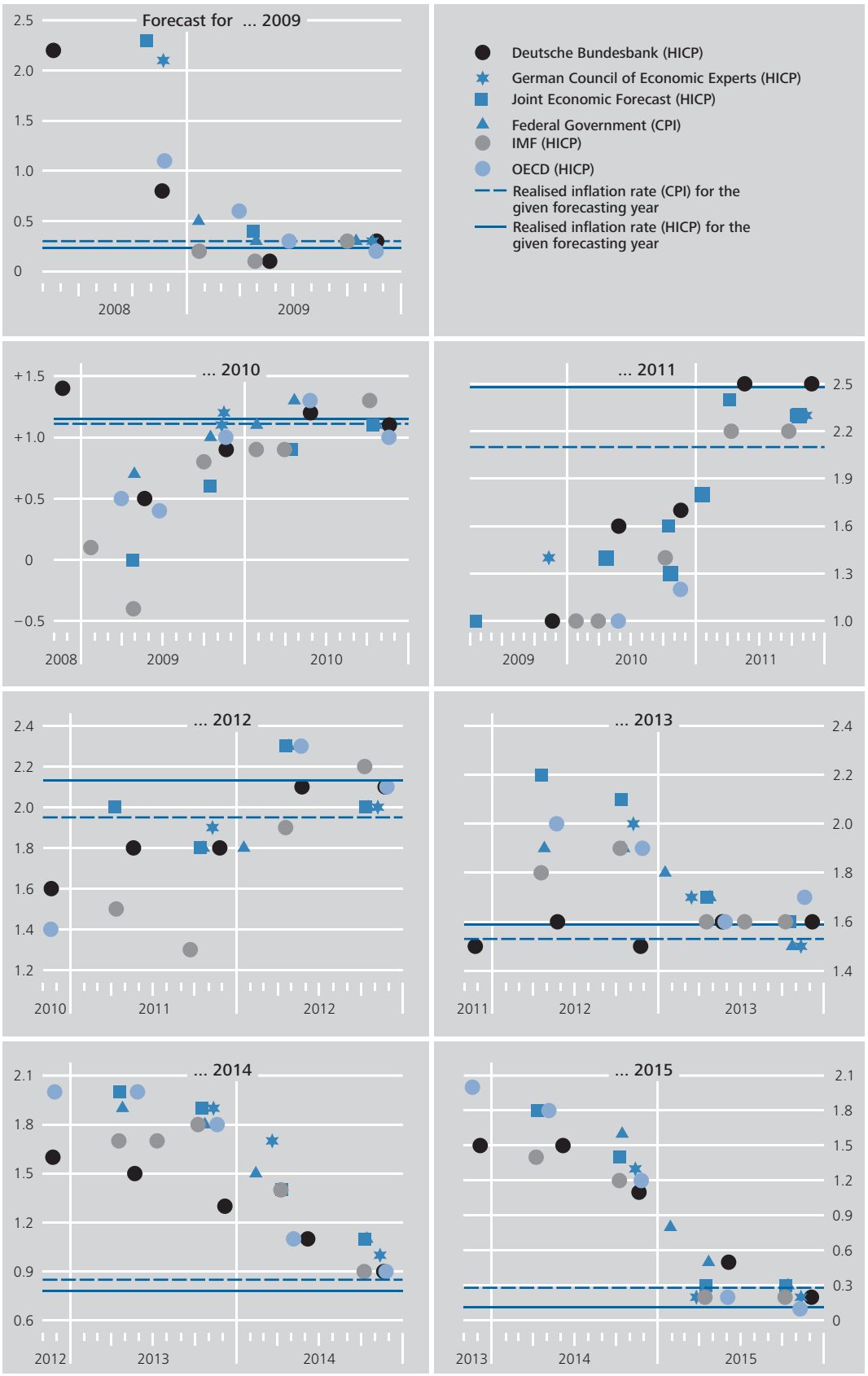
… modified versions

Over the past 50 years, the Phillips curve has time and again been the subject of contentious debate, leading to numerous modifications of the original specification. The New Keynesian Phillips curve, which is currently the most widely used version of the curve, is applied below. In addition to the impact of real economic activity, the current inflation rate in the

1 In this context, the price developments of selected product groups (food, energy, etc) are forecast on the basis of a number of individual items of information, ultimately resulting in a forecast for overall consumer price movements.
2 Alternatively, wrong forecasts for real economic growth may be the reason why the inflation rate was misjudged. However, this analysis focuses solely on the utility of the Phillips curve.
3 The analysis in this section is based on work performed by the Low Inflation Task Force of the Eurosystem.
4 See A W Phillips (1958), The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861-1957, Economica, 25 (100), pp 283-299. The original Phillips curve focused on the relationship between wages and unemployment.

Inflation forecasts and results since 2009 (HICP and CPI)

%



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New Keynesian Phillips curve is positively correlated with market participants' inflation expectations, as businesses adjust their prices only sporadically and therefore also take into account potential future changes in the overall price level. External influences, too, are accounted for as the changes in prices of internationally traded goods (especially crude oil) are reflected directly in the production costs.

Multiple versions of estimation approach and data used

Several aspects, which are outlined in detail in the methodological annex, must be borne in mind when modelling and estimating the New Keynesian Phillips curve. A total of 72 versions, representing a combination of nine different capacity utilisation variables and eight different expectation indicators, are estimated in order to take due account of the uncertainty regarding the adequate specification of the Phillips curve (thick modelling approach[5]). The quarterly growth rate of real gross domestic product (GDP), estimates on the output gaps by the Bundesbank, the International Monetary Fund (IMF) and the European Commission, capacity utilisation in the manufacturing sector according to the ifo institute's survey, the headline unemployment rate, a short-term unemployment rate,[6] the unemployment gap[7] according to Bundesbank estimates, and an unemployment recession gap[8] are used to model overall capacity utilisation. For better comparability, capacity utilisation variables are scaled and the sign for unemployment measures is reversed.[9] Inflation expectations are based on the Consensus Economics forecasts[10] for the next six quarters, along with the European Commission's qualitative measure of household inflation expectations[11] and the average inflation rate of the last four quarters. The Phillips curve is estimated both for headline HICP and HICP excluding energy and food. The relevant annual rate of change in import prices excluding energy is used as a measure of external influences; in addition, the quarterly rate of change in oil prices in euro is used for headline HICP. All variables are available as from 1995.

Use of lagged variables to avoid endogeneity problems

The capacity utilisation variables and inflation expectations are included in the estimation with a one-quarter lag to avoid any potential endogeneity problems.[12] Merely the oil price is included as a contemporaneous variable, which can be justified both by the rapid transmission of oil price changes to the HICP's energy price component and the fact that the oil price is most likely to be interpreted as an exogenous variable. On the basis of these assumptions, the parameters for the Phillips curve can be estimated consistently.

Only models with "correct" parameter signs

In theory, all explanatory variables (capacity utilisation rate, inflation expectations, import and oil prices) should have a positive impact on the inflation rate. However, similar studies show that not all specifications are estimated with the correct sign.[13] To avoid misinterpretations, all variants in which at least one variable has a negative price effect are excluded below. In the case of the core inflation rate (HICP excluding energy and food), this applies to around one-quarter of all specifications. It essentially affects specifications using the GDP growth rate and the unemployment recession gap as

5 See C Granger, Y Jeon (2004), Thick modeling, Economic Modelling, 21, pp 323-343.
6 Share of persons who have been unemployed for less than one year in the labour force.
7 Actual unemployment rate excluding the non-accelerating inflation rate of unemployment (NAIRU).
8 Unemployment rate excluding the lowest rate of the last three years.
9 For scaling purposes, the mean value of each variable is subtracted and the result divided by the standard deviation. Unlike the output gap and GDP growth, unemployment measures should have a negative impact on the inflation rate as higher unemployment will result in lower wage growth, reducing cost pressures on businesses.
10 Once every quarter, Consensus Economics surveys experts from around 30 commercial banks and economic research institutions with regard to their expectations for the annual rate of change in the national consumer price index (CPI) in the current quarter and the next seven quarters, amongst other things.
11 Defined as the annual rate of change in the share of households which expect inflation to rise over the next year, less the share of those who assume that the rate of inflation will remain unchanged or fall.
12 Import prices have a lag of two quarters, increasing the accuracy of the estimates.
13 See S Mavroeidis, M Plagborg-Møller and J Stock (2014), Empirical evidence on inflation expectations in the New Keynesian Phillips curve, Journal of Economic Literature, 52(1), pp 124-188.

the explanatory variable. The estimated coefficients for inflation expectations and import prices are positive across the board. By contrast, around three-quarters of all variants must be excluded for headline HICP, which is almost exclusively attributable to the measures of unemployment. This is most likely due to the simultaneous decline in headline inflation and unemployment in recent years. Furthermore, a negative coefficient is incorrectly estimated when using inflation expectations over a period of five to six quarters. The at times relatively large number of Phillips curves that bear the wrong sign highlights the estimation uncertainty outlined. This is also reflected by the fact that the coefficient of the capacity utilisation rate, in particular, is often not statistically significant.

Can the inflation rate be explained by the Phillips curve *ex post*?

Inflation in Germany since 2012 explained by the Phillips curve

In a next step, it is examined whether the estimated Phillips curves can explain the development of both the headline inflation rate and the rate excluding energy and food retrospectively as from 2012.[14] To this end, the various specifications are initially estimated for the first quarter of 1995 to the first quarter of 2012 period. Inflation rates are subsequently forecast until the end of 2015, with the realised values being used as the explanatory variables. It is examined whether the Phillips curve relationship, which prevailed until 2012, would have been able to predict the subsequent decline in inflation if perfect knowledge about the development of the real economy, external prices and inflation expectations had been available.[15] The main aim of this exercise is to uncover any structural changes in the Phillips curve relationship that appear to have recently emerged in some euro-area countries. In particular, it is often argued that structural reforms could have increased price flexibility and, as a consequence, strengthened the impact of the real economic situation on inflation.[16]

Results: decline in inflation after 2012 replicated relatively successfully using the Phillips curve and …

The two charts on page 36 show the values for HICP excluding energy and food and for headline HICP estimated with the help of the Phillips curve. The charts depict the respective annual rates of change which were returned from the estimated and seasonally adjusted quarterly growth rates. In line with the introductory comments, the charts contain only the forecasts where the explanatory variables in the Phillips curve variants carry the correct sign. As illustrated, both inflation rates are explained quite successfully by the Phillips curve.[17] The slight overestimation of headline inflation for 2014 and 2015 is likely to be attributable to the fact that the negative impact of the oil price on consumer prices was inadequately modelled by the Phillips curve. In 2012 and 2013, HICP excluding energy and food leaned more towards the lower end of the spectrum spanned by the Phillips curves, whereas it was closer to the middle of the range in 2014 and 2015.

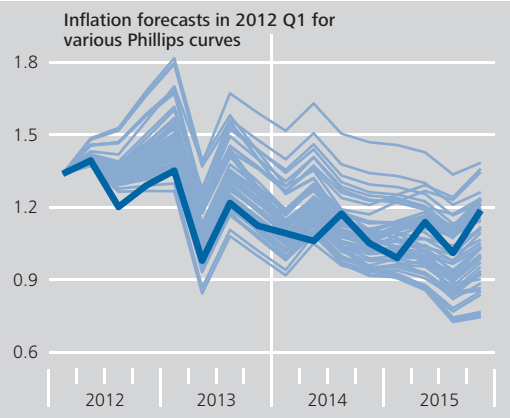
… in-sample forecasting accuracy depends on version of Phillips curve chosen

If the models are looked at from different angles in the form of the various capacity utilisation variables, using unemployment measures generally leads to an overestimation of core inflation, which can be explained by the (in a

14 This question is often discussed in the literature, too. See, for example, O Coibion and Y Gorodnichenko (2015), Is the Phillips curve alive and well after all? Inflation expectations and the missing disinflation, American Economic Journal: Macroeconomics, 7(1), pp 197-232. On more recent studies on the utility of the Phillips curve in Germany, see Deutsche Bundesbank, Cyclical sensitivity of the inflation rate in the euro area and in selected euro-area countries depending on the output gap estimate, Monthly Report, April 2014, pp 21-24; for the euro area, see ECB, The Phillips curve relationship in the euro area, Monthly Bulletin, July 2014, pp 99-114.
15 This procedure is a forecast inasmuch as the relevant estimated value of the preceding period is entered as the lagged inflation rate in the Phillips curve.
16 See, for example, M Riggi and F Venditti (2015), Failing to forecast low inflation and Phillips curve instability: a euro-area perspective, International Finance, 18(1), pp 47-67. The authors also discuss further factors which may have potentially contributed to an increase in real economic price sensitivity since the financial crisis, particularly in the euro area, Italy and France. These may include a decline in the number of businesses, which goes hand in hand with an increase in the desired mark-up on production costs, as well as an underestimation of the output gap.
17 With unemployment and inflation expectations for the fourth quarter as the explanatory variables, the model for core inflation deviates considerably from the other specifications.

Actual and estimated values for HICP excluding energy and food

Year-on-year percentage change



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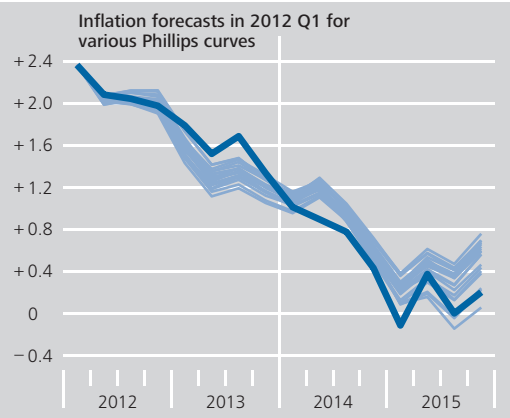
longer-term view) very low level of unemployment in recent years. On average, the model with the Bundesbank output gap provides the best result, whereas the models with the unemployment variables, in particular, deliver rather poor results. With regard to inflation expectations, those models containing household expectations and the consensus expectations for the fifth quarter provide the best estimation results, whereas models with the average past inflation rates and the consensus expectations for the fourth quarter are not as good at explaining core inflation.

Actual and estimated values for headline HICP

Year-on-year percentage change



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The model with the IMF's output gap delivers the best results for forecasting headline inflation. By contrast, models that use unemployment measures perform a great deal worse here, too. The best results in terms of the measures for inflation expectations regarding the headline rate are achieved with the average of past inflation rates combined with the consensus expectations for the second quarter.

Range used as measure of estimation uncertainty

Finally, comparing the ranges of the various specifications reveals that the estimates for core inflation, with the exception of the third and fourth quarters of 2015, exhibit a higher level of uncertainty than headline inflation estimates. On average, the Phillips curve boasts a corridor of ±0.5 percentage point for core inflation, while headline inflation has a range of merely 0.3 percentage point. However, to a considerable extent, this is due to the low number of theoretically "correct" Phillips curves for the headline inflation rate.

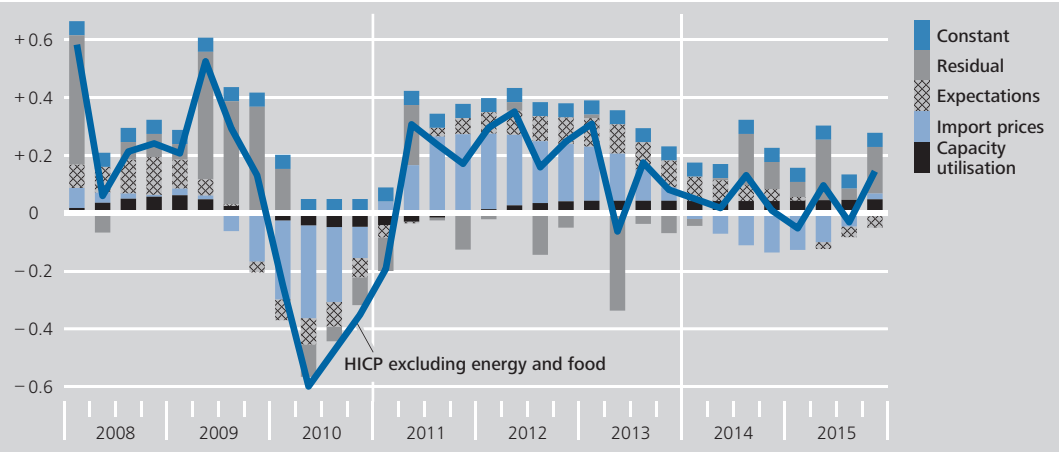
Significance of Phillips curve components for inflation rate: …

The differences in the results between the two inflation rates can largely be explained by the dominant influence of the oil price on headline HICP, which becomes clear when the contributions over time of the individual explanatory variables are calculated.[18] Annual rates of change are used for estimating the Phillips curves, as these tend to capture the mean trend and ignore short-term fluctuations caused by one-off effects.[19] The estimation period now also extends to the fourth quarter of 2015. A dynamic simulation can then be used to break down the actual inflation rate and identify the contributions of the individual explanatory variables. This involves setting the relevant variable to zero and simulating the inflation rate on the basis of all remaining variables. The respective contribution of each individual component is then given by the difference between these

18 See J Yellen (2015), Inflation dynamics and monetary policy, The Philip Gamble Memorial Lecture; and Banque de France (2015), Low inflation in the euro area: import prices and domestic slack, Rue de la Banque, Issue 6, pp 1-4.
19 Basing the estimates on quarterly rates of change delivers similar results.

Average estimated components of the core inflation rate based on the Phillips curve

Mean adjusted values



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results and the inflation rate estimated using all of the variables.

… influence of capacity utilisation on price movements low, impact of oil and import prices quite high

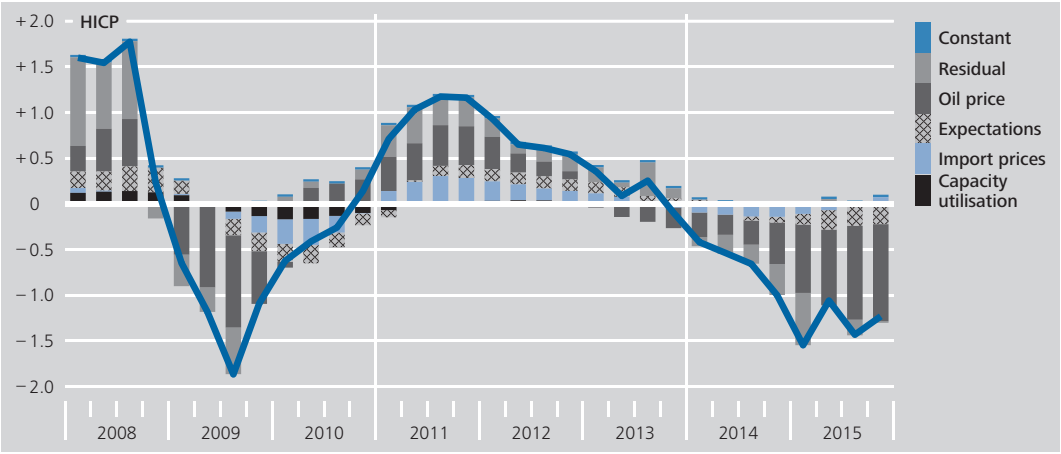
The charts both above and on page 38 depict the inflation rates decomposed in this way, although only the average contribution of the respective Phillips curve versions with the "correct" signs are shown. According to this breakdown, the core inflation rate can be largely explained by fluctuations in import prices since mid-2009. In the period directly following the Great Recession, import prices curbed the core inflation rate, whereas they tended to have a stimulating effect between 2011 and 2013. Then in 2014 and 2015, import prices tended to push core inflation back down. Inflation expectations, by contrast, made considerably less of an impact. After having contributed to the inflation rate's decline in the period directly following the outbreak of the crisis in 2009, these expectations re-established a positive impact on consumer price inflation between 2012 and 2014. The slightly negative result in 2015 could possibly be owing to the impact of the slump in oil prices, as these expectations relate to the headline inflation rate and this was strongly influenced by the oil price.[20] Finally, the breakdown of the various components' contributions suggests that the direct influence of aggregate capacity utilisation on the core inflation rate since 2012 may be positive yet relatively weak overall. However, it is conceivable that part of the impact of the real economic situation may be contained in the inflation expectations. This means that the results displayed in the charts may possibly understate somewhat the real economic situation's significance for the inflation rate. Furthermore, the capacity utilisation variables used suggest that the output gaps are virtually closed, which is why, according to the equations, these variables should not be assumed to have forced consumer prices upwards or downwards.

Changes in the headline inflation rate, on the other hand, are significantly influenced by the path of the oil price, which had a negative effect on the inflation rate in 2009 and again since 2013. Aggregate capacity utilisation's direct contribution to the path of inflation – which goes beyond the indirect effects possibly contained in other explanatory variables in the equation – is very low here as well.

20 For more information on the oil price's impact on inflation expectations, see, for example, O Coibion and Y Gorodnichenko (2015), op cit.

Average estimated components of the headline inflation rate based on the Phillips curve

Mean adjusted values



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Has the Phillips curve relationship changed since 2012?

No structural change in Phillips curve relationship since 2012

Next, the structure of the Phillips curve relationship is examined for changes since 2012, which could help to explain forecasting errors. One simple way to check for any changes is to estimate the model once up until 2012 and again up until the end of the sample in 2015 and then to compare the estimated values of the coefficients. Graphically, this can be represented by a two-dimensional system of coordinates, where the x-axis shows the estimated coefficients up until 2012 and the y-axis the estimated parameters to the present. If the value pairs fall approximately on the main diagonal (the 45° line), the respective determinants' influence on the prices has not changed since 2012. Values located above the 45° line, on the other hand, suggest an increased effect and values below this line a reduced impact.

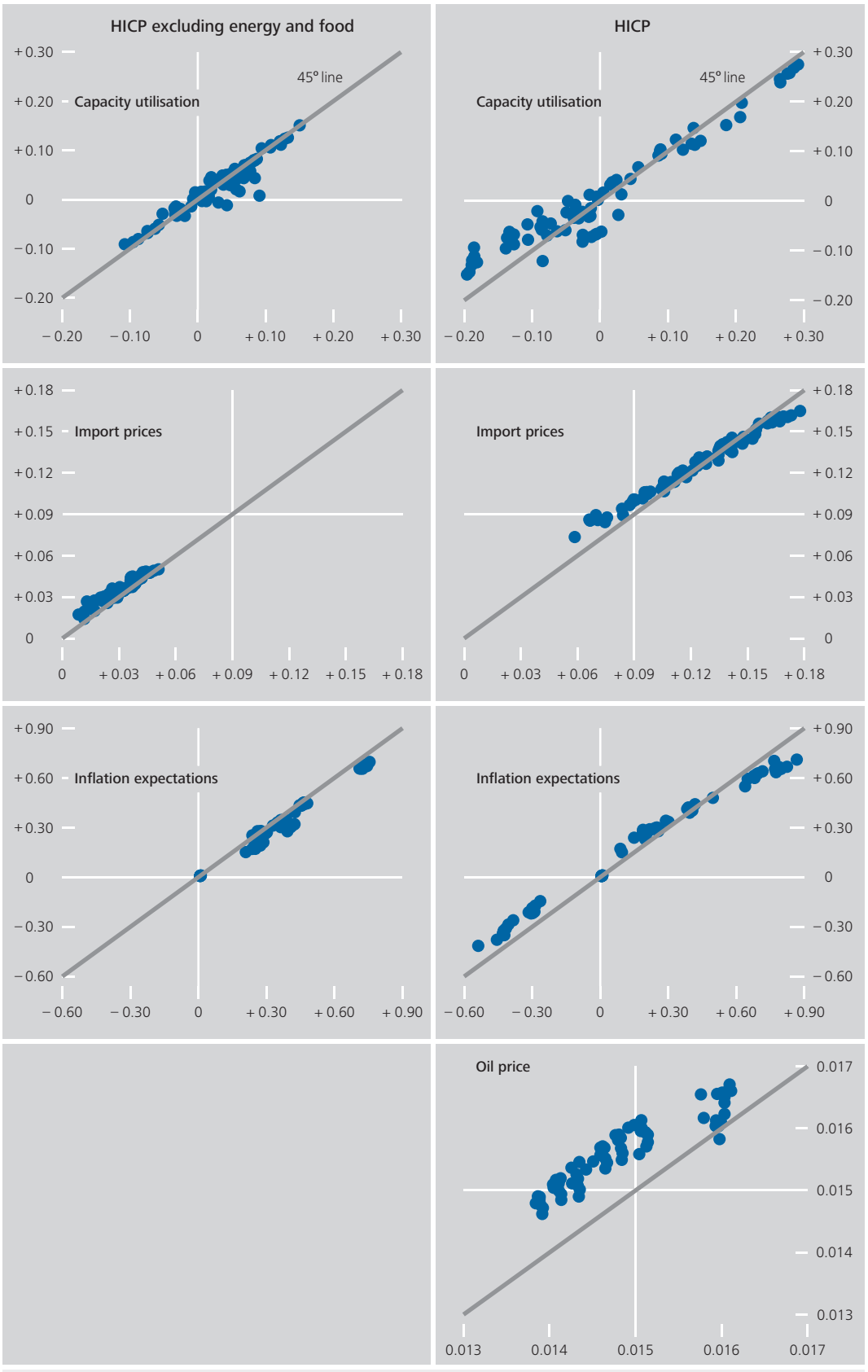
As the chart on page 39 shows, Germany's Phillips curve relationship appears to be quite stable overall. The estimated values for the coefficient that captures the real economic situation's impact on inflation remain very much unchanged over the extended estimation period, although they are often not statistically significant. The effect of import prices (and the oil price), by contrast, has grown somewhat. Since 2012, the core inflation rate seems to be slightly less strongly influenced by private sector price expectations.

Could the inflation rate since 2012 have been predicted *ex ante* using the Phillips curve?

Out-of-sample forecasts using the Phillips curve

Finally, the question of how well the inflation rate changes since 2012 could have been predicted using the Phillips curve and without knowledge of the actual values for the inflation determinants is investigated (a process referred to as "out-of-sample forecasting"). In the analysis thus far, the capacity utilisation rate, import prices, oil price and inflation expectations were all assumed to be known quantities. However, in order to properly forecast inflation, assumptions also need to be made about the explanatory variables' future paths. One option is to estimate the Phillips curve in the context of a larger system, such as a vector autoregressive (VAR) model, where the inflation equation of the VAR model is appropriately restricted in order to simulate the Phillips curve. In the specification presented here, the remaining model equations are also restricted insofar as each of the Phillips curve's explanatory variables is modelled and forecast using univariate autoregressive processes with four lags. The advan-

Estimated Phillips curve coefficients for 1995 to 2012 compared with 1995 to 2015*



* The x-axis shows the estimated Phillips curve coefficients for 1995 to 2012, while the y-axis covers the period from 1995 to 2015.
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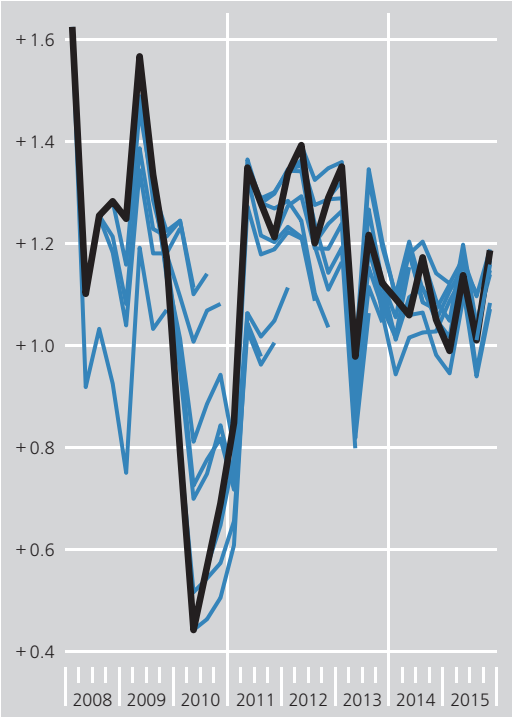
Actual and predicted values* for HICP excluding energy and food

Year-on-year percentage change



* Median of 72 individual quarterly forecasts.
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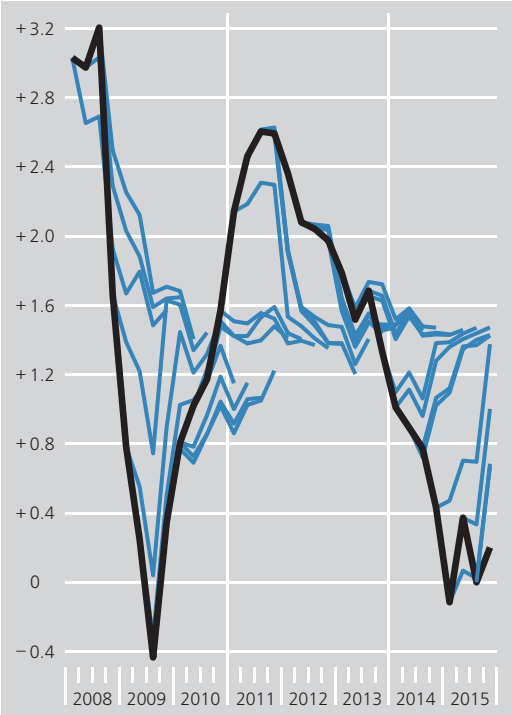
Actual and predicted values* for headline HICP

Year-on-year percentage change



* Median of 72 individual quarterly forecasts.
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tage of this approach is that, as opposed to using an unrestricted VAR model with four lags, considerably fewer parameters need to be estimated and the Phillips curve's theoretically derived form remains largely intact.[21, 22]

The adjacent charts show the inflation rates forecast using this approach. For each quarter starting from 2008, forecasts are made for a two-year horizon using all 72 versions of the Phillips curve. Both charts are limited to the median of the individual estimates so as to eliminate any extreme forecasts.

Phillips curve able to predict core inflation rate relatively accurately

Overall, the general thrust of the core inflation rate can be predicted quite accurately with the Phillips curve. However, these models are not able to reflect the surprisingly strong decline in the core inflation rate in 2010. For the headline inflation rate, the result is considerably worse. These models do not have the ability to capture the sharp drop in the inflation rate in 2009, and its subsequent rise is also underestimated by most models. Notably, the models do not predict the decline in inflation from 2014 onwards owing to the fact that the oil price slump is inadequately modelled by the basic AR process.

Conclusion

On balance, some versions of the New Keynesian Phillips curve are able to retrospectively ex-

21 The only difference from the single equation estimates used so far relates to headline HICP, as the oil prices are no longer contemporaneous inputs but instead have a lag of one period.
22 As an alternative to the restricted VAR estimate, the explanatory variables could first be extrapolated using individually estimated AR processes and these could then be used in the Phillips curve's single equation estimate. However, this approach is inefficient if exogenous shocks influence both the inflation rate and the explanatory variables, and the single equations are therefore indirectly correlated. The VAR model takes this correlation into account with its "seemingly unrelated regression" (SUR) equation and should therefore lead to better results. For a similar approach, see J Posch and F Rumler (2015), Semi-structural forecasting of UK inflation based on the hybrid New Keynesian Phillips curve, Journal of Forecasting, Vol 34, Issue 2, pp 145-162.

The risk of potential second-round effects in the current low-interest-rate environment

Given the persistently low inflation rates not only in the euro area but also in Germany, there has been growing talk of the risk of second-round effects potentially emerging.[1] This is generally understood as meaning that changes in the inflation rate will have an impact on wage growth,[2] which, in turn, could be reflected in a change in the rate of price increase. In the current situation, second-round effects would be said to occur if, in addition to the drastic decline in oil prices being reflected in inflation, the lower inflation rates were subsequently to encourage wage bargainers to reach lower wage agreements seeing as the fall in oil prices would lead to gains in real purchasing power in any case. From a monetary policy perspective, second-round effects are problematic in that they can amplify swings in the inflation rate and make a return to the price stability target more difficult.

During wage negotiations, wage bargainers base their positions not only on prices but also on other variables such as productivity growth or the labour market situation. Such additional determinants of wage formation should therefore be taken into account when analysing second-round effects. Moreover, the interaction between wages and prices is quite pronounced, which makes the identification of causality a challenging endeavour. In addition, the wage bargainers are likely, in a sense, to be looking not only at the current but also at the future inflation setting. There is no way of determining *a priori* which measure of prices will prevail in the wage discovery process, especially in Germany – a country with no statutory wage indexation mechanisms. In principle, the assertion can probably be made that, the more wage bargainers base their positions on past or present inflation and the greater the role played by short-run inflation expectations, the greater the risk of second-round effects will be. If longer-run inflation expectations, which should be as consistent as possible with the monetary policy target, play a major role, this is more likely to be conducive to stabilising the inflation rate towards the monetary policy target.

Against this background, wage Phillips curves have been estimated for Germany in which wage growth w_t is explained by the previous period's capacity utilisation x_{t-1} (in both the aggregate economy and the labour market), labour productivity p_t and past and expected inflation (π^{past} and π^{exp} in equation (1) and equation (2), respectively).[3]

$$w_t = \beta_0 + \beta_1 w_{t-1} + \alpha \pi_t^{past} + \beta_2 x_{t-1} + \beta_3 p_t + \varepsilon_t \quad (1)$$

$$w_t = \delta_0 + \delta_1 w_{t-1} + \gamma \pi_t^{exp} + \delta_2 x_{t-1} + \delta_3 p_t + \varepsilon_t \quad (2)$$

Based on this model, the risk of second-round effects is assumed to be particularly high in one or more of the following scenarios.

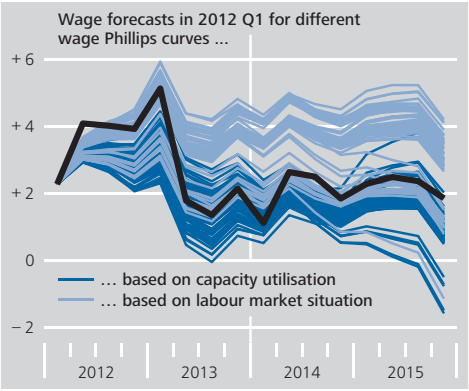
- Equation (1) explains wage growth better than equation (2) since, in this case, the wage bargainers tend to base their wage decisions more on past inflation than on expected inflation.

- Short-run expectations play a greater role than long-run expectations as they cause

1 See, for instance, Account of the monetary policy meeting of the Governing Council of the European Central Bank, presented in Frankfurt am Main, Germany on 20 and 21 January 2016 (http://www.ecb.europa.eu/press/accounts/2016/html/mg160218_content.en.html): "The sharp decline in oil prices and the downward shift in the oil futures curve had significantly dampened the inflation outlook for 2016 in the euro area, possibly increasing the risk of second-round effects."
2 See, for example, ECB, Oil prices and the euro area economy, Monthly Bulletin, November 2014, p 55.
3 See J Galí (2010), The return of the wage Phillips curve, Journal of the European Economic Association, 9(3), pp 436-461.

Actual and estimated values for compensation per hour

Year-on-year percentage change



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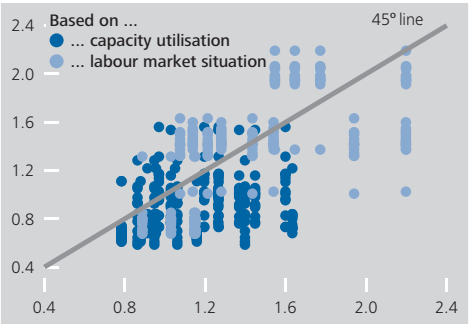
RMSE of predicted compensation per hour for 2012 to 2015*



* The x-axis shows the root mean squared error (RMSE) of compensation per hour estimated using past rates of inflation as in equation (1). The y-axis shows the corresponding RMSE from equation (2) using expected inflation.

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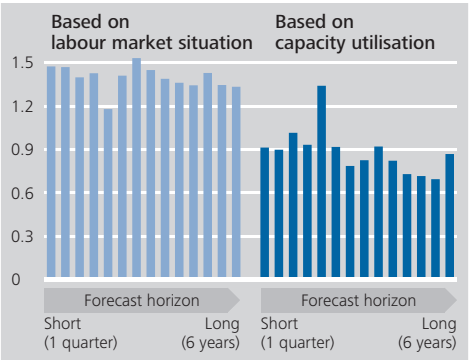
RMSE of predicted compensation per hour for 2012 to 2015 according to the horizon of expectation indicators



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the wage bargainers to respond increasingly to temporary factors.

– The influence of past inflation, measured as coefficient α, or of short-run inflation expectations amplifies over time.

Since – much as with the price Phillips curves – estimating the wage Phillips curve is made more difficult by the fact that neither capacity utilisation nor expected inflation is observable, a large number of different specifications are estimated (thick modelling approach).[4] Here, compensation per hour is chosen as the dependent variable.[5]

Similar to the analysis in the main text, it was first examined whether the wage Phillips curve can explain compensation per hour *ex post*. It turns out that wage growth has been consistent with real capacity utilisation since 2012; however, measured in terms of the very favourable labour market situation, higher wage growth would have been expected. This could reflect the fact that the labour supply in Germany has become more elastic over the past few years, due in part to migration, and that wage pressure is lower than in earlier periods despite the tight labour market. It may also possibly be a mirror of the greater employment intensity of growth over the past few years. Another possibility is that the overestimate is a reflection of diminishing collective bargaining coverage. Lastly, it could also be indicative of the fact that, in the past few years, wage policy has tended to be forward-looking in order to avoid job losses, especially

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4 The same nine variables used to estimate the price Phillips curves are used to measure aggregate capacity utilisation and the labour market situation. The average inflation rate of the last four quarters, the inflation rate lagged by one quarter and the trend of the past inflation rate estimated using a (recursive) Hodrick-Prescott (HP) filter are used as a measure of past inflation. In addition to the inflation expectations of the price Phillips curve, two to six-year-ahead consensus expectations are used. Real gross domestic product (GDP) per hour worked serves as the productivity measure.

5 Estimates using negotiated wages collected by the Bundesbank lead to qualitatively similar results.

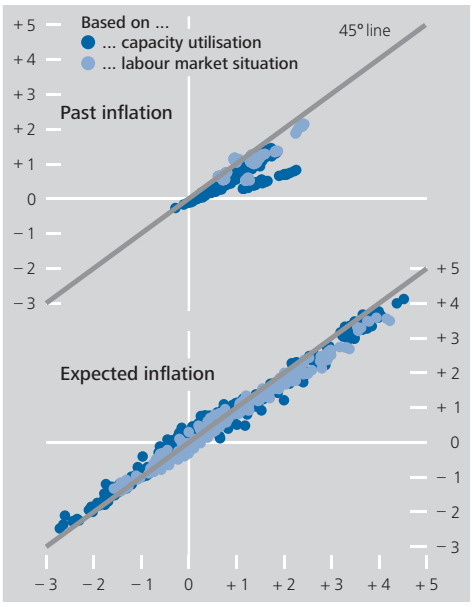
in the industrial sector, which is facing international competition.

If the various specifications regarding the inflation variable are broken down, wage growth in Germany since 2012 can be explained more readily by expected inflation than by past inflation. In the chart in the middle of page 42, the in-sample forecast errors, or root mean squared errors (RMSE), are plotted on the x-axis for the various specifications of equation (1), which looks at the past inflation rate, and the errors for the specifications according to equation (2), which contains the expected inflation rate, are plotted on the y-axis. Since most of the data points are below the 45° line, the past inflation rate seems to perform more poorly with respect to explaining wage growth in Germany than the expected price increase, since the RMSE from equation (1) are mostly higher.

A breakdown of expectations by the underlying time horizon shows that the longer the expectations horizon, the better the ability to explain wage growth (see bottom chart on page 42). Since the consensus expectations from a horizon of two years are generally near 2%, this could also indicate that the wage bargainers are basing their wage agreements more or less on the Eurosystem's inflation target. As is shown by the breakdown of contributions in the chart, overall capacity utilisation and the labour market situation have been contributing positively towards wage growth since 2012 – as have inflation expectations. By contrast, wage growth was stifled by weak productivity growth.

A comparison of the estimated coefficients over time shows, moreover, that the influence of past inflation, the contribution of which to explaining wages was already low to begin with, has receded since 2012. The influence of expected inflation, by contrast, has not changed at all in the past few years.

Estimated wage Phillips curve coefficients for 1995 to 2012 compared with 1995 to 2015*



* The x-axis shows the estimated Phillips curve coefficients for 1995 to 2012, while the y-axis covers the period from 1995 to 2015.

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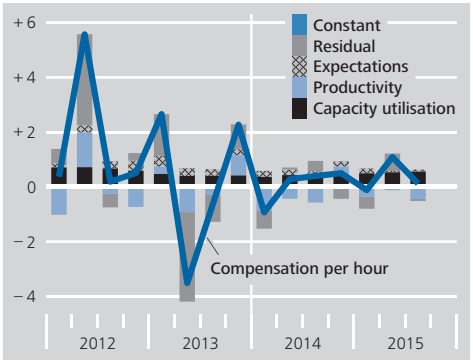
Average estimated components of compensation per hour based on the wage Phillips curve

Mean adjusted values



Deutsche Bundesbank

On the whole, therefore, there is, as yet, no evidence of a particularly high or elevated risk of second-round effects for Germany.

plain changes, in particular in Germany's core inflation rate since 2012, quite well, although compared with the capacity utilisation rate, unemployment measures as indicators of the economic situation tend to overestimate inflation. In isolation, however, the impact of the real economic determinants is rather low. Moreover, the coefficient of the capacity utilisation variable is often not statistically significant. But real economic determinants are not the only inputs into the New Keynesian Phillips curve specifications; inflation expectations and external determinants, such as the price of crude oil or non-energy import prices, are also included. An analysis of contributory factors shows that external inflation determinants, in particular, have quite a strong direct impact on inflation rate movements. The influence of expectations, on the other hand, is somewhat weaker. There is no evidence to suggest that a structural change in the Phillips curve parameters has occurred in Germany in recent years. As out-of-sample forecasts show, the Philips curve is able to roughly predict the direction of movement of the inflation rate excluding energy and food. This is less so the case for headline HICP. Here, the forecast accuracy depends heavily on the ability to correctly predict the path of the oil price.

Wage developments, which are a key determinant of consumer prices, are only indirectly taken into account in this Phillips curve analysis despite wages – as previously mentioned – playing a critical role in supporting the implied positive relationship between the real economy and price behaviour. Under certain circumstances, this can make price movements and wage growth mutually reinforcing. If, for example, unions assume that inflation rates will rise when the labour market is strong, they might be tempted to counteract the associated loss of purchasing power by demanding higher wages, which, in turn, could prompt enterprises to pass a portion of the higher labour costs on to consumers. Similar second-round effects could also occur in a low-inflation environment. However, as explained in the box on pages 41 to 43, there is, as yet, no sign of such effects in Germany.

This analysis has shown that the Phillips curve continues to be an important price analysis and forecasting tool. However, it is less suitable for modelling effects of changes in the oil price on consumer prices.[23] It is not only for this reason, but also because of the econometric problems described as well as the limits of the theoretical model, that it is advisable not to rely solely on the Phillips curve when conducting inflation analyses and forecasts, but instead to use a wide range of approaches.

Methodological annex

Challenges of estimating the New Keynesian Phillips curve

The starting point for the analysis of the relationship between inflation and aggregate capacity utilisation is the New Keynesian Phillips curve:

$$\pi_t = c + \rho\pi_{t-1} + \gamma\pi_t^e + \beta x_t + \delta p_t^f + \varepsilon_t, \qquad (1)$$

where

π_t represents the annualised quarterly growth rate[24] of seasonally adjusted HICP excluding energy and food or of headline HICP,

π_t^e is a measure of the private sector's inflation expectations,

x_t is a measure of economic development or the capacity utilisation rate,

p_t^f is a measure of external influences.

23 The impacts of changes in the oil price can be better estimated using a disaggregated approach limited to an analysis of the HICP's energy component. Additionally, non-linear effects and taxes play an important role.
24 In some studies, the Phillips curve is also estimated in annual rates of change; however, the theoretical foundation is a quarterly rate of change.

Estimation problems: endogeneity problem, …

When estimating the New Keynesian Phillips curve, a number of econometric challenges arise. The coefficients in Equation (1) can only be estimated without distortions if the capacity utilisation rate and the inflation expectations are independent of the error term ε_t. However, this cannot be assumed to be the case. The error term includes other factors influencing the inflation rate, such as technological changes, weather conditions or taxes. As these can have an effect on both prices and the capacity utilisation rate or expectations, the separate influence of the capacity utilisation rate can only be estimated approximately, since the coefficient would be measuring different impacts simultaneously and the results would therefore be distorted. This endogeneity problem can be addressed using instrumental variables estimators.[25] However, this is contingent not only on time series of maximum possible length but also on the availability of suitable instruments. Alternatively, the coefficients of Equation (1) can be estimated without distortions if the endogenous variables are included with a lag of at least one period. This was the approach adopted here.

… capacity utilisation rate cannot be observed, …

Another challenge arises from the fact that the economy's capacity utilisation rate cannot be observed and the results frequently depend on which measure of the real economic situation is selected.[26] New Keynesian Phillips curve theory[27] originally suggests a relationship between inflation and marginal costs, which are frequently measured by the wage share and are approximated on the basis of real unit labour costs.[28] However, the use of unit labour costs can be problematic in that they often take a countercyclical course and thus do not adequately capture the cyclical price impact.[29] Therefore, an output gap is normally used as an alternative variable for capacity utilisation, where potential output is estimated using either statistical filters or a production function approach. However, this is inconsistent with the theoretical definition of potential that would result from the Phillips curve model at completely flexible prices.[30] In addition, these estimates often undergo significant revisions over time.[31]

… inflation expectations cannot be observed

A final challenge arises from the inclusion of inflation expectations in the New Keynesian Phillips curve. These can be modelled using the assumption of rational expectations, where Equation (1) is estimated using the generalised method of moments (GMM) approach and the unknown term $\pi_t^e \equiv E_t[\pi_{t+1}]$ is instrumented. As an alternative to this, private sector survey results have increasingly been used in recent times to approximate inflation expectations.[32] However, survey expectations cannot generally be considered exogenous, which is why, as with the capacity utilisation rate, instrumental variables approaches or lagged expectations must be used for the estimate.[33] Moreover, expectations from survey results are not rational in most cases. This can pose a problem in that the New Keynesian Phillips curve in its standard form (1) can only be derived under the assumption of rational expectations.[34] Finally, it should be noted that the Phillips curve was derived from enterprises' optimisation calculations and their price expectations, and that there are hardly any survey data available on the sales price expectations or the general inflation expectations of enterprises. As a substitute, surveys of professional forecasters can be used, although there is no guarantee that these are consistent with the expectations of price setters.[35]

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25 See F Kajuth (2016), NAIRU estimates for Germany: new evidence on the inflation-unemployment trade-off, German Economic Review, Vol 17, Issue 1, pp 104-125.
26 This also applies to external influences, which are often measured by different variables (oil price, commodity prices, import prices, exchange rates etc).
27 See, for example, C Walsh (2010), Monetary theory and policy, MIT Press.
28 See J Galí and M Gertler (1999), Inflation dynamics: a structural econometric analysis, Journal of Monetary Economics, Vol 44, Issue 2, pp 195-222.
29 See J Rudd and K Whelan (2007), Modeling inflation dynamics: a critical review of recent research, Journal of Money, Credit and Banking, Vol 39, Issue Supplement s1, pp 155-170.
30 See S Neiss and E Nelson (2005), Inflation dynamics, marginal cost, and the output gap: evidence from three countries, Journal of Money, Credit and Banking, Vol 37, No 6, pp 1019-1045.
31 See Deutsche Bundesbank, On the reliability of international organisations' estimates of the output gap, Monthly Report, April 2014, pp 13-35.
32 This builds on J Roberts (1995), New Keynesian economics and the Phillips curve, Journal of Money, Credit and Banking, Vol 27, No 4, pp 975-984.
33 See S Mavroeidis, M Plagborg-Møller and J Stock (2014), op cit.
34 If deviations from rational expectations are permitted, such as incomplete data, alternative versions of the Phillips curve could result, such as in G Mankiw and R Reis (2002), Sticky information versus sticky prices: a proposal to replace the New Keynesian Phillips curve, Quarterly Journal of Economics, Vol 117, Issue 4, pp 1295-1328. However, to date there is no general consensus in the literature on what constitutes irrationally formed expectations.
35 For a rare analysis of the inflation expectations of enterprises, see O Coibion, S Kumar and Y Gorodnichenko (2015), How do firms form their expectations: new survey evidence, NBER Working Paper No 21092, pp 1-70.