2.1 HAS THE PHILLIPS CURVE CHANGED? EVIDENCE FOR LUXEMBOURG[1]

2.1.1 INTRODUCTION

The Phillips curve represents the relationship between inflation and real economic activity. It is the standard framework to explain and forecast inflation. This curve assumes a short-run link between inflation and economic slack[2] (see e.g. Bobeica and Sokol, 2019). Despite considerable uncertainty surrounding its exact specification, empirical evidence on the Phillips curve generally suggests that in recent decades inflation has become less responsive to movements in aggregate economic activity, including changes in the output gap. For instance, using several measures of slack, Stock and Watson (2019) find that the slope of the US Phillips curve declined in 1961-83, in 1984-99 and again in 2000-19, with most recent coefficient estimates being statistically indistinguishable from zero. Estimates for other advanced economies also suggest a similar flattening in 1984-99 and in 2000-19 (see Kamber et al., 2020, and Del Negro et al., 2020).

On the other hand, some authors find that although the slope of the Phillips curve has declined, it still remains significant (Ciccarelli and Osbat 2017, and Berson et al 2018) and that the role of expected inflation in determining actual inflation has actually increased (Blanchard et al, 2015, IMF, 2016).

The analysis that follows briefly elaborates on some of the possible explanations advanced for the flattening of the Phillips curve and applies the Phillips curve framework to Luxembourg over 1995-2019 to, first, empirically assess whether the relationship between inflation and economic activity changed since the Great Financial Crisis and, second, shed light on the main drivers of inflation in Luxembourg.

2.1.2 WHAT ARE THE EXPLANATIONS FOR A FLATTENING PHILLIPS CURVE?

The Phillips curve relationship depends on many economic factors, each of which could explain the decline in the coefficient on economic slack. The economic literature tends to group explanations in three categories[3]:

(i) **Globalisation and international developments influencing domestic inflation.** Globalisation affects inflation through several channels. First, a growing share of imports in GDP tends to increase the weight of international prices relative to domestic prices, reducing the response of domestic mark-ups to the state of the domestic economy. Second, the opening of new markets to international trade and the extension of global value chains may have reduced the importance of domestic measures of slack relative to global measures of slack. Third, the decline in labour bargaining power (increased mobility of production) and firms' pricing power (increased competition from abroad) may have reduced second-round effects.[4] Finally, inflation across countries displays an important common factor associated with globalisation, which explains a substantial part of variation in national inflation rates.[5]

1 Analysis drafted by Roberta Colavecchio, economist at the Department of Economics and Research.

2 Economic slack refers to excess supply capacity that appears when actual output (or GDP) is below potential output (potential GDP), where potential output is usually defined as the level that can be sustained without generating inflationary or deflationary pressure.

3 See Constâncio (2017).

4 Second-round effects reflect price- and wage-setters' ability to increase prices (through mark-ups or marginal costs) in response to a relative price shock. This could raise inflation expectations, transforming temporary price shocks into more persistent inflationary pressures.

5 Ciccarelli and Mojon (2010) and Ferroni and Mojon (2014) find that global inflation helps to forecast domestic inflation.

(ii) **Expectations better anchored to central bank targets.** Increased credibility of central bank policies means that inflation is more affected by (long-term) inflation expectations and less by cyclical phenomena. For example, better conduct of monetary policy increases credibility and therefore the weight that price setters put on policy targets when they set their price, reducing the link between inflation and output fluctuations[6]. Bullard (2018) claims that the Phillips curve slope may no longer be statistically different from zero because central banks have become more active and more successful in fighting inflation deviations from their policy targets.

(iii) **Non-linearities and time variation in the Phillips curve.** The coefficient on economic slack may depend on the sign, size or persistence of the gap measuring economic slack (output gap or unemployment gap), on the level and volatility of inflation, or on the degree of anchoring of inflation expectations.[7]

Bobeica and Sokol (2019) offer some insight on the drivers of euro area underlying inflation since the Great Financial Crisis. Estimating a large set of specifications for the Phillips curve[8], these authors calculate inflation contributions from economic slack, inflation expectations and external prices. In particular, the article finds that:

1) Between 2011 and 2013, Phillips curve estimates only partially account for the weakness in underlying inflation[9].

2) Between 2013 and 2018, Phillips curve estimates explain most of the weakness in underlying inflation. However, the relative importance of economic slack, inflation expectations and external prices varied.

3) Between 2017Q4 and 2018Q3, Phillips curve estimates only poorly account for the weakness of inflation (increasing contribution of unexplained residuals).

The analysis below reflects similar Phillips curve estimates for Luxembourg and evaluates changes in the responsiveness of inflation to economic activity since 2000. This period is particularly interesting, as the euro area experienced two recessions (in 2008-2009 and in 2011-2014) and a protracted low inflation episode starting in 2013.

6 See Constâncio (2017).

7 See, for example, Box 2 in Bobeica and Sokol (2019).

8 The basic specification is a version of the hybrid New Keynesian Phillips curve, with inflation driven by forward-looking inflation expectations, past inflation (to capture backward-looking expectations and other sources of persistence) and firms' marginal costs, proxied by measures of slack or economic activity. Several external variables are included to control for supply shocks.

9 In the recessions of 2008 and 2011, inflation did not fall as much as predicted by the Phillips curve, and in the economic recovery it did not rise as much as predicted. The empirical literature refers to Europe's 'missing disinflation' and 'missing inflation' (e.g. Ciccarelli and Osbat 2017, Bobeica and Sokol 2019). However, Ball and Mazumder (2020) have argued that this pattern is not as puzzling as suggested. Using core inflation measures that strip out transitory shocks to headline inflation, they find the Phillips curve captures most inflation movements since the start of the euro.

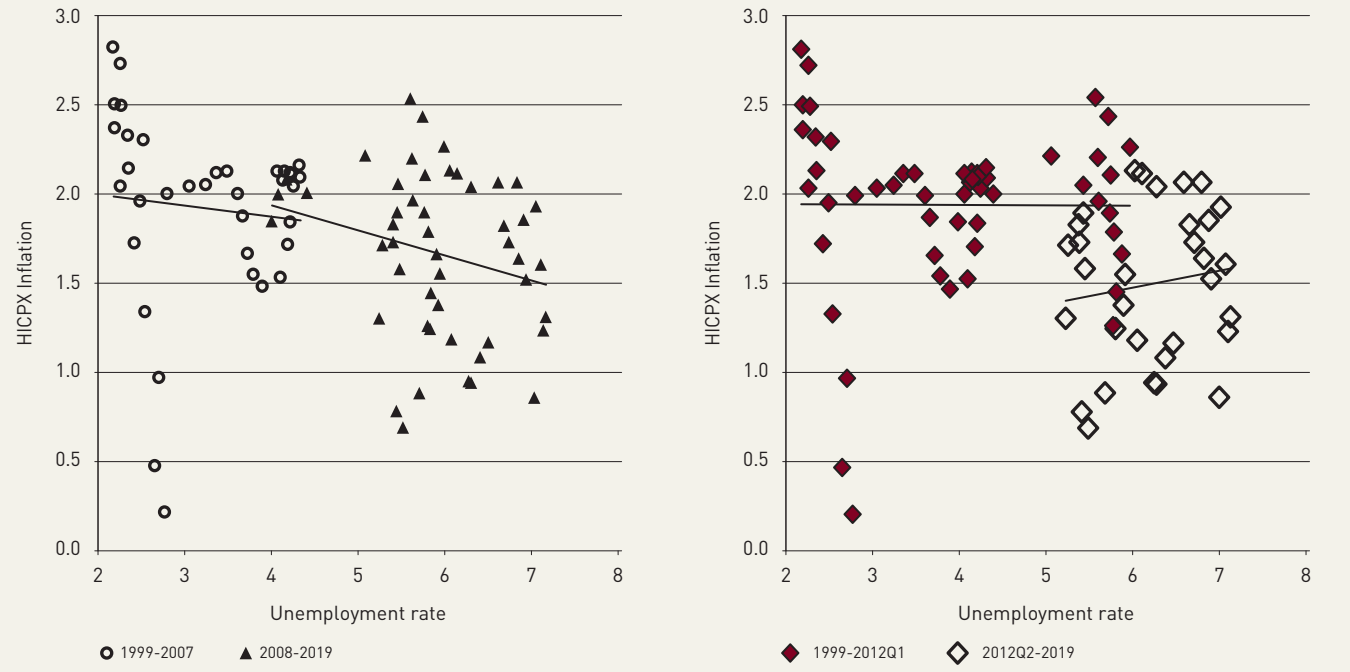
2.1.3 THE PHILLIPS CURVE IN LUXEMBOURG: RECENT DEVELOPMENTS

Figure 1 provides a first look at the relationship between underlying inflation, measured by the year-on-year change in the consumer price index excluding energy and food (HICPX)[10], and the national unemployment rate.[11]

Over two subsamples (1999Q1-2007Q4 and 1999Q1-2012Q1) correlations between inflation and unemployment are very low and provide hardly any evidence of the Phillips curve relationship. This section extends the bivariate analysis in Figure 1 by reporting a set of Phillips curve estimates that also account for inflation expectations and external prices.

Following Bobeica and Sokol (2019), we estimated a variety of specifications to allow for different sources of uncertainty[12]. First, we estimated Phillips curves over the entire sample using different measures

Figure 1
Underlying inflation and the unemployment rate in Luxembourg
(x-axis: percentages, y-axes: annual percentage changes)



Sources: Statec data, seasonally adjusted, BCL calculations
Note: Linear regression lines for the two subsamples are shown in grey.

10 Following Bobeica and Sokol (2019), underlying inflation is measured as HICP inflation excluding energy and food. Underlying inflation is more closely linked to domestic drivers than inflation in the headline index HICP. After excluding volatile energy and food prices, the harmonised and the national consumer price indices are quite similar. Data is seasonally adjusted using the EViews implementation of Tramo-Seats.

11 The unemployment rate is the seasonally adjusted series published by STATEC. The original formulation by Phillips (1958) used unemployment as a proxy for economic slack.

12 The (full) estimation sample spans 1995Q1 to 2019Q4, except for specifications employing inflation expectations from consumer surveys, which are only available since 2002Q1, somewhat limiting the comparability of results.

of economic slack[13] and of inflation expectations. Then, for all specifications, we evaluated evidence of parameter change by comparing estimates over different sub-samples, as well as by means of rolling regressions.[14]

The baseline specification is as follows[15]:

$$\pi_t = \mu + \rho \cdot \pi_{t-1} + \theta \cdot \pi_t^e + \beta \cdot x_{t-1} + \gamma \cdot \pi_{t-2}^{imp} + \varepsilon_t$$

where π_t is price inflation in period t, π_t^e is an inflation expectations measure, x_t is a measure of economic slack and π_t^{imp} is a measure of imported inflation capturing external price shocks. Inflation is measured by annualised quarter-on-quarter growth of the HICPX.

Two measures of inflation expectations are considered:

- average of past four quarters of the year-on-year inflation rate[16]
- inflation expectations from the monthly consumer confidence survey conducted by the BCL as part of the harmonised EU surveys.

And eight measures of economic slack:

- annualised quarter-on-quarter growth in real GDP
- unemployment rate (quarterly average)
- output gap (quarterly real GDP deviation from Hodrick-Prescott trend)[17]
- unemployment gap (quarterly deviation from Hodrick-Prescott trend)
- unemployment recession gap[18]
- short-term unemployment rate[19]
- European Commission output gap (linear interpolation of annual estimates)
- IMF output gap (linear interpolation of annual estimates).

Imported inflation is measured as year-on-year growth in the deflator of Luxembourg imports (goods and services) from outside the euro area.[20]

For each measure of slack or economic activity, Figure 2 compares the estimated Phillips curve slope coefficient β across specifications. This coefficient displays the expected sign in virtually all cases, but is rather close to zero and is statistically significant in only 16 % of specifications considered. This evidence is consistent with the visual impression in Figure 1. Regarding the other drivers, the ρ

13 Economic slack is unobservable and must be estimated using one of several possible filters or models, which might differ in their information content for inflation forecasting.

14 Rolling regressions compute time-varying parameter estimates by rolling a window of a fixed width through the entire data sample and re-estimating parameters in each window. If rolling-window estimates vary over time, this suggest parameter instability.

15 The choice of functional form and estimation strategy addresses tractability and simplicity concerns, but also reflects the proven ability of such models to fit euro area data reasonably well. For a discussion of this specification, see Ciccarelli and Osbat, eds. (2017).

16 As in Bobeica and Sokol (2019), year-on-year inflation rates are considered a better measure of inflation expectations.

17 Conclusions were robust in comparison to other de-trending methods (Harvey-Jaeger, Kuttner, Apel-Jansson).

18 As proposed by Stock and Watson (2010).

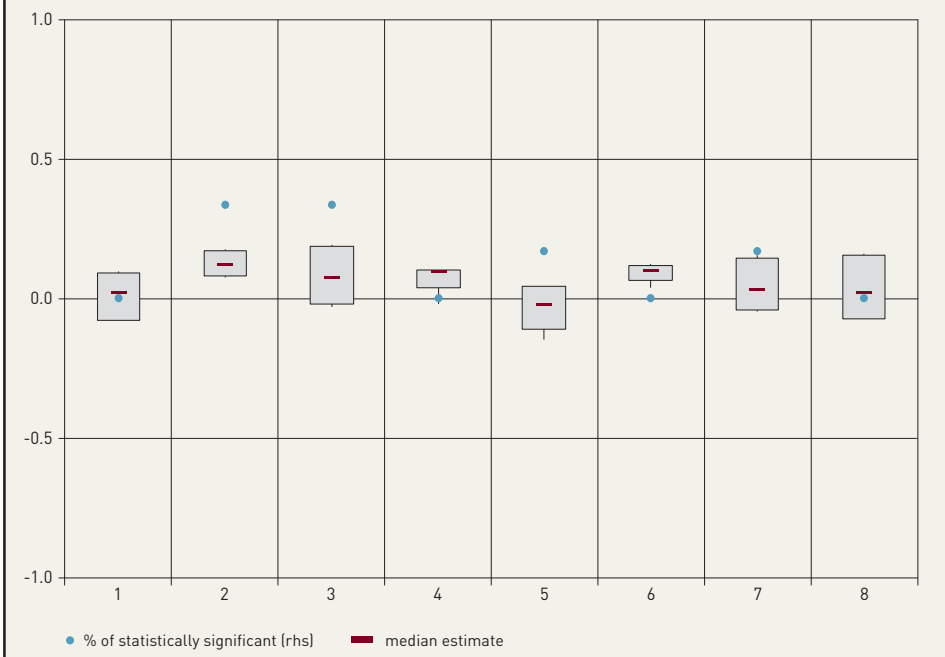
19 Ratio of those unemployed for less than one year to the active population. Data available since 2000M1 only.

20 Conclusions were unchanged using the deflator of Luxembourg imports of goods and services from all trading partners.

coefficient on inertia, the θ coefficient on expectations and the γ coefficient on external prices are often significant, confirming that economic slack alone is insufficient to adequately explain inflation developments.

The long-run slope coefficient, calculated as $\beta/(1-\rho)$, represents the long-term elasticity between slack and inflation. Since the estimated ρ coefficient is close to zero, the long-run slope of the Phillips curve turns out to be very close to the (short-run) slope, β (Figure 7 in the Appendix).

Figure 2
Estimated Phillips curve slope across specifications



Sources: European Commission, IMF, Statec data and BCL calculations
Notes: measures of slack along x-axis: (1) annualised quarter-on-quarter growth rate of real GDP; (2) unemployment rate; (3) output gap - Hodrick–Prescott; (4) unemployment gap - Hodrick–Prescott; (5) unemployment recession gap; (6) short-term unemployment rate; (7) output gap - European Commission; (8) output gap – IMF. Unemployment rates/gaps have been inverted for comparison. Sample: Q1 1995 to Q4 2019. All measures of slack/tightness are standardised for the coefficients to be comparable across specifications. The vertical bars show the range of coefficients across all specifications estimated using a given measure of economic slack/tightness or activity.

2.1.4 HAS THE PHILLIPS CURVE FLATTENED IN LUXEMBOURG?

In Luxembourg, did the relationship between inflation and real activity change following the Great Financial Crisis in 2008? This section addresses this question with two approaches. First, we use different subsamples to estimate the specifications of the baseline Phillips curve above using different measures of slack and of expectations. The subsample split is chosen using two potential "break dates": 2007Q4 and 2012Q1, both marking well-documented episodes of instability in euro area inflation (see, e.g. Ciccarelli and Osbat 2017 and Bobeica and Sokol 2019). We then compare the two subsamples estimates to full-sample estimates. Second, we perform rolling-window analysis for one standard Phillips curve specification (using the HP measure of the output gap)[21] to evaluate time variation in the coefficients.

Figure 3 summarises the results of the first exercise. The Phillips curve slope estimates generally lie below the 45-degree line, suggesting that for most specifications the coefficient associated with the slack measure is lower when more recent observations are added to the sample. This holds true for both subsamples (left and right panels of Figure 3). However, in about 60 % of cases the estimated slope coefficients are not statistically different from zero. This indication of high uncertainty also means that this exercise only provides weak evidence of flattening.

The remainder of this section provides time-varying estimates of the Phillips curve coefficient by rolling a window with a fixed width through the entire sample. If the estimated parameters differ across windows, this suggests instability over time.

21 This Phillips curve specification had the best in-sample fit (adjusted R-squared).

Figure 3
Phillips curve slope estimates in two sub-samples

Sources: Statec data and BCL calculations
Note: To ensure coefficients are comparable across specifications, unemployment rates/gaps have been inverted and all slack/tightness measures are standardised . Source: BCL calculations

The rolling window includes 40 consecutive observations[22], meaning that the first rolling window contains observations for 1995Q1 through 2004Q4, the second rolling window contains observations for 1995Q2 through 2005Q1, and so on. We associate coefficient estimates from the first available rolling window with the date 2005Q1. Among the 32 variants of the baseline Phillips curve, the rolling-window analysis focuses on the one including the Hodrick-Prescott output gap, past inflation and the extra euro area import deflator. We also included a dummy variable marking wage indexation episodes, since Luxembourg has a system of universal wage indexation[23], a semi-automatic mechanism that institutionalises second-round effects. This dummy equals 1 whenever the quarter includes a month in which the indexation mechanism triggered a 2.5 % raise in all wages (and social transfers) in the economy and zero otherwise. The estimated equation included the contemporaneous dummy term and its first two lags.

In Figure 4, the rolling window estimates of the output gap coefficient (top-left panel) display a sharp decline between 2008 and 2009 and hover around 0.1 until 2014, when they are no longer statistically different from zero. More specifically, a one percent change in the output gap would raise underlying inflation by approximately 0.5 percentage points between 2005 and 2007, but only by approximately 0.1 percent between 2009 and 2014. This result is consistent with a flattening of the Phillips curve in

22 Similar conclusions are reached with rolling windows including 28, 32 or 50 observations. Zivot and Wang (2006) note that there is no fixed rule to guide the choice of window size. In general, shorter windows are preferred for higher frequency data and longer windows to yield smoother estimates.

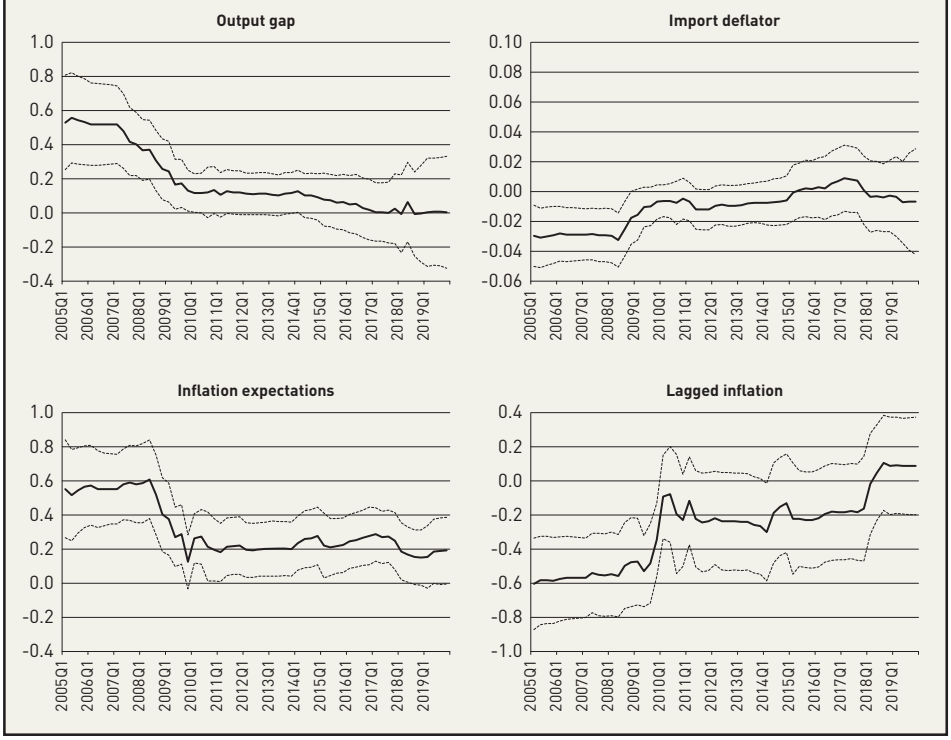
23 The automatic wage indexation is triggered by a 2.5 % increase in the national index of consumer prices since the last indexation episode. This is a strictly backward-looking mechanism.

Luxembourg following the Great Financial Crisis.[24]

The coefficients on the other variables also show signs of instability during the 2008-2009 recession. In the bottom left panel, the coefficient on inflation expectations declines sharply but remains sizeable and statistically significant for virtually all the rolling window estimates until the end of the sample. The specified equation proxies inflation expectations with the trailing four-quarter average of year-on-year inflation, so the estimated coefficient implies that between 2011 and 2019 a one percentage point increase in this measure would raise underlying inflation by approximately 0.2 percentage points. This suggests that Luxembourg inflation has a sizeable backward-looking component, consistent with the wage indexation mechanism. Towards the end of the sample, the uncertainty surrounding the rolling estimates increases to the point that "backward-looking" inflation expectations appear to be the only driver with a significant impact on inflation.

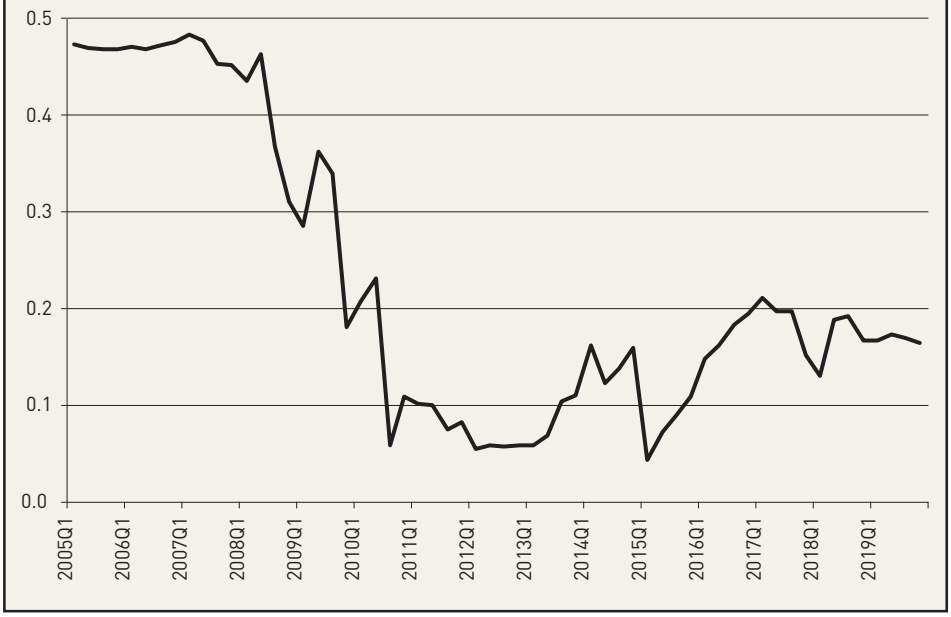
Figure 5 shows that, in Luxembourg, traditional Phillips curve determinants account for less

Figure 4
Rolling window estimation: changes in the coefficients



Sources: Statec data and BCL calculations
Note: The dotted lines are the 90% confidence bands.

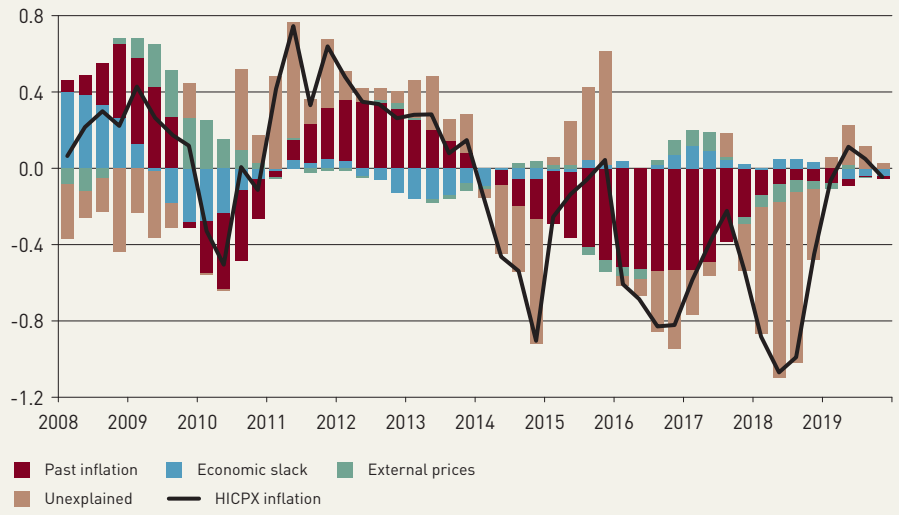
Figure 5
Rolling adjusted R-squared



Sources: Statec and BCL calculations

24 Ciccarelli and Osbat (2017) find a statistically significant relationship between inflation and economic activity in most euro area countries and evidence of some instability in the slope of the Phillips curve. However, the picture is very heterogeneous across countries in terms of increased or decreased sensitivity of inflation to economic slack. Their sample includes data from 1995Q1 to 2014Q4 and, their estimates suggest that the slope coefficient associated to the slack measure is 0.2 for the euro area as a whole, 0.15 for France, 0.25 for Spain, 0.05 for Germany and Italy (not statistically significant) and 0.15 for Luxembourg (also not statistically significant).

Figure 6
Phillips curve-based decomposition of underlying inflation
(annual percentage changes and percentage point contributions; all values in terms of deviations from their averages since 1999)



Source: BCL calculations
Notes: Phillips curve model considered in Section 4. Contributions are derived as in Yellen, J.L., "Inflation Dynamics and Monetary Policy", speech at the Philip Gamble Memorial Lecture, University of Massachusetts, Amherst, 24 September 2015.

than 20 percent of underlying inflation variability between 2017 and 2019. This is in line with the findings by Bobeica and Sokol (2019) for the euro area, where the more recent weakness of underlying inflation is difficult to explain within the Phillips curve framework.

2.1.5 THE DRIVERS OF UNDERLYING INFLATION IMPLIED BY THE PHILLIPS CURVE MODEL FOR LUXEMBOURG

The Phillips curve model estimated in Section 4 can provide a historical perspective on the relative importance of the main drivers of underlying inflation in Luxembourg. For the three main drivers, Chart 6 displays their respective contributions to inflation (deviations from average since 1999) between 2008 and 2019.[25]

The relative importance of the three key inflation drivers changed over the sample. As suggested in Section 4, inflation expectations (proxied by past inflation) and economic slack contributed to explain high inflation in 2008–2009 as well as the decline in inflation during the 2010-2011 recession. Underlying inflation fell well below its historical average in 2014, where it remained until 2019. Based on Chart 6, the early part of this period was dominated by unexplained factors (grey bars) after which inflation expectations dominated until 2017, when their contribution began to fade. In 2018-2019, the large negative contribution from unexplained residuals (grey bars in the chart) suggests that the Phillips curve was unable to account for recent weakness in inflation.

2.1.6 CONCLUDING REMARKS

The empirical analysis above implemented a standard single-equation linear Phillips curve, including lagged inflation, a measure of economic slack, a measure of inflation expectations and a measure of import prices. The main results can be summarised as follows. First, over the whole sample from 1995 to 2019, the traditional Phillips curve can only explain a limited part of inflation volatility in Luxembourg. In particular, the Phillips curve slope is found to be rather flat and often not statistically significant. Inertia, inflation expectations and external prices[26] do appear to affect price developments in Luxembourg, but they only explain a limited part of inflation volatility. Second, Luxembourg inflation has a sizeable backward-looking component. According to the rolling estimates, "backward-looking" inflation

25 This *ex post* analysis uses the full sample estimates of the Phillips curve coefficients.

26 Luxembourg imports include a lot of intermediate consumption and imports of services, both of which are not consumer goods. This might explain why the role of imported inflation in the estimated Phillips curve is not so important. Luxembourg imports its consumer goods mainly from the neighbouring economies. This represents a limitation of the analysis presented here. Future work may consider using the deflator of goods imports only (excluding services) or a CPI-deflated real effective exchange rate.

expectations appear to be the only driver to maintain a significant impact on inflation throughout the sample. This finding is consistent with the backward-looking nature of automatic wage indexation in Luxembourg. Third, there is some evidence that the Phillips curve in Luxembourg has flattened since 2007. The rolling-window results suggest that all Phillips curve parameters display some instability, especially around the 2008-2009 recession. This result is common in other euro area economies (Ciccarelli and Osbat, 2017). Fourth, increasing uncertainty after 2017 suggests that the Phillips curve can only provide limited insight into recent inflation developments in Luxembourg.

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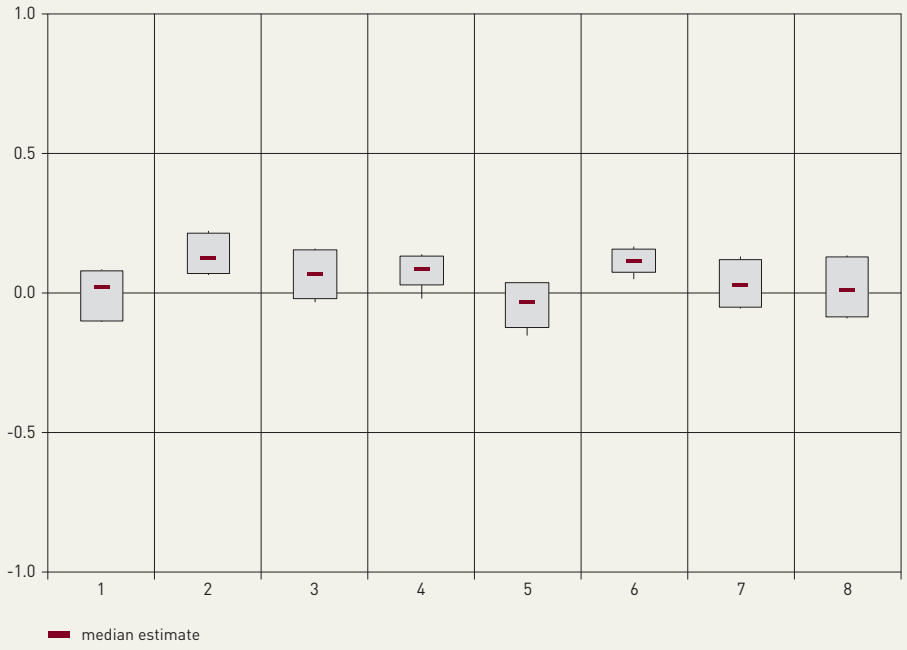
Figure 7
Estimated Phillips curve long-run slope across specifications



Sources: European Commission, IMF, Statec and BCL calculations
Notes: The following measures of slack are considered: (1) annualised quarter-on-quarter growth rate of real GDP; (2) unemployment rate; (3) Hodrick–Prescott output gap; (4) Hodrick–Prescott unemployment gap; (5) unemployment recession gap; (6) short-term unemployment rate; (7) output gap - European Commission; (8) output gap – IMF. The unemployment rates/gaps have been inverted. Sample: Q1 1995 to Q4 2019. All measures of slack/tightness are standardised for the coefficients to be comparable across specifications. The vertical bars show the range of coefficients across all specifications including a particular measure of economic slack/tightness or activity.

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Appendix *(Figure 7)*