OECD Economics Department Working Papers No. 1579

# Insights from OECD Phillips curve equations on recent inflation outcomes

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https://dx.doi.org/10.1787/d1e97b18-en

OECD

Organisation for Economic Co-operation and Development

ECO/WKP(2019)49

Unclassified

English - Or. English

13 November 2019

ECONOMICS DEPARTMENT

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JT03454606

On 25 May 2018, the OECD Council invited Colombia to become a Member. At the time of preparation, the deposit of Colombia's instrument of accession to the OECD Convention was pending and therefore Colombia does not appear in the list of OECD Members and is not included in the OECD zone aggregates.

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## ABSTRACT/RESUMÉ


### Insights from the OECD Phillips Curve Equations on Recent Inflation Outcomes

A statistically significant relationship between the unemployment gap and inflation can be found for a clear majority of OECD countries, but the magnitude of the effect is typically weak. A corollary is that the effect of labour market slack on inflation can often be dominated by other shocks, including imported inflation. The current Secretariat Phillips curve specification assumes inflation expectations are anchored at the central bank's target, although some experimentation suggests that alternative proxies for expectations sometimes work better and there is some evidence that persistent under-shooting of inflation has led to some de-anchoring of expectations from the target, especially in the euro area. For most OECD countries, a measure of the global output gap is both statistically significant and strongly preferred to a domestic gap measure in explaining the wedge between headline and core inflation, although domestic gaps are strongly preferred in explaining core inflation. Various forms of non-linearity in the Phillips curve provide possible explanations for recent weak inflation outcomes, but statistical testing provides only limited support for such explanations.



*JEL codes*: C22, E24, E31, J64

*Keywords*: Anchored expectations, Phillips curve, inflation expectations, global output gap


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### Que disent les courbes de Phillips de l'OCDE sur l'évolution récente de l'inflation ?

Pour une claire majorité des pays de l'OCDE, il est possible de trouver une relation statistiquement significative entre l'écart de chômage et l'inflation, mais l'effet est typiquement de faible magnitude. Le corollaire est que l'effet du chômage sur l'inflation est souvent dominé par d'autres chocs, incluant l'inflation importé. La spécification actuelle de la courbe de Phillips du Secrétariat assume que les anticipations inflationnistes sont ancrées sur la cible d'inflation de la banque centrale, bien que des expérimentations suggèrent que d'autres indicateurs d'anticipations sont parfois supérieurs et certains indices portent à croire que la faiblesse persistante de l'inflation a mené les anticipations à se désancré de la cible, particulièrement dans la zone euro. Pour la plupart des pays de l'OCDE, l'écart global de production est à la fois statistiquement significatif et hautement préférable à l'écart domestique pour expliquer la différence entre l'inflation totale et l'inflation sous-jacente, bien que les écarts domestiques demeurent hautement préférables pour expliquer l'inflation sous-jacente. Des formes variées de non-linéarité dans la courbe de Phillips peuvent potentiellement expliquer la faiblesse récente de l'inflation, mais les tests statistiques ne fournissent qu'un appui limité à ces hypothèses.



*Codes JEL*: C22, E24, E31, J64

*Mots-clés*: Anticipations ancrées, courbe de Phillips, anticipations inflationnistes, écart global de production

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# INSIGHTS FROM OECD PHILLIPS CURVE EQUATIONS ON RECENT INFLATION OUTCOMES

By David Turner, Thomas Chalaux, Yvan Guillemette and Elena Rusticelli[1]

## 1. Introduction

1. The Phillips curve, originally an empirical relationship between wage inflation and unemployment for the United Kingdom, has been re-interpreted, adapted and re-formulated many times since the seminal work by Phillips (1958). More broadly interpreted as a relationship between inflation and a measure of demand pressure, it remains one of the most frequently discussed and estimated empirical relationships in macroeconomics, not least because it arguably encapsulates the most important trade-off faced by macroeconomic policy-makers. The current paper does not attempt to summarise this vast literature, but rather focuses on using the Phillips curve relationships maintained by the Secretariat in the context of its regular forecasting round to see what insight they can provide on recent inflation developments in the major OECD economies. In particular, using them as a lens to examine the puzzle of why inflation currently remains weak in many countries despite the sustained recovery.

2. The specification underlying the current Secretariat Phillips curves implies that as the unemployment gap closes, in the absence of shocks to import prices or indirect taxes, core inflation will tend towards inflation expectations, which are anchored on central bank's inflation targets. However, this property appears to be contradicted by the current situation in many OECD economies. Core inflation remains significantly below official inflation targets, especially in the euro area, despite a broad range of indicators, including the Secretariat's own unemployment gap measures, suggesting demand pressures are tight, as illustrated by the cluster of countries in the southeast quadrant of Figure 1. The difficulty of explaining recent low inflation in the euro area is confirmed by a recent ECB study that adopts a 'thick modelling' approach (Bobeica and Sokol, 2019); not one of 550 versions of an area-wide Phillips curve are able to explain low inflation outcomes since mid-2017.

3. The main findings of the paper are as follows:

- For most OECD countries, there is evidence of a Phillips curve relationship between inflation and a measure of the unemployment gap, although the goodness of fit is at best mediocre.

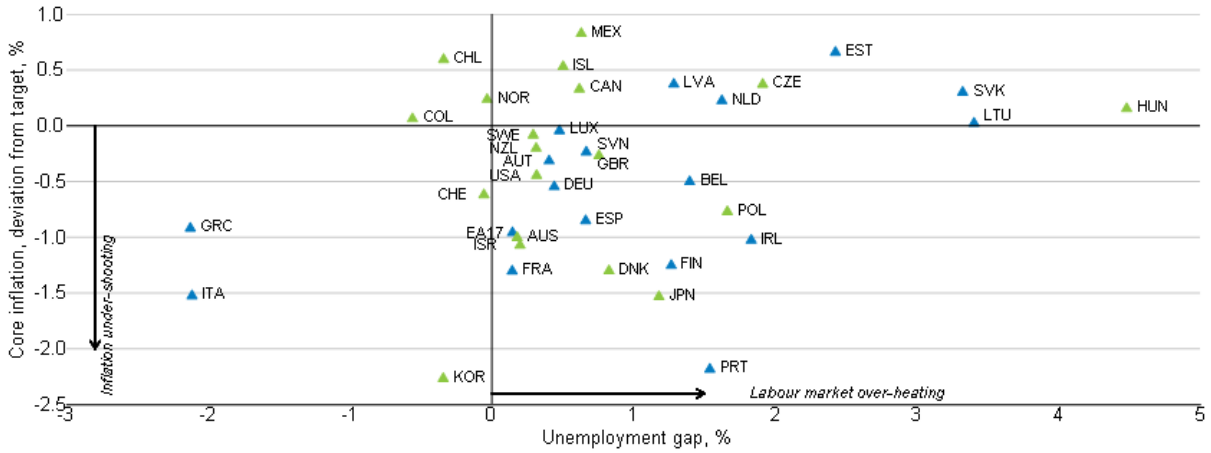
[1] The authors are members of the Economics Department of the OECD. They would like to thank Laurence Boone, Aida Caldera Sanchez, Luiz de Mello, Alain de Serres, Alessandro Maravalle, Lukasz Rawdanowicz, Cyrille Schwellnus, Douglas Sutherland and participants to the March 2019 Working Party 1 meeting of the OECD Economic Policy Committee for comments and suggestions on earlier drafts of the paper; as well as Veronica Humi for preparing the document for publication.

- While it is possible to find a statistically significant relationship between the unemployment gap and inflation for a clear majority of OECD countries, the magnitude of the effect is typically weak. For the median OECD country, a sustained change in the unemployment gap by 1 percentage point is associated with a change in core inflation by 0.4-0.5 percentage points. As a result, the unemployment gap effect on inflation is often dominated by other shocks, including imported inflation, particularly when the unemployment gap is small.
- The current Secretariat specification assumes that the central bank's target is a proxy for inflation expectations and so acts as an 'attractor' to which inflation will tend once the unemployment gap is closed. However, this implies a puzzle as to why inflation currently remains stubbornly below target in many OECD countries, despite the prolonged recovery. Alternative specifications, which allow for expectations slipping below the official target following persistent under-shooting, help to explain recent low inflation outcomes.
- This slippage of expectations is marked in most individual euro area countries as well as at the aggregate area level. The euro area could be more vulnerable to such slippage because the target relates to area-wide inflation, but there is no such commitment for any individual member country. In these circumstances, maintaining an expansionary macroeconomic policy stance for longer than might appear justified on the basis of looking at measures of slack alone, so deliberately 'over-heating' the economy, might appear warranted in order to re-anchor expectations at the target.
- Japan provides a salutary example of the danger of allowing inflation expectations to become entrenched around stable prices. While the introduction of an explicit inflation target temporarily lifted inflation expectations, this effect dissipated as it became apparent that the target was being consistently under-shot. To achieve the inflation target might require a policy of deliberately over-heating the economy reinforced by clear communication concerning the permanence of the target.
- Various forms of non-linearity in the Phillips curve provide possible explanations for recent weak inflation outcomes. Tests using the standard Phillips curve provide only limited support for downward rigidity at low inflation rates, although this appears most convincing in the case of Japan, where there is most experience of low inflation.
- There appears to be somewhat stronger evidence that a given change in unemployment has stronger effects on inflation when the initial gap measure is positive (corresponding to over-heating) than when negative. The policy implications of this non-linearity are not necessarily alarming; even if the inflationary effects from positive gaps are actually a multiple (typically estimated to be two or three times larger) of those usually estimated in a linear specification, the effects may still be modest. Indeed, simulations suggest a non-linearity of this form may be helpful in trying to raise and re-anchor inflation expectations in the euro area. The same argument would apply more strongly to Japan.
- For other countries, where inflation has been closer to target and for which there is less evidence of a slippage in inflation expectations, including the United States, the case for deliberately running the economy 'hot' is much less compelling. Macroeconomic policy should instead focus on running the economy at full capacity and targeting inflation over the medium term, accepting that idiosyncratic factors as well as imported inflation will lead to unavoidable short-term deviations of inflation from target.

4. The remainder of the paper addresses the current low inflation puzzle in the context of the Secretariat's Phillips curves equations, including some further variations and possible improvements on the current specification. The next section describes the Secretariat's Phillips curve equations and the rationale for the current 'anchored expectations' specification. Section 3 explores whether the inflation target is the best long-run 'attractor' in the Phillips curve, or whether alternative measures, which allow for some slippage of inflation expectations, are better able to explain recent inflation developments. Section 4 examines whether global measures of demand pressure have traction in country-specific Phillips curves; and section 5 considers the use of alternative measures of labour market slack. Section 6 considers the evidence of non-linearities in the Phillips curve specification. The concluding section raises some tentative

policy implications of the findings. Details of the econometric results of the some of the most important estimations referred to in the paper are shown in Annexes.

### Figure 1. In many countries core inflation remains low despite closed unemployment gap




Note: The scatter plot shows the deviation of annual core inflation in 2019Q2 from the inflation target plotted against OECD estimate of the unemployment gap averaged over the year to 2019Q2 (where a positive number indicates over-heating of the labour market). The inflation puzzle is then illustrated by the preponderance of countries in the southeast quadrant. For countries where the target is a range, the mid-point is assumed, and for all euro area countries, the target is assumed to be 2% per annum, although formally the target is specified as being close to, but just below, 2% for the area as a whole. Euro area countries are distinguished from other countries by the use of a different colour.
Source: Authors' calculations.

## 2. The form of the Secretariat's Phillips curve equation

5. In 2014, the Secretariat revised the Phillips curve specification used to estimate equilibrium unemployment for OECD countries as input to forecasts published in the *Economic Outlook* (Rusticelli et al., 2015). The new specification abandoned the previous 'accelerationist' form of the Phillips curve and relies instead on the notion that inflation expectations are anchored, most usually around the central bank's target.[2]

6. A general reduced-form Phillips curve representation of the inflation process is given by:

$$\pi_t = \pi_t^e + \alpha(U_t^* - U_t) + supply\ shocks + \varepsilon_t, \qquad [1]$$

where $\pi$ is consumer price inflation, $\pi^e$ is expected inflation, $U$ is unemployment, $U^*$ is a measure of equilibrium unemployment and supply shocks include relative import price inflation and indirect tax changes.[3] The new specification further assumes that inflation expectations are ultimately anchored at some level, $\pi^T$, usually defined by the central bank's (explicit or implicit) inflation target, but because expectations are partly backward-looking, lags of inflation are also included, so that [1] is transformed to:

2. A general model of the Phillips curve that encompasses both the former 'accelerationist' specification and the current 'anchored expectations' specification is provided in Annex A, with further explanation as to why the latter specification was preferred to the former.

3. The sign convention adopted in [1], and throughout the paper, is such that a positive unemployment gap is a situation where actual unemployment is lower than equilibrium unemployment so that the labour market can be characterised as facing excess demand pressures.

$$\Delta\pi_t = \beta(\pi^T - \pi_{t-1}) + \theta(L)\Delta\pi_{t-1} + \alpha(U_t^* - U_t) + \text{supply shocks} \quad [2]$$

Given that *U** is unobserved, equation [2] is estimated using a Kalman filter which allows *U** to evolve over time, but under constraints that ensure that movements are relatively smooth and gradual. In the years following major labour market reforms there are typically substantial falls in the estimates of *U**.[4]

7. Importantly, the model is estimated over the recent period when inflation has been relatively stable and so inflation expectations can plausibly be considered to be anchored; so for most countries the sample estimation period begins in 1998. When the specification was first introduced, a test of the validity of the restriction that expectations were anchored at the central bank's inflation target using a sample estimation period ending in 2014, described further in Rusticelli et al. (2015), could not be rejected for most countries with inflation-targeting regimes. For euro area countries, a restriction of 2% for inflation expectations was tested for each individual country, even though the ECB's target is for area-wide inflation to be "below, but close to, 2% over the medium term". For the United States, even though the Federal Reserve did not formally introduce the inflation target until 2012, the Phillips curve specification assumes a 2% target over the entire period given the general consensus underpinning the Federal Reserve policy.

8. The goodness-of-fit of updated estimates of the Secretariat's current Phillips curve specifications, usually estimated over the period 1998Q1-2019Q1, is typically only mediocre, with an adjusted R-sqd statistic for the median country around 40%, implying that much of the quarter-to-quarter variation in inflation is unexplained (Table 1 and for more detailed results see Annex B).[5] For the remainder of the paper, these equations are subject to various tests as well as to modifications designed to improve their goodness-of-fit, particularly where they may help to better explain the more recent puzzle of persistently low inflation. For these purposes, and for reasons of tractability, the estimates of the equilibrium unemployment rate (*U**) are fixed at currently estimated values rather than repeatedly re-estimated with the Kalman filter.

[4] Following 35 major labour market reforms -- identified using Duval et al. (2018) and OECD Economic Surveys since 2008 and Going for Growth since 2005 -- Secretariat estimates of *U** fall by an average of 1.4 percentage points over the following five years. However, the falls are at least twice this average in some cases, for example: Germany following the Agenda 2010 legislative package of labour market reforms; Portugal following the 2012 reform of the unemployment benefit system; and Ireland following the 1994 reform of the unemployment insurance system.

[5] The goodness-of-fit for Japan is artificially high because the greatest variation in inflation occurs around indirect tax hikes that are well captured by dummy variables.

## Table 1. The long-run effect of the unemployment gap in Secretariat's Phillips curves

| Country | Unemployment gap measure from: OECD | | IMF | | EC | |
|---|---|---|---|---|---|---|
| | Long-run GAPUNR coefficient | Adj. R2 | Long-run GAPUNR coefficient | Adj. R2 | Long-run GAPUNR coefficient | Adj. R2 |
| *G7 countries & euro area aggregate* | | | | | | |
| United States | 0.11 *** | 0.50 | 0.15 *** | 0.47 | 0.10 *** | 0.44 |
| Japan | 0.69 *** | 0.68 | 0.67 *** | 0.68 | NA | NA |
| Germany | 0.87 *** | 0.30 | 0.52 ** | 0.25 | 0.13 | 0.21 |
| United Kingdom | -0.30 * | 0.46 | 0.04 | 0.39 | -0.12 | 0.39 |
| France | 1.00 * | 0.33 | 0.88 | 0.32 | 0.39 | 0.31 |
| Italy | 0.37 *** | 0.66 | 0.49 ** | 0.64 | 0.43 | 0.62 |
| Canada | 0.18 | 0.29 | -0.32 | 0.30 | NA | NA |
| Euro area | 0.32 * | 0.25 | 0.45 ** | 0.26 | 0.37 * | 0.25 |
| *Other euro area countries* | | | | | | |
| Austria | 0.21 | 0.28 | -0.06 | 0.27 | 0.03 | 0.27 |
| Belgium | -0.08 | 0.49 | 0.17 | 0.49 | 0.22 | 0.49 |
| Estonia | 0.18 | 0.17 | NA | NA | 0.46 | -0.01 |
| Finland | 0.32 | 0.14 | 0.08 | 0.14 | 0.87 *** | 0.29 |
| Greece | 0.29 *** | 0.35 | 0.24 *** | 0.33 | 0.23 *** | 0.33 |
| Ireland | 0.36 | 0.10 | NA | NA | 0.25 | 0.07 |
| Latvia | 0.99 *** | 0.36 | NA | NA | 0.79 *** | 0.27 |
| Lithuania | 0.47 *** | 0.36 | 0.51 *** | 0.35 | 0.51 *** | 0.35 |
| Luxembourg | 0.63 ** | 0.46 | 0.28 *** | 0.48 | 0.40 *** | 0.46 |
| Netherlands | 0.49 ** | 0.28 | 0.42 ** | 0.28 | 0.63 *** | 0.32 |
| Portugal | 0.36 *** | 0.42 | 0.49 *** | 0.37 | 0.38 ** | 0.33 |
| Slovak Republic | -0.38 | 0.15 | NA | NA | 0.09 | 0.12 |
| Slovenia | 0.58 | 0.25 | 0.42 | 0.17 | 0.21 | 0.17 |
| Spain | 0.16 *** | 0.40 | 0.23 *** | 0.40 | 0.20 *** | 0.40 |
| *Other non-euro area countries* | | | | | | |
| Australia | 0.91 ** | 0.81 | 0.49 *** | 0.81 | NA | NA |
| Chile | 0.52 ** | 0.35 | NA | NA | NA | NA |
| Colombia | 0.83 | 0.05 | NA | NA | NA | NA |
| Czech Republic | 1.27 *** | 0.39 | 0.94 *** | 0.43 | 0.84 | 0.32 |
| Denmark | 0.10 | 0.21 | 0.03 | 0.21 | 0.34 ** | 0.26 |
| Hungary | 0.40 | 0.27 | NA | NA | 0.99 | 0.27 |
| Iceland | 0.54 | 0.26 | -0.14 | 0.25 | NA | NA |
| Israel | 0.40 | 0.53 | 0.36 | 0.53 | NA | NA |
| Korea | 1.13 *** | 0.42 | 0.69 *** | 0.41 | NA | NA |
| Mexico | -1.45 | 0.12 | NA | NA | NA | NA |
| New Zealand | 1.05 *** | 0.46 | 0.53 *** | 0.45 | NA | NA |
| Norway | 0.90 *** | 0.35 | 0.33 | 0.28 | NA | NA |
| Poland | 0.42 | 0.12 | NA | NA | 0.40 | 0.12 |
| Sweden | 0.69 *** | 0.53 | 0.54 *** | 0.55 | 0.60 *** | 0.58 |
| Switzerland | 0.32 | 0.33 | 0.43 *** | 0.44 | NA | NA |
| Turkey | 2.01 | 0.23 | 5.60 | 0.21 | NA | NA |

Note: The table shows the long-run effect on core inflation of a sustained 1-percentage point increase in the unemployment gap based on the most recent estimates of the anchored expectations version of the Phillips curve. The sample period for all equations is 1998Q1 to 2019Q1. The sign convention here, and throughout the paper, is that a positive unemployment gap implies labour-market over-heating. The first pair of columns show the results when using the Secretariat's estimate of the unemployment gap, whereas the second and third pair of columns show the results using IMF and European Commission (EC) unemployment gap measures, but without changing the underlying Phillips curve specification. The IMF and EC quarterly unemployment gap measures are interpolated from annual data. "***", "**" and "*" denote statistical significance at the 1%, 5% and 10% level, respectively. "NA" denotes the unemployment gap is not available from the relevant institution.
Source: Authors' calculations.

### *2.1. The importance of unemployment in the Phillips curve specification*

9. The coefficients on the unemployment gap in the updated Phillips curves are positive for an overwhelming majority of OECD countries and statistically significant to at least the 10% level in about 60% of these cases (Table 1).[6] Tests for stability of the coefficients on the unemployment gap, comparing the pre-crisis period (starting in 1998) and the post-crisis period, cannot be rejected for a clear majority of countries.[7] Moreover, the statistical significance of the unemployment gap terms is also robust to using alternative IMF or European Commission measures of the unemployment gap in an unchanged Phillips curve equation (see the second and third pair of columns in Table 1).

10. While the unemployment gap coefficients are mostly statistically significant, the magnitudes of the coefficients are small, so that increases in unemployment above the equilibrium level imply relatively modest falls in inflation. Moreover, the form of the specification implies that, provided expectations remain anchored, there is no tendency for inflation to fall continuously, even with a sustained negative unemployment gap. Thus, across OECD countries, the median effect of a 1-percentage point fall in the unemployment gap is to eventually reduce annual inflation by 0.4-0.5 percentage points, although among the major OECD countries this effect is notably even smaller for the United States (Table 1). This property helps to explain why disinflation was not more marked in the aftermath of the Great Recession and contrasts strongly with earlier vintages of the Secretariat's Phillips curves (Richardson et al., 2000) based on an 'accelerationist' specification, which would have implied much stronger disinflation.

11. A corollary of the weakened link between inflation and unemployment is that the relationship may be obscured by the effect of temporary supply shocks, particularly imported inflation, especially when unemployment gaps are nearly closed. This is illustrated by a decomposition of US core inflation using the estimated anchored expectations Phillips curve (Figure 2).[8] While the effect of the unemployment gap is estimated to be relatively weak, even compared to other OECD countries (Table 1), it does have a visible dominant negative influence on core inflation over the crisis. Nevertheless, there are many quarters when the effect of imported inflation or idiosyncratic factors (captured by the equation residual) outweighs the effect from the unemployment gap.

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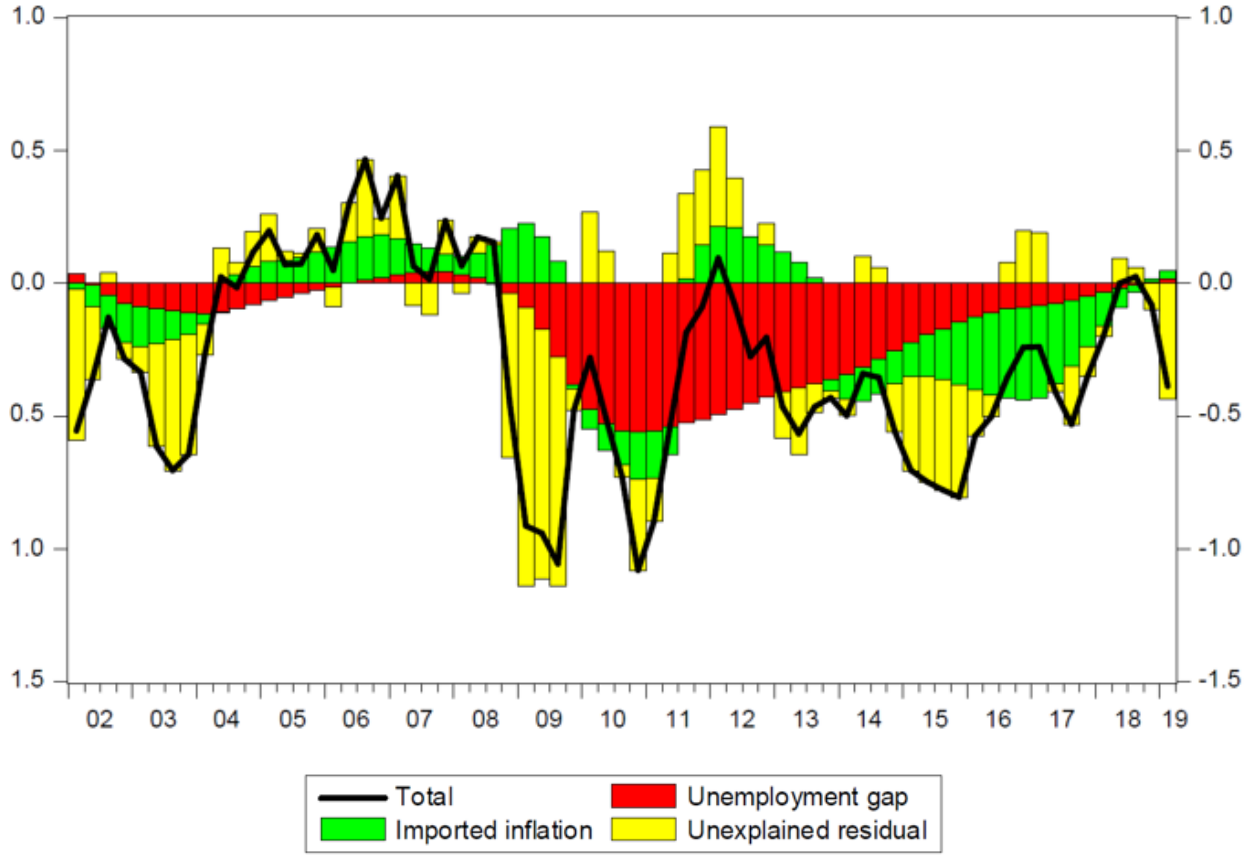
6. Restricting the sample of countries to the 20 OECD countries considered by Blanchard et al. (2015) (which excludes some countries which came late to inflation targeting) raises the proportion of countries in which the unemployment gap is significant to about three-quarters, which is also similar to the proportion found by Blanchard et al. (2015). Among the major OECD countries, the United Kingdom stands out as being the country where it is difficult to find a correctly signed effect on the unemployment gap in the Phillips curve estimation (Blanchard et al., 2015 get a similar result). It is consistent with the persistent over-shooting of inflation following the Great Recession, largely due to the marked depreciation of sterling, despite a substantial rise in unemployment.

7. A simple test splitting the unemployment gap impact before/after the Great Recession, suggests that in less than one-quarter of cases it has a significantly different coefficient. This is consistent with Blanchard et al. (2015), who find that the slope of the Phillips curve with a similar specification estimated across 20 advanced economies has been low and relatively stable since the mid-1990s.

8. The decomposition illustrated in Figure 2, as well as other similar charts in the paper, rely on expressing inflation only in terms of distributed lags of the explanatory variables and the residual and eliminating the lags of inflation that appear in the estimated equation. Consider a dynamic equation explaining a variable $y$ in terms of lags of itself and an exogenous variable $x$ expressed as $y = \theta(L)y_{-1} + \beta(L)\, x + \varepsilon$, where $L$ is the lag operator, $\theta(L)$ and $\beta(L)$ are polynomials in the lag operator and $\varepsilon$ is a residual. This equation can be re-formulated so that $y$ is expressed just as a distributed lag of $x$ and $\varepsilon$, so that $y = \beta'(L)\, x + \alpha(L)\, \varepsilon$, where $\beta'(L) = \beta(L)/ [1- \theta(L)L]$ and $\alpha(L) = 1/ [1- \theta(L)L]$.

### Figure 2. A decomposition of US core inflation

Departures of four-quarter annual core PCE inflation from 2% per annum




Note: The chart shows a decomposition of departures of annual four-quarter US core inflation, as measured by the core personal consumer's expenditure deflator, from 2% per annum, using an update of the Secretariat's Phillips curve equation. The equation assumes the target was 2% over the entire period, because there was a general consensus that this was what underpinned Federal Reserve policy, even though the target was not formally introduced until 2012.
Source: Authors' calculations.

## 3. Specifying the 'attractor' in the Phillips curve

12. The number of countries for which inflation remains below official targets simultaneously with estimates of positive unemployment gaps, as illustrated by the large number of countries in the southeast quadrant of Figure 1, raises questions as to whether the central bank's inflation target is the appropriate attractor in the Phillips curves. The poor performance of the equations in predicting recent inflation for these countries can be demonstrated by the addition of a dummy variable after mid-2017.[9] For the clear majority of countries, especially those in the euro area, the coefficient on the dummy variable is large and often statistically significant.[10] For nine of the 13 euro area countries (including the aggregate euro area)

[9] The choice of adding a dummy variable after mid-2017 is somewhat arbitrary, but it corresponds to the period for which Bobeica and Sokol (2019) find no satisfactory explanation of low inflation outcomes in the euro area.

[10] Conversely, in the original paper reporting these equations, but over a sample period ending in 2013 or early 2014, Rusticelli et al. (2015) report a set of tests that suggest that the inflation target is accepted as valid attractor in this form of Phillips curve for the majority of OECD countries (see Annex A for further details of the tests). Repeating these

in the southeast quadrant of Figure 1, the coefficient on the dummy suggests a systematic over-prediction of annualised core inflation of around 1 percentage point or more. For Japan, the over-prediction is more than 1½ percentage points; for Australia, New Zealand and Sweden the over-prediction is close to ½ percentage point. The only countries for which the coefficient on the dummy is statistically insignificant and implies a systematic over-prediction of only ¼ percentage point or less are Canada, the United Kingdom and the United States. The failure of the equations to explain recent inflation outcomes casts doubt on the use of the inflation target as an attractor and motivates the search for alternative attractors.

### *3.1. Alternatives to the inflation target as the 'attractor'*

13. An alternative attractor commonly adopted in estimated Phillips curves is a survey measure of long-term inflation forecasts, often taken to be the six to ten-year-ahead expected headline consumer inflation rate from the Survey of Business Economists (Figure 3, panel A).[11] This measure is generally close to official inflation targets, but persistent deviations of inflation from the target tend to be reflected in corresponding revisions to survey expectations. Thus, one approach is to assume that inflation expectations, $\pi^e$, can be represented by a linear function of the inflation target, $\pi^T$, and surveyed long-term inflation forecasts, $\pi^L$:

$$\pi^e = \theta\, \pi^L + (1 - \theta)\, \pi^T, \qquad [3a]$$

which can equivalently be expressed in terms of the target and the difference between the target and the survey forecast:

$$\pi^e = \pi^T + \theta\, (\pi^L - \pi^T) \qquad [3b]$$

14. A more general determination of the attractor allows for the possibility that the appropriate measure of expectations is over a shorter horizon than six to ten years. This can be achieved by including surveyed one-year ahead forecasts of CPI inflation, $\pi^S$, (Figure 3, panel B) in the determination of inflation expectations:

$$\pi^e = \theta\, [\omega\, \pi^L + (1 - \omega)\, \pi^S] + (1 - \theta)\, \pi^T, \qquad [4a]$$

or equivalently:

$$\pi^e = \pi^T + \theta\, \{[\omega\, \pi^L + (1 - \omega)\, \pi^S] - \pi^T\} \qquad [4b]$$

15. Several possibilities are nested within the formulation represented by [4b] depending on the parameters $\omega$ and $\theta$:

- The relative weights on long- and short-term surveyed forecasts are determined by $\omega$. In the following empirical investigation, three possibilities are considered: $\omega = 1$, meaning the full weight is put on long-term survey forecasts (so that [4b] becomes [3b]), which corresponds to the case commonly adopted by other researchers; $\omega = ½$, meaning equal weight is put on short-term and long-term survey forecasts; and $\omega = 0$, meaning the full weight is put on short-term survey forecasts.
- The parameter $\theta$ determines the relative weight placed on the official inflation target versus surveyed forecasts of inflation in determining expectations: if $\theta = 0$, then expectations are anchored at the central bank's target; if $\theta = 1$ then expectations are well proxied by survey forecasts; if $0 < \theta$

same tests on a more up-to-date sample suggests that the restrictions are now rejected for the majority of OECD countries.

[11] An alternative time series of surveyed inflation forecasts at a five-year horizon is available for the aggregate euro area only. Separate testing of this series, both alone and in combination with short-term surveyed forecasts, produced similar results to using the six to ten-year forecast series and so is not reported here.

< 1, then expectations are equal to the target plus some fraction of the deviation of survey forecasts from the target; if $\theta$ > 1 then expectations are equal to the target plus some multiple (greater than one) of the deviation of survey forecasts from the target. This final possibility would suggest that survey measures maybe a reliable indicator of the *direction* in which expectations deviate from the target, but may understate the *magnitude*.

16. To test the alternative possibilities represented by [4b], additional terms are added to the right hand side of equation [2] so that the attractor is no longer just the inflation target, but rather a weighted average of survey forecasts and the target, where the weights are determined by empirical estimation.

17. Another possibility that is investigated for the attractor is that persistent past under- or over-shooting of the target leads to expectations being revised away from the target in the same direction, so that:

$$\pi_t^e = \pi^T + \varphi \sum_{t-1}^{t-n}(\pi_t - \pi^T)/n \,, \qquad [5]$$

where the $\sum$ term, hereafter referred to as the 'slippage' variable, measures the average deviation of inflation from the target over the previous *n* quarters (where *n* is here taken to be 16).[12]

18. The different modifications of the target as an attractor have varying degrees of success (Table 2). Least successful is the use of long-term survey forecasts alone, which are statistically significant in only about 45% of countries, with the coefficient often much greater than unity, which is awkward to interpret. Short-term survey forecasts, either alone or in combination with longer-term forecasts, are statistically significant in nearly two-thirds of countries, although coefficients are often greater than unity (although usually less extreme than for long-term forecasts). Most successful is the addition of the slippage variable, which is statistically significant in three-quarters of all countries, as well as for the euro area aggregate equation, with the coefficient usually close to, but less than, unity. Statistical significance of the modified attractor also tends to reduce the extent to which the equations over-predict inflation at the end of the sample as illustrated by a decomposition analysis for the euro area aggregate, Germany and France (Figure 4).

19. The finding that short-term survey forecasts of inflation are helpful in explaining recent inflation outcomes is also a result in Moretti et al. (2019), who conclude both that expectations are the "*single most important determinant*" explaining euro area inflation and that shorter-term expectations are the most relevant form of expectations after 2013. However, the use of survey forecasts in general, and short-term forecasts in particular, to rescue empirically failing Phillips curves raises other issues. As noted by Coeuré (2019), the assumption that households and firms have expectations similar to professional forecasters is questionable. It is also noteworthy that the long-run coefficients on short-term forecasts (more precisely their deviation from the target) are often greater than unity, which suggests the forecasts are helpful in predicting the direction of the divergence of expectations from the target, but consistently understate the magnitude. Most importantly, it is difficult to extract policy implications from a Phillips curve relationship that depends heavily on short-term forecasts, which themselves are quite volatile (Figure 3, panel B) and *ex post* often have a poor track record.[13]

20. On the other hand, the slippage term in the anchored expectations specification has a clear policy implication because it represents a way to test for "*the risk that a too prolonged period of low inflation becomes embedded in inflation expectations*" (Draghi, 2014). The estimated coefficients on the slippage term -- which are mostly close to, but less, than unity -- suggest that for most euro area countries, a

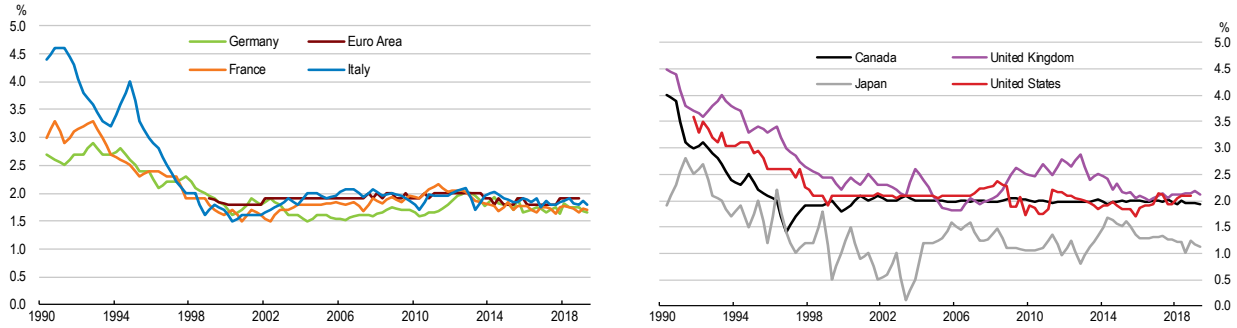
[12] Note that because inflation is measured in terms of core inflation, this specification implies that even if headline inflation remains on target, a persistent wedge between headline and core inflation would lead to expectations of core inflation being revised away from the target.

[13] For example, since December 2013, the ECB has systematically over-estimated one-year ahead forecasts of core inflation by a significant margin (Darvas, 2018).

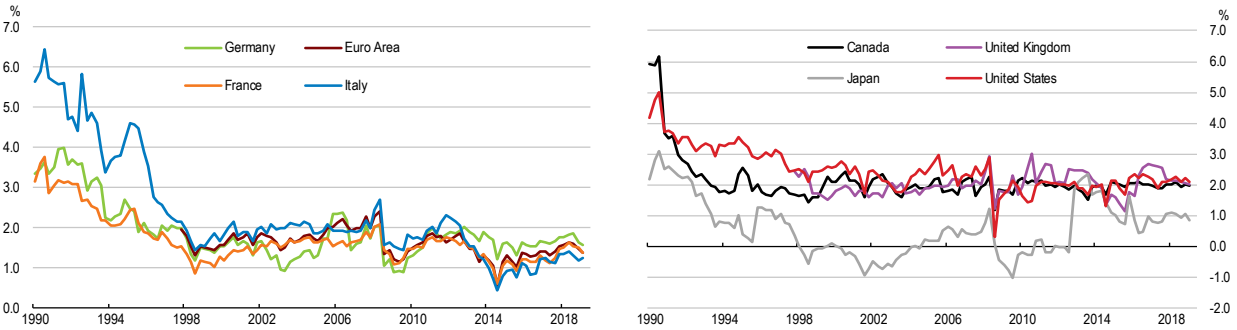
sustained period in which inflation remains below the inflation target has led to a downwards revision of expectations below the target. This can be demonstrated by simulating the inflation response of two estimated euro area Phillips curves to the unemployment gap shock experienced following the Great Recession, which is here taken to be exogenous (Figure 5). In the first simulation, represented by the red solid line, inflation expectations are anchored on the inflation target, which is assumed to be 2% per annum. In the second simulation, represented by the blue dashed line, expectations are influenced by persistent deviations of core inflation from the target according to the slippage term (described in [5] above, with the parameter $\varphi$ determined in estimation). While the initial fall in inflation is quite similar across the two simulations, the long-term inflation effects are strikingly different: in the first, inflation returns quite quickly to the target once the unemployment gap has closed; in the second, persistent under-shooting of the inflation target leads to slippage in inflation expectations and inflation remains below target, even after the unemployment gap has closed. The second form of the equation implies that, if the unemployment gap remains closed, then inflation will eventually gravitate to the target, although this is likely to take many years.[14] Re-anchoring expectations at the target over a more practical policy horizon would require a sustained positive unemployment gap, its magnitude depending on whether it affects inflation linearly or non-linearly, as discussed further below.

## Figure 3. Surveyed inflation forecasts

(A) Six to ten-year ahead forecast inflation from the Survey of Business Economists




(B) One-year ahead forecast inflation from the Survey of Business Economists




Note: For some periods/countries, surveys are only available on a semi-annual basis and so have been interpolated.
Source: Consensus Economics.

[14] In the example considered in Figure 5, inflation would have closed less than half the gap with the target even after a decade if the unemployment gap remained at zero.

## Table 2. Testing for modifications of the inflation target as an attractor in the Phillips curve

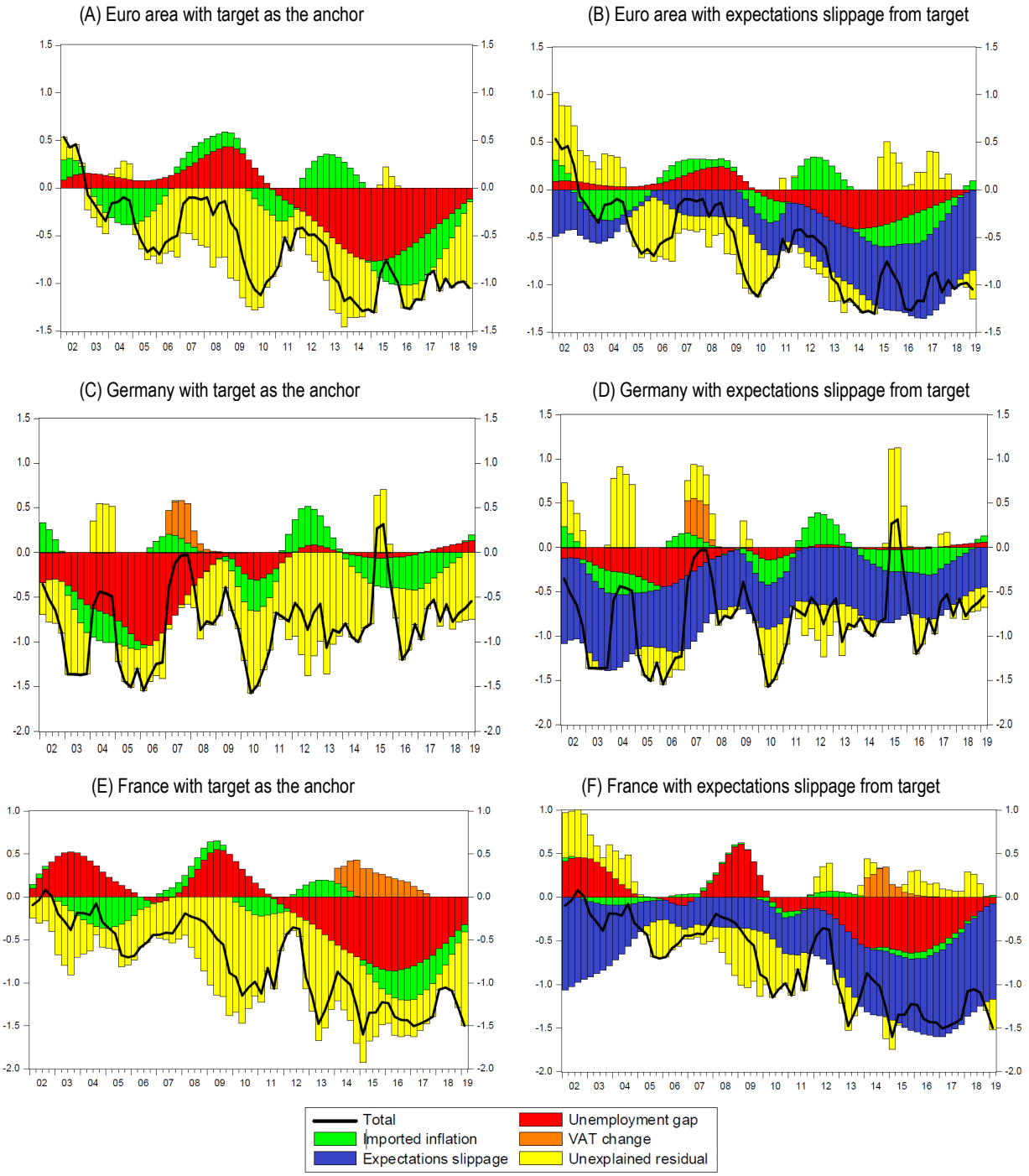
Size and significance of coefficients on terms that adjust the target as the attractor

| Country | Combination of survey forcasts | | | Variable to capture slippage for persistent under- or over-shooting |
|---|---|---|---|---|
| | Long-term forecasts only | Short-term forecasts only | Average of short- & long-term forecasts | |
| *G7 countries & euro area aggregate* | | | | |
| United States | | | | |
| Japan | 1.09 *** | 0.88 *** | 0.59 *** | 1.13 *** |
| Germany | 1.76 *** | 1.07 *** | 0.81 *** | 0.73 *** |
| United Kingdom | | | | 0.49 ** |
| France | 2.72 ** | 1.37 *** | 0.98 *** | 0.82 *** |
| Italy | | | | |
| Canada | 5.02 * | | | 0.62 ** |
| Euro area | | 1.17 ** | 0.89 ** | 0.77 *** |
| *Other euro area countries* | | | | |
| Austria | 1.30 * | 0.64 ** | 0.42 * | 0.63 ** |
| Belgium | | 1.29 *** | 1.04 *** | 0.81 *** |
| Estonia | | 0.81 *** | | 0.68 *** |
| Finland | 2.64 ** | 1.42 *** | 1.21 *** | 0.98 *** |
| Greece | | 0.53 ** | 0.32 ** | |
| Ireland | | 1.04 * | 0.96 * | |
| Latvia | | 0.54 *** | 0.34 *** | 0.28 *** |
| Lithuania | | | | |
| Luxembourg | | | | 0.82 *** |
| Netherlands | 2.63 ** | 1.42 *** | 1.18 *** | 0.82 *** |
| Portugal | | 1.24 *** | 1.08 *** | 0.63 *** |
| Spain | | 0.90 *** | 0.41 ** | 0.50 ** |
| Slovak Republic | 1.40 *** | 0.89 *** | 0.59 *** | 1.00 *** |
| Slovenia | | 1.07 *** | | 0.51 *** |
| *Other non-euro area countries* | | | | |
| Australia | | | | |
| Chile | | | | |
| Colombia | 0.85 * | 0.63 ** | 0.38 * | |
| Czech Republic | | | | 0.39 ** |
| Denmark | 2.92 *** | 1.50 *** | 1.36 *** | 1.20 *** |
| Iceland | | | | 1.19 *** |
| Israel | | | | 0.40 ** |
| Hungary | 3.34 *** | 1.24 *** | 1.07 *** | 0.59 *** |
| Korea | 1.46 *** | 0.84 *** | 0.63 *** | 0.94 *** |
| Mexico | | | | 0.48 * |
| New Zealand | | 0.58 ** | 0.31 * | |
| Norway | 0.77 * | 1.05 *** | 0.62 ** | 0.76 *** |
| Poland | 2.39 ** | 1.14 *** | 0.73 ** | 0.55 *** |
| Sweden | 2.03 * | | | 0.45 ** |
| Switzerland | | | | 0.80 *** |
| Turkey | 1.35 ** | 0.92 *** | 0.61 *** | 0.72 *** |

Notes: The table reports the size and significance of estimated coefficients on variables (specified in the column headings) that adjust the inflation target as an attractor for inflation in the Phillips curve. The sample period for all equations is 1998Q1 to 2019Q1. If a coefficient is statistically insignificant, then the relevant cell in the table is left blank. For Luxembourg and Iceland, time series of survey forecasts are too short. Reported coefficients are normalised on the coefficient for the attractor term ($\pi_{-1} - \pi^{T}$) to provide a measure of the extent to which the attractor deviates from the inflation target. For example, a coefficient of 0.5 in the second column would suggest that the attractor is equal to the inflation target plus 0.5 times the difference between the short-term inflation forecast and the target. Statistical significance at the 1%, 5% and 10% levels are denoted by "***", "**" and "*", respectively.
Source: Authors' calculations.

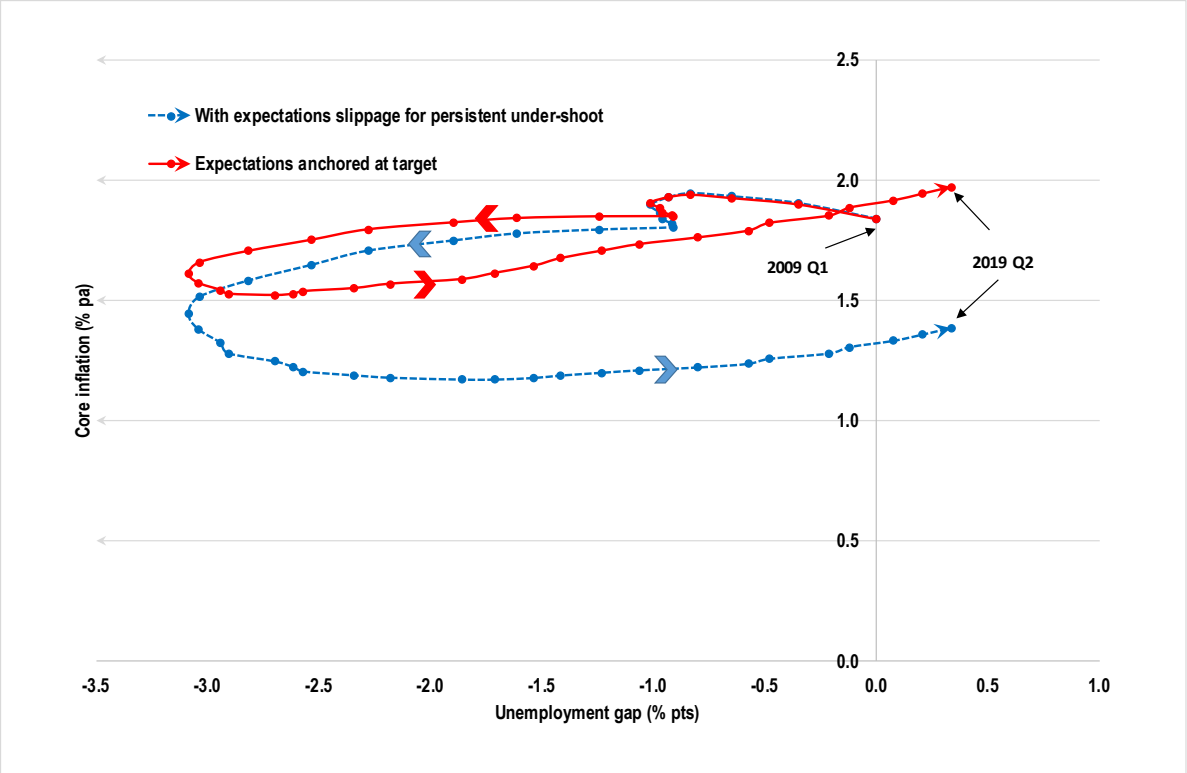
## Figure 4. A decomposition analysis of inflation in the euro area, Germany and France

Departures of four-quarter annual core inflation from 2% per annum




Note: The charts shows a decomposition of departures of annual four-quarter core inflation from 2% per annum, according to different variants of the Secretariat's Phillips curve equation with alternative attractors. In the left-hand-side panels, the attractor is the inflation target. In the right-hand-side panels, the attractor is the target but the specification includes a term which proxies the effect of persistent deviations of inflation expectations from the target.
Source: Authors' calculations.

## Figure 5. Simulations of the Great Recession unemployment shock on euro area inflation




Note: The chart compares the simulation properties of two estimated Phillips curves for the euro area to the unemployment gap shock experienced following the Great Recession, which is here taken to be exogenous. In the first simulation, represented by the red solid line, inflation expectations are anchored on the inflation target, assumed to be 2% per annum. In the second simulation, represented by the blue dashed line, expectations deviate from the target as a result of persistent deviations of core inflation from the target and the magnitude of this effect is determined by estimation.
Source: Authors' calculations.

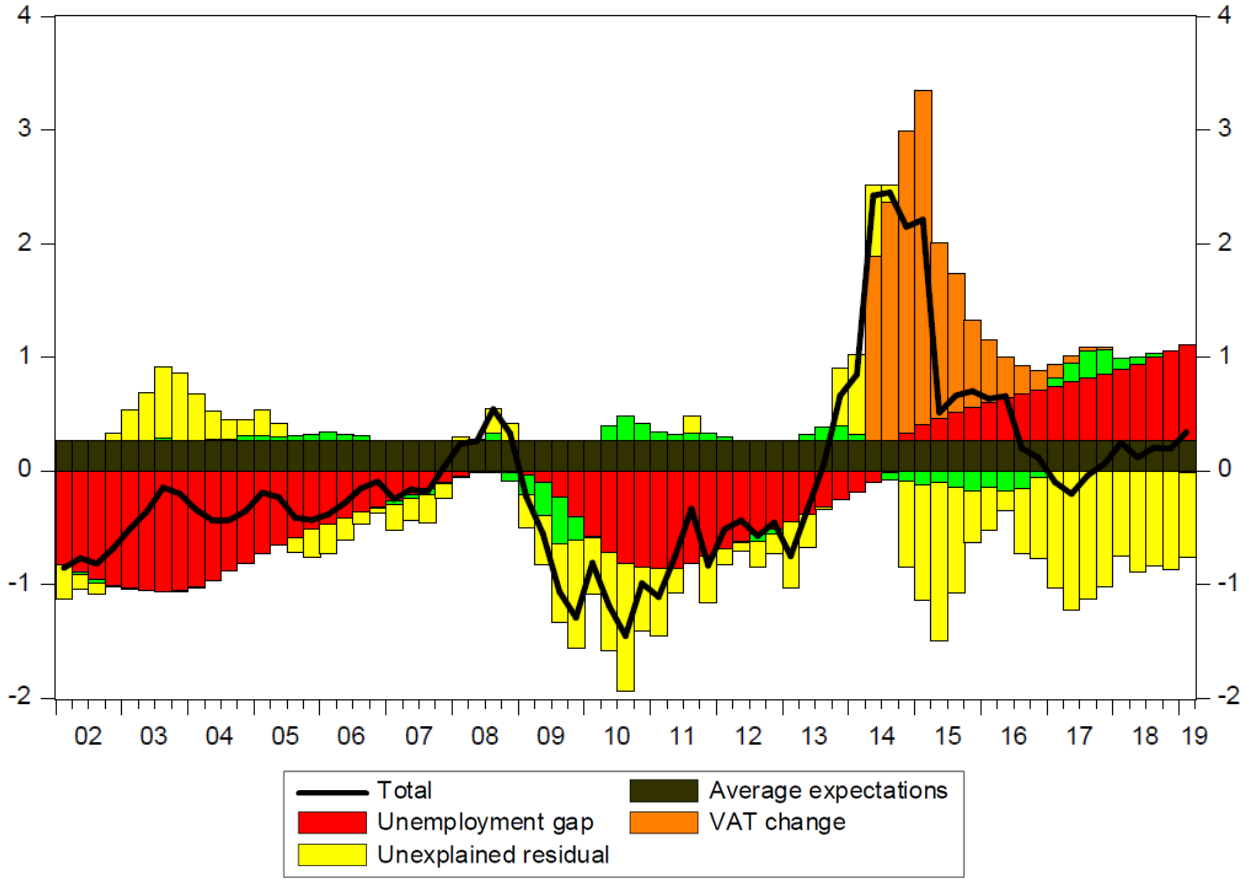
### *3.2. Japan as a special case*

21. Japan is a special case as it has experienced a prolonged period of low and relatively stable inflation since the early 1990s, but has only very recently introduced an inflation target. The current Secretariat Phillips curve specification therefore includes a constant term as an attractor, which when freely estimated gives a value close to, and statistically insignificantly different from, zero, suggesting that expectations are conditioned on unchanged prices. This would appear to be consistent with a recent sectoral study, which suggests that Japan is an outlier compared to other countries, with a default expectation that prices remain unchanged (Watanabe and Watanabe, 2018). There does appear to have been some temporary effect on inflation from the introduction of the target in 2013, as suggested by the series of positive residuals over the period 2013-14 (Figure 6), although the effect may be partly blurred by the indirect tax hike in 2014. However, the effect of introducing the target is difficult to perceive beyond 2015 (as the residuals turn negative) and the inclusion of the target variable from 2013 onwards is statistically insignificant and is therefore not included in the equation.

22. The failure of the introduction of the inflation target to permanently influence expectations is explained by De Michelis and Iacoviello (2016) in terms of the slow response of both inflation and inflation expectations after the announcement of the increase in the target. They argue that the Bank of Japan needs to take further steps to strengthen its credibility by more effectively communicating the permanent nature of the monetary regime shift.

### Figure 6. A decomposition analysis of inflation in Japan

Departures of four-quarter annual core inflation from 0% per annum




Note: The chart shows a decomposition of departures of annual four-quarter core inflation from 0% per annum, using the Secretariat's Phillips curve equation. The 'average expectations' component reflects the size of a constant term in the equation, although this term is statistically insignificant from zero.
Source: Authors' calculations.

## 4. Additional effects from global demand pressures

23. In the current Phillips curve specification, there are important global effects from imported inflation, which may also capture the increased importance of global value chains (Andrews et al., 2018). Moreover, given that imported inflation terms in the Phillips curve are weighted by the extent of import penetration, the effect of any given change in import prices has risen over the sample period; thus the effect of a given shock to import prices is typically between 15% and 25% higher now than in the late 1990s.

24. In addition, Borio and Filardo (2007) found that a measure of the global output gap adds explanatory power to country-specific Phillips curves and that such global effects have become more important over time. More recent support for such an effect is provided by Jasova et al. (2018), although they take a different approach by pooling groups of advanced and emerging market economies, rather than estimating country-specific Phillips curves. One potential channel through which such global effects might operate is that the increasing importance of global value chains might let firms relocate production to countries with slack (Auer et al., 2017). On the other hand, many other researchers have failed to find a similar global effect in country-specific Phillips curves, casting doubts on the robustness of the effect (Ihrig et al., 2010; Calza, 2008; Gerlach, 2004; Pain et al., 2006; Yellen, 2017; Mikolajun and Lodge, 2016).

25. Adding measures of global slack to the Phillips curve specifications described above adds only limited explanatory power. There are only four small OECD countries (Estonia, Lithuania, Chile and Colombia) for which a global gap measure is significant and preferred to a domestic unemployment gap measure and one other country (Korea) for which the global gap is significant, but dominated by the domestic gap variable. For all other OECD countries, once a domestic unemployment gap and imported inflation are included, there is no significant additional role for a measure of global slack.

26. One possible explanation for the difference in findings is that the studies that have found significant positive effects from global demand pressures have focused on headline measures of inflation, whereas most of the studies that find contrary results, including those of the Secretariat, have used core inflation. Global demand pressures might be expected to have stronger effects on energy, food and commodity prices that feed more directly and immediately into headline than core consumer prices. Indeed, the world output gap is nearly always preferred to a domestic unemployment or output gap measure in regressions explaining the wedge between headline and core inflation in individual OECD countries. Moreover, from a visual inspection, there does appear to be a correlation between a measure of the global output gap and an aggregate measure of the wedge across OECD countries (Figure 7). In further regressions that explain the wedge in terms of a global output gap (excluding domestic gap variables), the latter is positive and statistically significant for three-quarters of countries (Table 3). Furthermore, the size of the global output gap effect is economically significant: a one-percentage point increase in the global output gap increases the annualised difference between headline and core inflation by about 0.4 percentage points in the median country; which is about the same magnitude as the median effect of the unemployment gap on core inflation (as summarised in Table 1).

## Figure 7. The wedge between OECD headline and core inflation and the global output gap


Note: The world output gap is derived from a Hodrick-Prescott filter of world GDP. The OECD wedge variable is the difference between annual headline and core consumer price inflation in OECD countries, aggregated using consumption weights.
Source: Authors' calculations.

## Table 3. Regressions explaining the inflation wedge in terms of the world output gap

| Country | Constant | wdg(-1) | wld_gap | Δexch | Δexch(-1) | Adj. R2 | Obs | Long-run wld_gap | Long-run constant |
|---|---|---|---|---|---|---|---|---|---|
| *G7 countries & euro area aggregate* | | | | | | | | | |
| United States | 0.04 | 0.09 | 0.07 *** | -7.59 *** | | 0.43 | 84 | 0.32 | 0.18 |
| Japan | 0.06 ** | -0.12 | 0.09 *** | | | 0.09 | 84 | 0.34 | 0.22 |
| Germany | 0.09 *** | 0.16 | 0.08 ** | -6.52 ** | | 0.17 | 84 | 0.39 | 0.42 |
| United Kingdom | 0.07 *** | 0.43 *** | 0.06 *** | | | 0.30 | 84 | 0.42 | 0.45 |
| France | 0.07 ** | 0.23 ** | 0.08 ** | | | 0.16 | 84 | 0.43 | 0.37 |
| Italy | 0.04 * | 0.29 *** | 0.08 *** | | | 0.26 | 84 | 0.43 | 0.22 |
| Canada | 0.07 * | -0.09 | 0.13 *** | 3.02 ** | | 0.12 | 84 | 0.47 | 0.26 |
| Euro area | 0.06 ** | 0.26 ** | 0.08 *** | | | 0.20 | 84 | 0.44 | 0.34 |
| *Other euro area countries* | | | | | | | | | |
| Austria | 0.03 | 0.24 ** | 0.09 *** | | | 0.22 | 84 | 0.46 | 0.16 |
| Belgium | 0.09 * | 0.16 | 0.18 *** | | | 0.21 | 84 | 0.84 | 0.42 |
| Estonia | 0.16 *** | 0.33 *** | 0.13 ** | -9.57 *** | | 0.34 | 84 | 0.78 | 0.97 |
| Finland | 0.06 ** | 0.25 ** | 0.09 *** | -4.38 *** | | 0.27 | 84 | 0.46 | 0.31 |
| Greece | 0.09 ** | 0.26 ** | 0.02 | -3.76 * | | 0.09 | 84 | 0.10 | 0.50 |
| Ireland | 0.06 | 0.15 | 0.09 ** | | | 0.10 | 84 | 0.43 | 0.26 |
| Latvia | 0.15 *** | 0.55 *** | 0.11 ** | -3.05 ** | | 0.50 | 84 | 0.98 | 1.33 |
| Lithuania | 0.18 *** | 0.35 *** | 0.10 | -7.63 ** | | 0.27 | 84 | 0.60 | 1.12 |
| Luxembourg | 0.08 | 0.27 ** | 0.10 * | | | 0.13 | 84 | 0.54 | 0.44 |
| Netherlands | 0.07 *** | -0.06 | 0.11 *** | | | 0.13 | 84 | 0.41 | 0.28 |
| Portugal | 0.05 | 0.29 *** | 0.08 ** | | | 0.20 | 84 | 0.46 | 0.28 |
| Slovak Republic | 0.16 ** | -0.19 * | 0.14 * | | | 0.04 | 84 | 0.47 | 0.52 |
| Slovenia | 0.08 | 0.16 | 0.13 | | | 0.04 | 84 | 0.62 | 0.40 |
| Spain | 0.07 * | 0.19 * | 0.08 * | | | 0.09 | 84 | 0.42 | 0.36 |
| *Other non-euro area countries* | | | | | | | | | |
| Australia | 0.02 | 0.07 | 0.04 | | | 0.00 | 84 | 0.15 | 0.07 |
| Chile | 0.13 *** | 0.21 * | 0.17 *** | | | 0.27 | 78 | 0.87 | 0.67 |
| Colombia | 0.09 *** | 0.18 | 0.06 ** | | | 0.07 | 74 | 0.31 | 0.43 |
| Czech Republic | 0.21 *** | 0.21 * | 0.16 ** | | | 0.10 | 84 | 0.82 | 1.06 |
| Denmark | 0.04 | 0.14 | 0.08 *** | -5.58 *** | | 0.24 | 84 | 0.35 | 0.17 |
| Hungary | 0.03 | 0.38 *** | 0.14 ** | | | 0.27 | 84 | 0.91 | 0.17 |
| Iceland | -0.03 | 0.22 ** | 0.01 | -2.69 *** | | 0.24 | 84 | 0.04 | -0.16 |
| Israel | 0.06 * | 0.22 ** | 0.09 ** | 3.33 *** | -3.59 *** | 0.24 | 84 | 0.44 | 0.31 |
| Korea | 0.09 ** | 0.10 | 0.01 | -2.71 *** | | 0.11 | 84 | 0.06 | 0.38 |
| Mexico | 0.10 *** | 0.04 | 0.01 | | | -0.02 | 84 | 0.03 | 0.42 |
| New Zealand | 0.05 | 0.02 | 0.11 *** | | | 0.09 | 84 | 0.45 | 0.21 |
| Norway | 0.05 | -0.07 | 0.05 | | | -0.01 | 84 | 0.20 | 0.20 |
| Poland | 0.04 | 0.54 *** | 0.04 | | | 0.31 | 84 | 0.32 | 0.36 |
| Sweden | -0.05 ** | 0.28 *** | 0.12 *** | 2.91 *** | 2.67 *** | 0.51 | 84 | 0.68 | -0.29 |
| Switzerland | 0.05 ** | 0.15 | 0.07 *** | -3.22 *** | | 0.20 | 84 | 0.35 | 0.26 |
| Turkey | 0.63 *** | 0.22 ** | 0.07 | 11.84 *** | | 0.21 | 84 | 0.34 | 3.22 |
| Median | | | | | | | | 0.43 | 0.35 |

Note: The table reports the results of regressions to explain the difference between quarterly headline and core inflation (wdg) with a measure of the world output gap constructed using a Hodrick-Prescott filter (wld_gap) and the logged difference of the nominal effective exchange rate (Δexch), over the sample period 1998Q1–2018Q4. The penultimate (final) column reports the long-run effect of the wedge (the long-run constant) calculated as the coefficient on the wedge (constant) divided by one minus the coefficient on the lagged dependent variable, with this result multiplied by four in order to give the implied long-run effect on the difference between *annualised* headline and core inflation. "***", "**" and "*" denote statistical significance at the 1%, 5% and 10% levels, respectively.
Source: Authors' calculations.

27. The strong relation found between global capacity measures and the wedge between headline and core inflation suggests policymakers should be wary of headline inflation picking up sharply when many countries overheat simultaneously. It might also raise questions as to the appropriate price index to target; if this wedge is strongly influenced by global, rather than domestic, conditions then targeting core might be more attractive than headline inflation because it relates more closely to domestic monetary policy. Moreover, the experience of recent decades suggests that the difference between headline and core inflation can be very persistent and should not be dismissed as short-term noise. On the other hand, excluding important components of the consumer basket from the official target is open to objections about

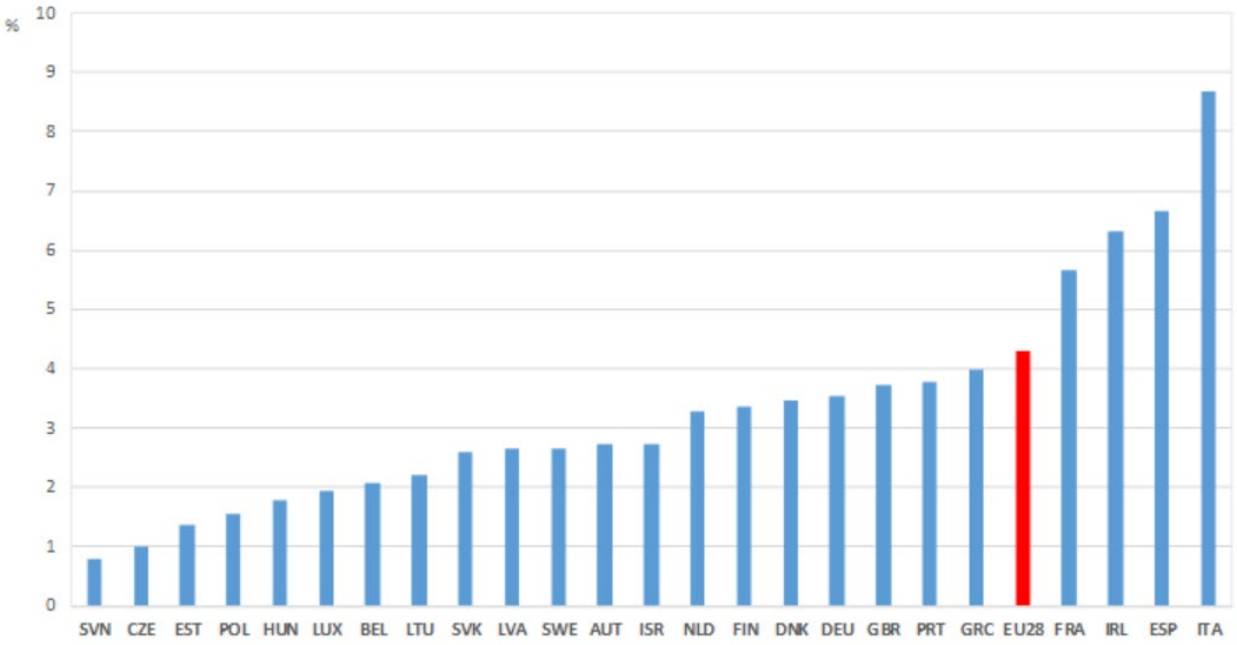
the diminished relevance of a narrower policy objective, less closely related to living standards and so less relevant to agents in the wider economy.

## 5. Alternative measures of labour market slack

28. In order to address the unsatisfactory performance of standard Phillips curve specifications, recent studies (ECB 2017; Moretti et al., 2019) have investigated alternative definitions of unemployment to estimate labour market slack. Involuntary part-time workers, those employees that would like to work more hours than demanded by their employers, represent the broadest form of labour under-utilisation and the most commonly used for alternative estimates of the unemployment gap. To construct an alternative measure of slack, half the share of involuntary part-time workers in the labour force was added to the standard unemployment rate definition and OECD standard Phillips curve equations were re-estimated on a sub-group of countries.[15] The standard methodology applies a Kalman filter to estimate simultaneously and consistently the equilibrium unemployment rate (and the unemployment gap) and the coefficients of a Philips curve incorporating anchored inflation expectations (as described in Rusticelli et al., 2015). The four countries examined, namely France, Ireland, Spain and Italy, are those characterised by involuntary part-time employment above the European Union's average since the Great Recession (Figure 8). In these countries, the incidence of involuntary part-time employment increased during the Great Recession at a rate of nearly three times that of the European Union average.

### Figure 8. Share of involuntary part-time employment in European countries

Percentage of total employment, average 2009Q1 – 2018Q4

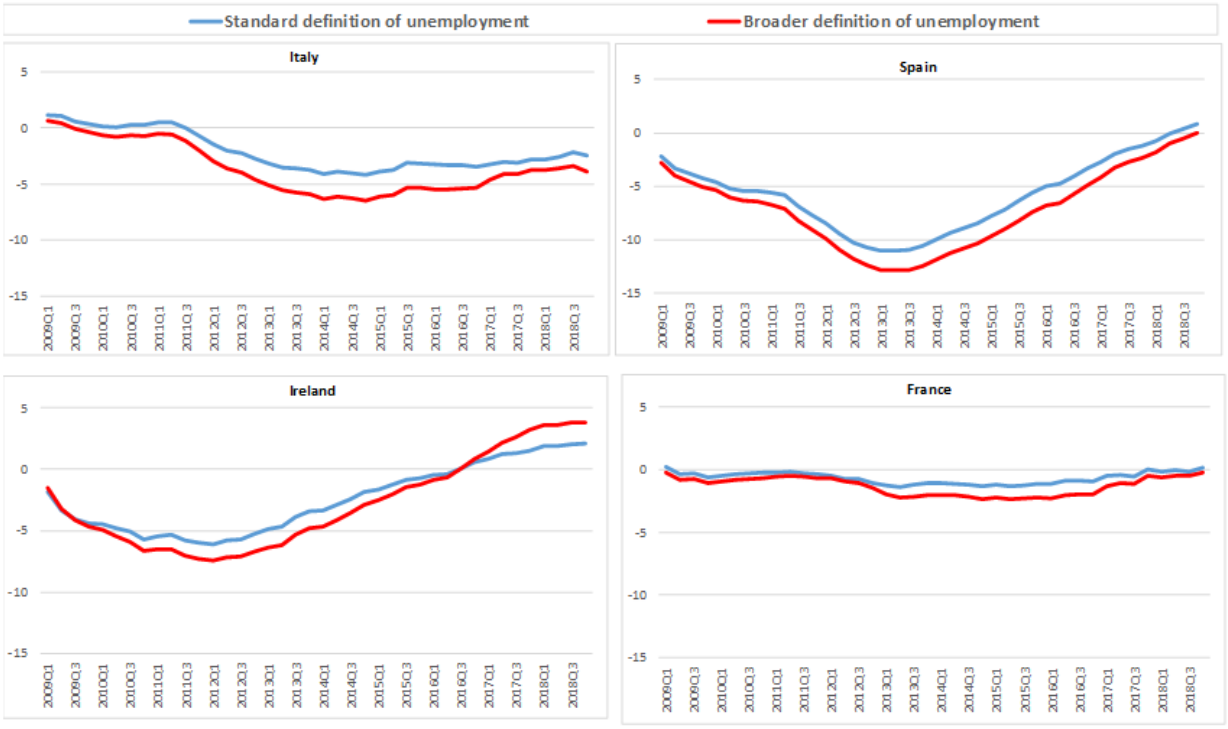



Source: OECD Labour Force Statistics database.

[15] As involuntary part-time workers are partially employed, only half the share is added to the usual unemployment rate.

29. The unemployment gap estimates obtained using the broader definition of unemployment are one percentage point larger on average than those from a standard Phillips curve specification, with the greatest revision estimated for Italy (Figure 8). For Ireland, the share of involuntary part-time employment has halved in the last two years and is now lower than in the pre-crisis period. As a consequence, over 2017-2018, the alternative estimate of the unemployment gap is about 1½ percentage points more positive (i.e. more over-heating) than the standard estimate (Figure 9). Despite the broader estimate of labour market slack obtained through the inclusion of labour under-utilisation in the Phillips curve, there is little or no improvement in the prediction of underlying core inflation.

### Figure 9. Unemployment gap estimates using alternative measures of unemployment




Note: The charts display the unemployment gap estimates obtained by means of the standard version of the Phillips curve with anchored inflation expectations applied over the sample 1998Q1-2018Q4. The use of the standard definition of unemployment is compared to the alternative version, where a measure of labour under-utilization is added to the unemployment rate. Precisely, half the share of part-time workers in the labour force is added to the standard unemployment rate definition.

Source: Authors' calculations.

## 6. Evidence of non-linear effects

30. The Phillips curve is typically modelled as a linear relationship linking a measure of economic slack to inflation. However, a strand of research has also explored the possibility that the Phillips curve may be non-linear, which could help to explain the 'missing disinflation' that followed the Great Recession. The non-linearity may be a function of inflation itself, or a function of economic slack.

### *6.1. Non-linearity depending on inflation*

31. One form of non-linearity, or regime change, concerns the initial level of inflation itself. It could be that the Phillips curve has a different slope when inflation is high than when it is low, sometimes referred

to as 'inflation saliency' (Blanchard et al., 2015). The idea is that when inflation is high, people tend to pay attention to the evolution of prices, giving rise to a trade-off between economic activity and inflation dynamics. When inflation is low, however, people do not pay much attention to prices and the trade-off becomes much less apparent.

32. Evidence for this hypothesis comes from looking at simple Phillips curve relationships and separating out periods of low inflation from high inflation. For many OECD countries, univariate Phillips curves relating unemployment gaps to changes in core inflation (relative to its average level of the previous three years) have noticeably steeper slopes when inflation is above 3% than when it is below (as illustrated for the United States, Japan and the United Kingdom in Figure 10).

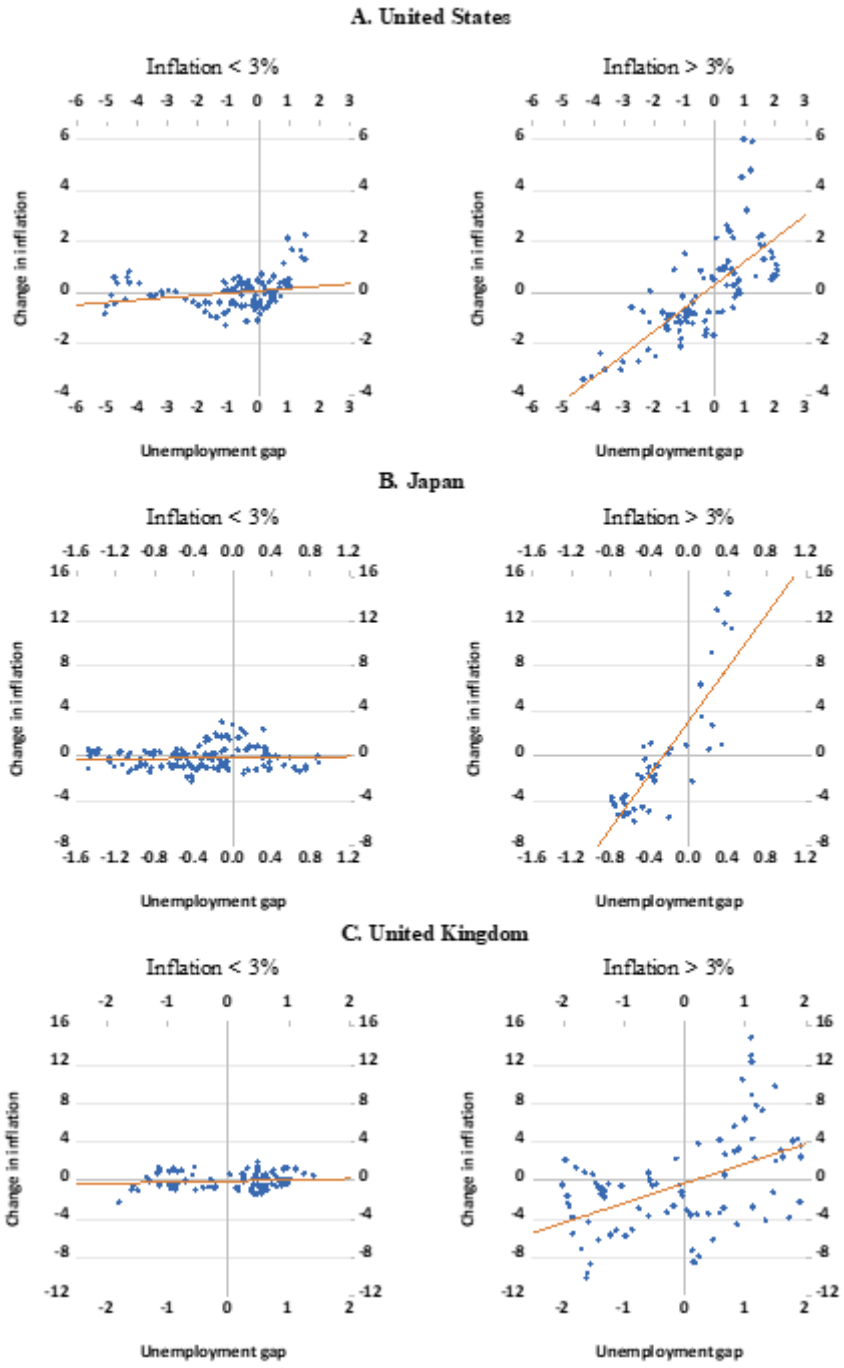
33. This evidence must be qualified in several respects, however. For one, the apparent regime change between low and high inflation is only visible in countries with a consistent measure of core inflation going back to at least the 1970s. However, almost all of the high-inflation observations come from the pre-1990 period, and almost all of the low-inflation ones come from the post-1990 period. Therefore, as much as the two panels of each chart distinguish periods of high and low inflation, they also distinguish different eras. Moreover, in countries with shorter sample periods, including all euro area countries for which consistent data series begin in the 1990s, Phillips curves do not appear to have significantly different slopes in high versus low-inflation periods, even if the inflation threshold is lowered, as there are often too few instances of above 3% inflation.

34. The timing of the regime change suggests an explanation for the flattening of Phillips curves. From the 1960s to the mid-1990s, before inflation targeting became the norm in advanced countries, poor anchoring of inflation expectations may have made inflation more sensitive to economic conditions. Since the advent of inflation targeting and the gain of credibility by central banks, inflation has gradually come down and expectations have firmed around explicit targets, which is the rationale for the Secretariat's current anchored expectations specification.

35. Reduced sensitivity of inflation to unemployment at low inflation rates could be due to the presence of downward nominal wage rigidities, which implies asymmetries in the responsiveness of nominal wage growth (and hence inflation) to the unemployment gap (Daly et al., 2012; Yellen, 2012; Abritti and Fahr, 2013). If workers resist nominal wage cuts, excess capacity may have a weaker effect on prices when inflation is already low, generating an asymmetry with respect to the output gap. In theoretical models at least, downward nominal wage rigidity implies convexity in the Phillips curve, which materialise at times of excess supply (Stiglitz, 1986; Fisher, 1989).

36. This asymmetry can be formally tested by seeing whether the estimated coefficient on the unemployment gap changes in a statistically significant way when core inflation falls below a particular (low) level. Tests for this form of non-linearity were performed using the current set of Phillips curves specifications and a set of arbitrarily low inflation thresholds (½ and 1% per annum at an annualised rate). In the overwhelming majority of cases, the null hypothesis of symmetry cannot be rejected, although in many cases this is probably due to having too few low-inflation observations. Japan is an important exception, however.

## Figure 10. The Phillips curve slope and the level of inflation




Note: The y-axis shows y-o-y core inflation at the quarterly frequency minus average y-o-y core inflation in the previous three years, in percentage points. The x-axis is the unemployment gap lagged 4 quarters, in percentage points. The split between left and right-hand side panels is based on year-on-year core inflation lagged 4 quarters. Ranges for both axes are standardised across the two panels.
Source: OECD *Economic Outlook*, No. 104 database.

37. Japan's Phillips curve equation is estimated over a sample period spanning 1990 to 2018, when annualised quarterly core inflation was below 1% about three quarters of the time. Japan thus provides a useful ground for testing the presence of an asymmetry in the response of inflation to economic slack. The unemployment gap coefficient is estimated to be 0.08 (*p*-value < 1%) when core inflation is below 1% per

annum, versus 0.65 (*p*-value < 1%) when it is above, with the null hypothesis of equality between these two coefficients being rejected at the 1% significance level.[16,17] Given the very low inflation thresholds used in the tests, it seems likely that the results stem from downward nominal wage and price rigidity, which is reassuring from the perspective of avoiding deflation. If this is indeed the case, then it is also likely that countries other than Japan would experience similar price stickiness if core inflation rates were to slip below 1% for an extended period.

### *6.2. Non-linearity depending on the unemployment gap*

38. Another potential form of non-linearity in the Phillips curve may stem from capacity constraints introducing convexity into the effect of economic slack and reducing the sensitivity of inflation to negative gaps (Clark and Laxton, 1995; Macklem, 1997). Spare capacity in depressed conditions may allow firms to satisfy higher demand without abrupt price increases, whereas during expansions firms may increase prices more readily as capacity constraints bite and marginal costs increase. Thus, as economic conditions strengthen, inflation may become increasingly sensitive, imparting a convex shape to the Phillips curve. This type on non-linearity has been widely analysed in the literature. According to a survey of dozens of studies published in the last two decades, the slope of Phillips curves is two to three times larger in boom phases than contractionary phases (St-Cyr, 2018).

39. Two approaches are usually adopted in the literature to test for non-linearity conditional on the size and sign of the unemployment gap:

- A non-linear specification for the Phillips curve (e.g. adding the square of the output or unemployment gap or the use of a dummy variable separating positive from negative gaps) to account for structural changes in the inflation process (Laxton et al., 1995; Fisher and Koenig, 2014). Alternative approaches have considered splitting short-run and long-run unemployment or using a spline to allow for a kink in the unemployment gap with the purpose of demonstrating varying steepness in the slope of the Phillips curve depending on the level of unemployment (Guichard and Rusticelli, 2011; Babb and Detmeister, 2017).
- Thresholds models, like Markov switching chains, where the relationship between the output or unemployment gap measure and the level of inflation depends on the underlying state of the economy (Demers, 2003; Nalewaik, 2016; Gross and Semmler, 2017).

40. The analysis undertaken here applies the approach of Gross and Semmler (2017) to the identification of non-linear Phillips curves for a number of OECD economies.[18] The hypothesis of convexity is evaluated through the estimation of Markov switching probability-based models that start from the preferred linear specification of the Phillips curves described earlier in the paper. The coefficient on the unemployment gap is estimated using a two-regime switching equation with intercept and variance-switching residuals, which ensures that the slope of the Phillips curve evolves smoothly between the two states corresponding to negative and positive unemployment gaps.

41. Comparing slope estimates from the linear and the non-linear regime-switching specifications indicates that coefficients on the unemployment gap are consistently higher in expansions than recessions, with the former typically 2-3 times greater than the coefficient estimated in a linear framework (Table 4, Figure 11). This result is similar to that of Gross and Semmler (2017) who find that the ratio of coefficients

16. The null hypothesis of equality of coefficients is also rejected at the 1% level if the inflation threshold is lowered to 0.5%.

17. Evidence of a flatter Phillips curve slope at lower rates of inflation for Japan was also found in earlier OECD work (Mourougane and Ibaragi, 2004).

18. The United Kingdom was excluded because of the difficulty of getting a correctly-signed unemployment gap term in the linear specification.

from non-linear and linear approaches is between 1.1 to 3.5 for a range of Phillips curves estimated for the euro area using different measures of slack and expectations.

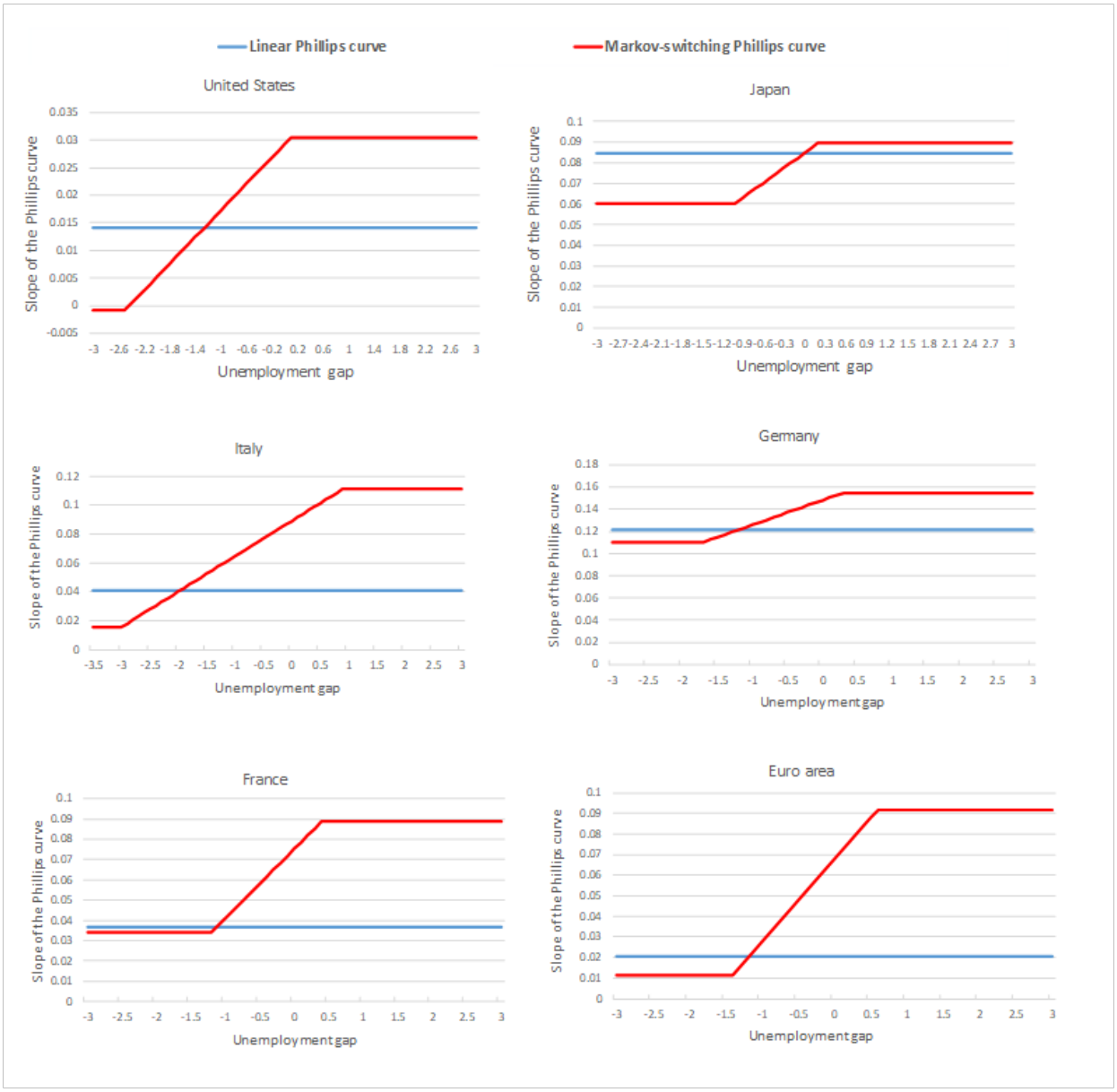
### Table 4. The slope of the Phillips curve in linear and non-linear specifications

| | Slope of the Phillips curve | | | Likelihood Ratio test p-value | Ratio of positive non-linear to linear slope coefficient |
|---|---|---|---|---|---|
| | Linear | Nonlinear | | | |
| | | Positive GAP | Negative GAP | | |
| United States | 0.014* | 0.030*** | 0.000 | ** | 2.1 |
| Japan | 0.084*** | 0.089** | 0.060** | *** | 1.1 |
| Germany | 0.121*** | 0.155*** | 0.110* | *** | 1.3 |
| France | 0.037* | 0.089*** | 0.034* | *** | 2.4 |
| Italy | 0.040*** | 0.111* | 0.016 | ** | 2.7 |
| Euro area | 0.021* | 0.092*** | 0.012 | ** | 4.5 |

Note: Coefficients estimates of the unemployment gap obtained by means of a linear and a probability-based Markov switching Phillips curve. *, ** and *** indicate statistical significance at 10%, 5% and 1% level, respectively. The ratio of the slope coefficients in the final column is computed by dividing the slope of the positive regime by the linear slope. The likelihood ratio test compares the goodness of fit of the linear model against the non-linear specification, with *, **, *** indicating that the null hypothesis of the equivalence of the two specifications is rejected in favour of the non-linear model at the 10%, 5% or 1% significance level, respectively.
Source: Authors' calculations.

42. Given that linear Phillips curves imply very weak unemployment gap effects, the policy implications of having two to three times larger effects in boom phases are not necessarily alarming. Such a conclusion is supported by the findings of an entirely different type of study by Babb and Detmeister (2017), who find strong statistical support for a non-linear Phillips curve for the United States using metropolitan-wide data, but also calculate that the inflation implications are "*only slightly different to the linear version over the next couple of years*".

## Figure 11. Unemployment gap coefficients in linear and non-linear Phillips curves




Note: The charts show coefficients estimates on the unemployment gap obtained by means of a linear and a probability-based Markov switching Phillips curve.
Source: Authors' calculations.

## 7. Summary and possible policy implications

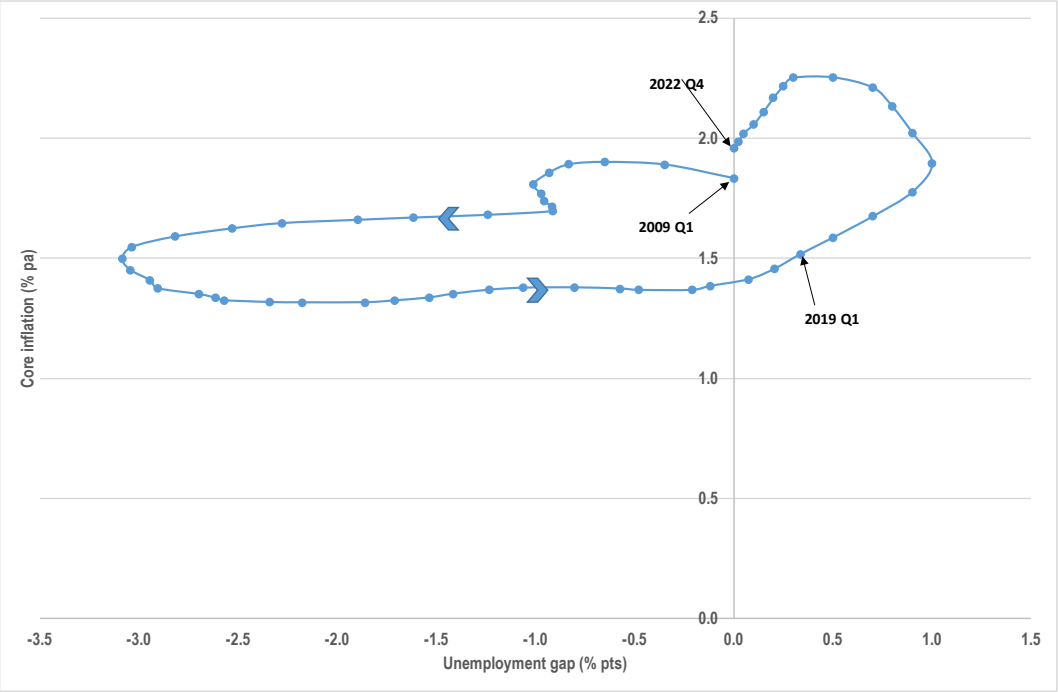
43. The lower sensitivity of inflation to economic conditions reflects increased credibility of central bank targets, which is a positive development, especially to the extent that more stable inflation underpins broader confidence in the macro environment, so favouring risk taking, investment and growth. On the other hand, the flattening of Phillips curves means that central banks need to make larger interventions on the real economy than before to get the same traction on inflation. So the risk of under or over-shooting may have shifted somewhat from inflation to real activity. One possible implication is that central banks should resist the temptation to 'fine tune' inflation. Blanchard et al. (2015) go further and argue that a small but still significant coefficient on the unemployment gap reinforces the case for a dual mandate and implies that monetary policy reaction functions should put more weight on the output gap relative to inflation.

44. On the other hand, recent persistent low inflation outcomes, particularly with unemployment close to pre-crisis levels, raise concerns that the prolonged period of low inflation has become embedded in inflation expectations, particularly in euro area countries and in Japan. This is not always immediately obvious in Professional Forecasters' long-term forecasts of inflation over the next six to ten years. However, for many countries, the only satisfactory empirical explanation for low inflation in the current Phillips curve framework is that inflation expectations include at least some weight on one-year-ahead forecasts of inflation. The policy implications of the need to incorporate short-term forecasts of inflation into the Phillips curve are unclear, particularly as such forecasts have been quite volatile and, *ex-post*, often rather poor.

45. An alternative and better explanation of recent low inflation outcomes allows for the possibility that persistent under-shooting of the inflation target lowers inflation expectations. Such models suggest that inflation expectations may now be closer to 1% than 2% in many euro area countries. The euro area may be particularly vulnerable to such risks because the commitment to inflation is area-wide and does not apply to any individual country. The slippage of inflation expectations is a cause for concern, because if faced with another large negative demand shock, then the scope for conventional monetary policy to lower nominal interest rates would be highly constrained. Moreover, the euro area would be in danger of repeating the experience of Japan where there is evidence that stable prices have become entrenched in expectations. These circumstances might warrant maintaining an expansionary monetary and fiscal policy stance for longer than appears justified on the basis of looking at measures of slack alone.

46. A *linear* Phillips curve, incorporating a mechanism by which persistent under-shooting of the inflation target leads to slippage of expectations (such as that described in equation [5] above), if taken literally, would carry the surprising (and perhaps implausible) implication that to re-anchor expectations over any medium-term horizon would require a 'Great Boom' to mirror the effects of the 'Great Recession'. However, evidence of *non-linearities* in the Phillips curve, whereby positive gaps have a larger inflationary effect than the weak disinflationary effect of negative gaps, would suggest that a more modest period of over-heating might be required, as illustrated by the example in Figure 12 that is based on the non-linear euro area Phillips curve estimated previously. Japan is in a similar, but more extreme, situation with inflation expectations more entrenched and even further below the official target and so likely to require a more prolonged period of over-heating to jump-start inflation expectations as well as clear communication regarding the permanent commitment to the inflation target.

## Figure 12. Simulation of a hypothetical recovery on euro area inflation




Note: The chart uses an estimated non-linear euro area Phillips Curve to simulate the response of core inflation to the unemployment gap shock experienced following the Great Recession followed by a hypothetical recovery. The unemployment gap is treated exogenously. Inflation is anchored by expectations, which are initially equal to the inflation target (assumed to be 2%), but also influenced by persistent deviations of core inflation from the target, as summarised by equation [5] in the text. The estimated non-linearity allows for the possibility that inflationary effects of a positive unemployment gap are larger than the disinflationary effect of a negative unemployment gap, as reported in Table 4.
Source: Authors' calculations.

47. For other countries, for which there is less evidence of slippage in inflation expectations – including the United States, United Kingdom and Canada – this form of non-linearity would suggest greater vigilance at this late stage of the economic cycle with estimated unemployment gaps already closed. A shock that raised inflation well above target in an already overheating economy could cause inflation to accelerate faster than expected, particularly if inflation rose to more 'salient' rates for firms and workers. However, such concerns should be balanced by a recognition that, as emphasised above, even if estimated non-linearities suggest that positive gaps have an effect on inflation which is a multiple (typically two or three times larger) of the estimated effects in a linear specification, the effects on inflation may still be modest because the linear effects are typically so weak.

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# Annex A. A general Phillips curve framework

A general framework, which encompasses the evolution of models used by the Secretariat, is the familiar expectations-augmented Phillips curve, where inflation ($\pi$) is explained in terms of: expected inflation ($\pi^e$); demand represented by the unemployment gap, which is the difference between actual unemployment ($U$) and equilibrium unemployment ($U^*$); and supply shock variables which have a temporary effect on inflation, such as real import price inflation and changes in indirect taxes:

$$\pi_t = \pi_t^e + \beta(U_t^* - U_t) + supply\ shocks + \varepsilon_t \quad [1]$$

Inflation is specified in terms of core CPI inflation (excluding food and energy) to purge the dependent variable from the direct impact of some of the main supply shocks. Inflation expectations are postulated to follow a general autoregressive process of the following form:

$$\pi_t^e = [1 - b(1)]\pi^T + b(L)\pi_{t-1} \quad [2]$$

where $b(L)$ is a lag polynomial and $\pi^T$ is the inflation rate targeted by the central bank. Within this set-up, three cases can be distinguished:

- unanchored adaptive expectations which are based on recent historical experience and where time averaging imposes the long-term constraint that $b(1) = 1$ on the lag polynomial;
- expectations are fixed at the inflation target in the special case where $b(L)=0$, so that $\pi^e = \pi^T$;
- and intermediate cases in which $b(1) < 1$, so that expectations are partially backward-looking, but still tend towards the target over time.

Equation [2] for inflation expectations can be reformulated as:

$$\pi_t^e = [1 - b(1)]\pi^T + b(1)\pi_{t-1} + \tilde{b}(L)\Delta\pi_{t-1}, \text{ where} \quad [3]$$

$$\tilde{b}(L) \equiv (1 - L)^{-1}[b(L) - b(1)], \quad [3a]$$

so that when [3] is substituted into the Phillips Curve [1], it gives the general formulation:

$$\Delta\pi_t = -[1 - b(1)](\pi_{t-1} - \pi^T) + \tilde{b}(L)\Delta\pi_{t-1} + \beta(U_t^* - U_t) + supply\ shocks + \varepsilon_t \quad [4]$$

### *The former backward-looking Phillips curve specification*

The former OECD approach to estimating the Phillips curve and deriving the unemployment gap adopted a traditional backward-looking Phillips curve specification (Richardson et al. (2000); Gianella et al., 2008; Guichard and Rusticelli, 2011), in which $b(1) = 1$, so that inflation and inflation expectations follow unit root processes, and [4] simplifies to:

$$\Delta\pi_t = \tilde{b}(L)\Delta\pi_{t-1} + \beta(U_t^* - U_t) + supply\ shocks + \varepsilon_t \quad [5]$$

Under this specification, but not the more general form of [4], the equilibrium unemployment rate corresponds to what is often referred to as the Non-Accelerating Inflation Rate of Unemployment (NAIRU). As the unemployment gap and the NAIRU are unobservable, the system was completed with two equations modelling the movement in the NAIRU as a random walk process and the unemployment gap as a second order autoregressive process.

A major problem with this backward-looking specification is that when estimated over a recent sample period beginning in 1998, the coefficient on the unemployment gap ($\beta$) is found to be small, sometimes incorrectly signed and not statistically significant for most OECD countries (Rusticelli *et al.*, 2015).

***The revised anchored expectations Phillips curve***

Long-term inflation expectations have become better anchored as central banks have become more explicit about their inflation objectives, often adopting specific targets for inflation (Benati, 2008; Gurkaynak et al., 2010; Davis, 2012 and 2014]. The Reserve Bank of New Zealand was the first OECD central bank to adopt a specific target for inflation in 1990, but central banks in almost all OECD countries have adopted some form of explicit objective for inflation since then.[19]

The revised OECD modelling framework incorporates the notion of partially anchored inflation expectations, given by the general form of [4] with $b(1) < 1$, so that inflation and inflation expectations are stationary and will gravitate towards $\pi^T$. The economic interpretation of equilibrium unemployment ($U^*$) in the more general form of [4] is, however, very different from the NAIRU concept in [5], because if the unemployment rate differs from $U^*$, inflation can still be stable. In the absence of any other shock, the backward-looking specification of the Phillips curve implies that inflation will only be stable when the unemployment gap is closed (i.e. when unemployment equals the NAIRU), and it will keep falling as long as unemployment exceeds the NAIRU. In other words, a stable negative unemployment gap generates a constant rate of disinflation. Conversely, the anchored expectations specification implies that, in the absence of any other shock, when the unemployment gap is closed inflation will stabilise at the level consistent with long-run inflation expectations, which in most cases will be anchored at the central bank's inflation objective. As a consequence, a stable and negative unemployment gap generates an inflation rate which is stable, but at a lower level than the central banks inflation objective.

To estimate equation [4], the term $(\pi_{t-1} - \pi^T)$ is replaced by a separate lagged inflation variable, with freely estimated coefficient $\theta$, and an (initially) unrestricted intercept term ($\tau$):

$$\Delta\pi_t = \tau - \theta\pi_{t-1} + \tilde{b}(L)\Delta\pi_{t-1} - \beta(U_t^* - U_t) + supply\ shocks + \varepsilon_t \qquad [6]$$

The implied level of stable inflation expectations, comparing [4] with [6], is then given by ($\tau/\theta$) and when there is an explicit central bank numerical objective for inflation the restriction that ($\tau/\theta$) is equal to this objective is imposed when consistent with the data (which is equivalent to testing for the restriction that the coefficients on the lagged inflation and numerical target variables have the same magnitude, but opposite signs).

Given the rationale underlying the new specification, the model is only estimated over a sample period when inflation expectations can plausibly be considered to be anchored. One option, to only estimate the equation over sample periods in which a formal inflation target is in operation, is rejected because there are a number of countries for which this would imply a very short sample period over which it would be difficult to derive plausible parameter estimates. Moreover, an over-arching objective of the exercise is to come up with an approach which could readily be adopted across most, if not all, OECD countries. Instead, the approach adopted is to begin the sample estimation period in 1998, and for those countries for which an inflation target was introduced more recently, the restriction that inflation expectations are anchored at the target is only imposed for this more recent period (Table A1). For euro area countries, a restriction of 2% inflation expectations is chosen for each individual country, even though the ECB's target is for area-wide inflation to be "below, but close to, 2% over the medium term".

[19] Although until recently there was no specific inflation objective for the United States, the financial market reaction to FOMC statements suggested that the markets believed the Federal Reserve had an implicit long-run inflation objective of between 1% and 3.5%, with a mid-point close to former Chairman Bernanke's suggestion of 2% as optimal long-run average inflation (Thornton, 2007; Bernanke, 2004).

There are then two clear reasons why the current revised anchored expectations specification performs better than the former backward-looking Phillips curve specification:

- The backward-looking Phillips curve specification in [5] is a special case of the more general specification [4], implying no role for the lagged level of inflation or any separate influence for the inflation target. However, such restrictions on the general model were overwhelmingly rejected: The coefficient on lagged inflation was found to be significantly different from zero for almost all countries; the restriction that the estimated constant ($\tau$) and the coefficient on lagged inflation ($\theta$) are consistent with expectations being anchored at the central bank's inflation target also could not be rejected for most countries.
- While the backward-looking specification yields estimates of the unemployment gap coefficient ($\beta$) which are statistically significant to at least the 10% level for nearly all countries over a full sample (usually beginning in the 1960s or early 1970s), the coefficient was only significant in one-quarter of the cases over a shorter sample starting in 1998. Conversely, the unemployment gap was found to be statistically significant in the expectations-augmented Phillips curve for virtually all countries.

**Table A1. The inflation target restriction, 1998-2018**

| Country | Official target (%)[1] | Target in Phillips curve (%) | Country | Official target (%)[1] | Target in Phillips curve (%) |
|---|---|---|---|---|---|
| Australia | 2-3 | 2.5 | Latvia | 2 since 2005 | not accepted |
| Canada | 2 +/-1 | 2 | Korea | 2.5-3.5 | 3 |
| Chile | 3 +/-1 | 3 | Mexico | 3 | 3 |
| Colombia | 3 +/-1 | 3 | Norway | 2.5 since 2001 | 2.5 since 2001 |
| Czech Republic | 3-4 (2002-05); 3 (2006-09); 2 since 2010 | Time-varying, according to target | New Zealand | 0-2 (1998-2002); 1-3 since 2002 | 2 since 2002 |
| Denmark[2] | none | N/A | Poland | 2.5 | 2 since 2004 |
| Euro Area[3] | < 2 | 2 | Sweden | 2 | 2 |
| Hungary | 3 +/-1 | 3 | Switzerland | 0-2 | 1 |
| Iceland | 2.5 +/-1.5 | 2.5 | Turkey | from 3.5 to 5 between 2002-2012; 5 since 2012 | Time-varying, according to target |
| Israel | 2 +/-1 since 2003 | 2 since 2003 | United Kingdom | 2 | 2 |
| Japan | 2 since 2013 | not accepted | United States | 2 since 2012 | 2 since 2012 |

Note:

1. The official target is set on HICP inflation for euro area countries, core CPI inflation for Korea, and CPI inflation for all other countries.
2. The restriction imposed is that the intercept divided by the coefficient on lagged inflation ($\theta$) is equal to the number in this column. Denmark does not have an official inflation target, rather monetary policy aims to keep a fixed exchange rate with the euro.
3. In the euro area, the official target is an area-wide HICP inflation close to, but below, 2%. To operationalise this as a country-specific target, a restriction of 2% was tested on each country individually from 1998, except Latvia, Slovenia and Slovak Republic for which the restriction was tested from 2005 and Estonia from 2011. This restriction cannot be rejected in all countries with the exception of Estonia.

# Annex B. Detailed results for the Secretariat Phillips curves

For each country, two equations are reported: the first is the current Secretariat specification summarised in equation [2] in the main paper; the second adds the slippage term described in equation [5].

## Table B1. Detailed estimation results

(i) G7 and euro area aggregate

| Dependent variable $\Delta\pi$ | USA | | JPN | | DEU | | GBR | | FRA | | ITA | | CAN | | EA17 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| $(\pi_{-1} - \pi^T)$ | -0.97 *** | -1.01 *** | -0.48 *** | | -0.58 *** | -0.85 *** | -0.66 *** | -0.75 *** | -0.15 ** | -0.57 *** | -0.42 *** | -0.48 *** | -0.59 *** | -0.69 *** | -0.24 *** | -0.52 *** |
| U* - U | 0.03 *** | 0.02 *** | 0.08 *** | | 0.13 *** | 0.08 ** | -0.05 * | -0.01 | 0.04 * | 0.07 *** | 0.04 *** | 0.04 *** | 0.03 | 0.01 | 0.02 * | 0.02 * |
| $f_1(\pi^m)$ | | | 0.15 | | | | | | | | | | | | | |
| $f_2(\pi^m)$ | 0.66 *** | 0.66 *** | | | | | | | | | 0.38 ** | 0.37 ** | | | | |
| $f_3(\pi^m)$ | | | | | | | | | | | | | | | | |
| $f_4(\pi^m)$ | 0.56 *** | 0.51 *** | | | 0.24 | 0.26 * | 0.35 *** | 0.41 *** | 0.12 | 0.06 | | | 0.21 * | 0.24 * | 0.14 * | 0.19 ** |
| $\Delta\pi_{-1}$ | | | -0.25 *** | | | | | | | -0.27 ** | -0.69 *** | -0.64 *** | | | -0.32 *** | -0.17 |
| $\Delta\pi_{-2}$ | | | | | | | | | -0.48 | | -0.28 *** | -0.26 ** | | | | |
| SLIP | | 0.24 | | | | 0.62 *** | | 0.37 ** | | 0.47 *** | | 0.09 | | 0.43 ** | | 0.40 *** |
| Constant | | | 0.03 | | | | | | | | | | | | | |
| Dummies | | | 1997Q2 ; 2014Q2 | | 2007Q1 | | 2008Q4 ; 2011Q1 | | 2014Q1 | | 2011Q4 | | | | | |
| Adj R2 | 0.50 | 0.51 | 0.68 | | 0.30 | 0.40 | 0.46 | 0.49 | 0.33 | 0.40 | 0.66 | 0.66 | 0.29 | 0.32 | 0.25 | 0.30 |

Note:

1. The sample estimation period for all equations is from 1998Q1 to 2019Q1. The dependent variable, $\Delta\pi$, is the quarterly percentage change in the core CPI, except for the United States where it is the quarterly change in the PCE deflator. For European countries, where there is a difference, harmonised rather than national definitions of core CPI are used.

2. The import variables take a variety of dynamic forms to allow for different patterns of pass-through. These different import inflation variables, $f_i(\pi_t^m)$, $i$ =1 to 4, are defined as follows. First, define a moving average of real import inflation over $n$ quarters as $m_t^n = \sum_{t-1}^{t-n}(\pi_t^m - \pi_t)/n$, where $\pi_t^m$ is the quarterly growth rate of the price of imported goods and services based on national accounts data, $\Delta ex$ is the quarterly growth rate of the nominal effective exchange rate and $\omega_t$ is a measure of openness defined as a moving average of nominal imports divided by nominal GDP and nominal imports; then, $f_1(\pi_t^m) = \omega_t\,(m_t^8 - m_t^{20})$; $f_2(\pi_t^m) = \omega_t \sum_{t-1}^{t-4} \Delta m_t\,/4$; $f_3(\pi_t^m) = \omega_t \sum_{t-1}^{t-4} \Delta ex_t\,/4$; $f_4(\pi_t^m) = \omega_t\, m_t^8$.

3. SLIP refers to the inflation "slippage" from target defined as $\sum_{t-1}^{t-16}(\pi_t - \pi^T)\,/16$ and the inclusion of this variable is the difference between equations [1] and [2] for each country. The dummies pick out spikes in inflation which, in nearly all cases, are related to indirect tax changes.

4. For Japan, no target variable is included so the attractor is implicitly given by the intercept term, which is estimated to be close to zero. The separate inclusion of a target variable from 2013 was found to be insignificant. Given there is no target variable, it is not possible to estimate equation [2].

Source: Authors' calculations.

## Table B1. Detailed estimation results *(contd.)*

(ii) Other euro area countries

| Dependent variable $\Delta\pi$ | AUT | | BEL | | ESP | | EST | | FIN | | GRC | | IRL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| $(\pi_{-1} - \pi^T)$ | -0.59 *** | -0.73 *** | -0.39 *** | -0.74 *** | -0.83 *** | -0.94 *** | -0.40 *** | -0.65 *** | -0.28 *** | -0.54 *** | -0.72 *** | -0.78 *** | -0.22 *** | -0.25 *** |
| U* - U | 0.01 | 0.03 | -0.01 | 0.02 | 0.03 *** | 0.02 *** | 0.02 | 0.06 *** | 0.02 | 0.09 ** | 0.05 *** | 0.05 *** | 0.02 | 0.01 |
| $f_1(\pi^m)$ | | | | | | | | | | | | | | |
| $f_2(\pi^m)$ | | | | | | | | | | | 0.16 | 0.17 | | |
| $f_3(\pi^m)$ | | | | | | | | | | | | | | |
| $f_4(\pi^m)$ | 0.25 * | 0.29 ** | 0.15 ** | 0.15 ** | 0.12 | 0.28 | 0.16 | 0.64 ** | 0.13 | 0.10 | | | 0.13 | 0.20 |
| $\Delta\pi_{-1}$ | | | -0.46 *** | -0.28 ** | | | | | | | | | | |
| $\Delta\pi_{-2}$ | | | | | | | | | | | | | | |
| SLIP | | 0.46 ** | | 0.60 *** | | 0.47 ** | | 0.44 *** | | 0.53 *** | | 0.15 | | 0.15 |
| Constant | | | | | | | | | | | | | | |
| Dummies | | | | | | | | | | | | | | |
| Adj R2 | 0.29 | 0.33 | 0.49 | 0.53 | 0.40 | 0.44 | 0.17 | 0.24 | 0.14 | 0.23 | 0.35 | 0.36 | 0.10 | 0.10 |

| Dependent variable $\Delta\pi$ | LTU | | LUX | | LVA | | NLD | | PRT | | SVK | | SVN | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| $(\pi_{-1} - \pi^T)$ | -0.72 *** | -0.76 *** | -0.93 *** | -1.15 *** | -0.56 *** | -0.82 *** | -0.55 *** | -0.76 *** | -0.74 *** | -0.89 *** | -0.28 *** | -0.49 *** | -0.54 *** | -0.92 *** |
| U* - U | 0.08 *** | 0.09 *** | 0.15 ** | 0.20 *** | 0.14 *** | 0.20 *** | 0.07 ** | 0.12 *** | 0.07 *** | 0.04 ** | -0.03 | 0.03 | 0.08 | 0.11 ** |
| $f_1(\pi^m)$ | | | | | | | | | | | | | | |
| $f_2(\pi^m)$ | | | | | | | | | | | 0.31 * | 0.36 ** | | |
| $f_3(\pi^m)$ | | | | | | | | | | | | | | |
| $f_4(\pi^m)$ | 0.17 * | 0.19 * | -0.02 | 0.08 | 0.32 *** | 0.49 *** | 0.19 | 0.27 ** | 0.14 | 0.22 | | | 0.01 | 0.36 |
| $\Delta\pi_{-1}$ | | | | | | | | | | | | | | |
| $\Delta\pi_{-2}$ | | | | | | | | | | | | | | |
| Slip | | 0.19 | | 0.94 *** | | 0.23 *** | | 0.62 *** | | 0.56 *** | | 0.49 *** | | 0.47 *** |
| Constant | | | | | | | | | | | | | | |
| Dummies | | | | | | | | | 2011Q1 | | | | | |
| Adj R2 | 0.36 | 0.35 | 0.46 | 0.53 | 0.36 | 0.44 | 0.28 | 0.35 | 0.42 | 0.48 | 0.15 | 0.23 | 0.25 | 0.44 |

Note: see notes to Table (i).

Source: Authors' calculations.

## Table B1. Detailed estimation results *(contd.)*

(iii) Other non-euro area countries

| Dependent variable $\Delta\pi$ | AUS | | CHE | | CHL | | COL | | CZE | | DNK | | HUN | | ISL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| $(\pi_{-1} - \pi^T)$ | -0.84 *** | -0.88 *** | -0.39 *** | -0.70 *** | -0.57 *** | -0.57 *** | -0.14 ** | -0.26 ** | -0.79 *** | -0.98 *** | -0.47 *** | -0.84 *** | -0.20 *** | -0.73 *** | -0.28 *** | -0.59 *** |
| U* - U | 0.19 ** | 0.20 ** | 0.03 | 0.03 | 0.07 ** | 0.07 ** | 0.03 | 0.05 | 0.25 *** | 0.23 *** | 0.01 | 0.05 ** | 0.02 | 0.03 | 0.04 | 0.21 *** |
| $f_1(\pi^m)$ | | | 0.10 | 0.16 ** | | | | | | | | | | | | |
| $f_2(\pi^m)$ | | | | | 0.38 *** | 0.38 *** | | | | | | | | | | |
| $f_3(\pi^m)$ | | | | | | | | | | | 0.11 | 0.17 | | | 0.48 *** | 0.45 *** |
| $f_4(\pi^m)$ | 0.06 | 0.15 | | | | | 0.07 | 0.20 | 0.45 * | 0.47 ** | | | 0.15 | 0.45 *** | | |
| $\Delta\pi_{-1}$ | -0.15 ** | -0.13 * | | | | | | | | | | | | | | |
| $\Delta\pi_{-2}$ | | | | | | | | | | | | | | | | |
| SLIP | | 0.29 | | 0.56 *** | | -0.01 | | 0.14 | | 0.38 ** | | 1.01 *** | | 0.43 *** | | 0.70 *** |
| Constant | | | | | | | | | | | | | | | | |
| Dummies | 2000Q3 | | 2011Q4 | | | | | | | | | | 2009Q3 | | | |
| Adj R2 | 0.81 | 0.82 | 0.33 | 0.46 | 0.35 | 0.34 | 0.05 | 0.06 | 0.39 | 0.46 | 0.21 | 0.36 | 0.27 | 0.54 | 0.26 | 0.39 |

| Dependent variable $\Delta\pi$ | ISR | | KOR | | MEX | | NOR | | NZL | | POL | | SWE | | TUR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) | (1) | (2) |
| $(\pi_{-1} - \pi^T)$ | -0.74 *** | -0.83 *** | -0.60 *** | -0.90 *** | -0.08 *** | -0.23 *** | -0.64 *** | -0.87 *** | -0.90 *** | -0.89 *** | -0.14 *** | -0.53 *** | -1.02 *** | -1.10 *** | -0.23 *** | -0.68 *** |
| U* - U | 0.07 | 0.16 * | 0.17 *** | 0.28 *** | -0.03 | 0.02 | 0.14 *** | 0.16 *** | 0.24 *** | 0.24 *** | 0.01 | 0.05 *** | 0.18 *** | 0.17 *** | 0.12 | 0.42 * |
| $f_1(\pi^m)$ | | | | | | | | | | | | | | | | |
| $f_2(\pi^m)$ | | | | | | | | | 0.09 | 0.09 | 0.16 | 0.14 | 0.53 ** | 0.56 ** | 2.06 *** | 2.45 *** |
| $f_3(\pi^m)$ | 1.54 *** | 1.56 *** | 0.20 *** | 0.19 *** | | | | | | | | | | | | |
| $f_4(\pi^m)$ | | | | | 0.05 | 0.15 | 0.59 *** | 0.95 *** | | | | | | | | |
| $\Delta\pi_{-1}$ | | | | | | | | | | | | | | | | |
| $\Delta\pi_{-2}$ | | | | | | | | | | | | | | | | |
| Slip | | 0.33 ** | | 0.85 *** | | 0.11 * | | 0.67 *** | | -0.10 | | 0.29 *** | | 0.49 ** | | 0.49 *** |
| Constant | | | | | | | | | | | | | | | | |
| Dummies | | | | | | | | | | | | | | | | |
| Adj R2 | 0.53 | 0.56 | 0.42 | 0.54 | 0.09 | 0.11 | 0.35 | 0.44 | 0.46 | 0.45 | 0.12 | 0.26 | 0.53 | 0.55 | 0.23 | 0.44 |

Note: see notes to Table (i).

Source: Authors' calculations.