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Violaine Faubert

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Directorate-General for Economic and Financial Affairs

Is the Irish Phillips Curve broken?

Violaine Faubert

Abstract

Contrary to the predictions of a traditional Phillips curve relationship, inflation in Ireland has remained subdued in recent years, regardless of improving labour market conditions before the covid-19 outbreak. To examine this apparent puzzle, we test econometrically the relevance of the Phillips curve in Ireland between 1999 and 2018. Linear regressions provide robust evidence that inflation does react to cyclical conditions both in Ireland and in its main trading partners. We also find that inflation dynamics are largely imported, in particular through imports from the UK. Low import prices have partly offset the upward pressures exerted by cyclical variables and contributed to the subdued inflation observed in recent years. We also investigate whether the Irish Phillips curve may be non-linear. We find some evidence that the Phillips curve is flatter when there are high excess capacities and turns steeper as economic slack is eliminated. However, when comparing different specifications on the basis of their pseudo out-of-sample forecasting performance, we find that non-linear specifications do not systematically outperform linear specifications.

JEL Classification: E31, E37, C22, C24, C50.

Keywords: Inflation, Phillips curve, Ireland, non linearities.

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Contact: Violaine Faubert, European Commission, Directorate-General for Economic and Financial Affairs, Economies of the Member States II, ECFIN.G2 - Denmark, Ireland, Portugal. This paper was written while the author was on secondment from the Banque de France (violaine.faubert@banque-france.fr).

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1. INTRODUCTION

Following the financial and economic crisis of 2008-2012, Ireland has experienced a sustained expansion phase[i]. Before the covid-19 outbreak, the unemployment rate was approaching its pre-crisis level, wage pressure was building up and capacity constraints were becoming increasingly apparent. Yet inflation had remained persistently low. Despite Ireland's strong growth performance relative to other euro area countries, Irish inflation remains one of the lowest in the euro area.

Persistently low inflation despite a closing output gap has cast doubt on the usefulness of the Phillips curve both in the US (Ball and Mazumder, 2011) and in the euro area (Onorante et al., 2019; Berson et al., 2018). This "missing inflation" puzzle led economists to reconsider the relation between economic activity and inflation and the global nature of the drivers of inflation.

Low inflation despite considerable reductions in labour market slack could reflect different factors. The Phillips curve could be difficult to estimate owing to mismeasurements in the level of slack in the economy. The Phillips curve could have flattened (with inflation reacting less to the business cycle) or be non-linear, with different pricing behaviours at different stages of the economic cycle. Low inflation could also reflect low import prices. In a small open economy like Ireland, much of inflation is imported. A large literature on the Irish inflation process has failed to find a role for domestic demand (Gerlach et al., 2016) and sees inflation as largely determined by import prices: indeed, if such an economy is a price taker, domestic excess demand is met at existing prices by imports.

We contribute to the empirical literature on the Phillips curve by examining the following questions:

i) Does inflation react to domestic cyclical conditions in a small, open economy like Ireland?
ii) What is the role of external drivers of inflation?
iii) Does the link between demand and prices vary depending on the state of the economy? Is there a role for non-linearities in the Irish Phillips curve?

Our contribution to the literature is threefold. Firstly, we provide robust evidence that domestic cyclical conditions drive Irish inflation. To the best of our knowledge, this article is the first to test systematically the impact of different indicators of demand on different measures of inflation for Ireland. We consider both headline inflation, which reflects the price of tradable and non-tradable products, and the price of services, which mostly reflects the price of non-tradable products. Domestic cyclical conditions significantly affect both the price of tradable products, which are expected to be mainly determined on international markets, and the price of non-tradable products, which are more likely driven by domestic factors. Indicators reflecting cyclical conditions in Ireland's major economic partners, such as the output gap in the UK and the euro area, are also statistically significant. We compare different specifications on the basis of their pseudo out-of-sample forecasting performance. We find that models relying on some indicator of domestic demand generate more accurate forecasts than models relying on indicators of demand in Ireland's economic partners. This result is consistent with Mikolajun and Lodge (2016) and McCoy et al. (2019), who do not find evidence that measures of domestic cyclical conditions are superseded by global output gap variables in the euro area Phillips curve.

Secondly, we analyse the role of external price pressures on headline inflation in Ireland. We pay particular attention to imported inflation from the UK, Ireland's main trading partner, by testing the impact of the euro/sterling exchange rate and of the UK consumer and producer prices. Phillips curve specifications augmented with the bilateral euro/sterling exchange rate, in conjunction with an indicator of commodity prices, generate the most accurate pseudo out-of-sample forecasts. This result is consistent with Reddan and Rice (2017), who find that Irish consumer prices are predominantly affected by the euro/sterling exchange rate, rather than by the effective exchange rate. By contrast, we find that specifications including the UK producer or consumer prices do not outperform other models.

Thirdly, we examine non-linearities in the relationship between inflation and cyclical conditions. We test several approaches to ensure the robustness of our results. Markov-switching regressions and threshold regressions suggest that the Phillips curve is flatter when excess capacities are high and turns steeper as economic slack is eliminated. However, non-linear specifications do not systematically yield more accurate pseudo out-of-sample forecasts than linear specifications.

The paper is organised as follows. Section 2 reviews the related literature. In Section 3, we estimate linear Phillips curve specifications to examine whether inflation reacts to cyclical conditions. Section 4 examines whether external factors drive headline inflation. In Section 5, we analyse non-linearities in the Phillips curve and compare the pseudo out-of-sample forecasting performances of linear Phillips curves with that of non-linear models. Section 6 concludes.

2. LITERATURE REVIEW

This article relates to several strands of literature.

2.1. THE PHILLIPS CURVE BREAKDOWN

A recent literature, mainly focused on the U.S., examines the apparent breakdown in the Phillips curve following the Great Recession. A possible explanation for this breakdown is the increasing role of external supply shocks, resulting in inflation becoming less sensitive to domestic developments (Gordon, 2013; Watson, 2014). Non-linearities in the relationship between inflation and real activity, implying that the Phillips curve coefficient on the output gap depends on the state of the business cycle (see Section 2.4), might also explain subdued inflation (Ball and Mazumder, 2011). The apparent breakdown in the Phillips curve could also reflect difficulties in measuring labour market slack and identifying the measure of slack most appropriate in determining inflation dynamics. Distinguishing between the cyclical and structural factors affecting labour market variables (such as labour force participation, part-time employment and demographic factors) has become especially challenging in the aftermath of the recession (Yellen, 2014). As a result, the existence of more slack than suggested by the unemployment rate could explain the lack of inflationary pressure. This could for instance be the case if inflation were not only sensitive to the level of the unemployment rate but also to its composition, for example if short- and long-term unemployment exerted different pressures on prices. "Ranking" practices, by which firms receiving multiple acceptable applications hire the worker with the shortest unemployment spell, may imply that long-term unemployed have little effect on wages (Blanchard and Diamond, 1994). However, for the US, Kiley (2015) does not find evidence that long-term unemployment exerts less pressure on prices than short-term unemployment.

2.2. THE ROLE OF WAGES IN DRIVING INFLATION

Another strand of literature investigates whether wages add any information when forecasting inflation. While the cost-push view of inflation suggests that wage increases in excess of productivity put upward pressure on prices, empirical studies provide mixed evidence. In the U.S., wages are not a good predictor of inflation (Stock and Watson, 2008; Bidder, 2015) and the pass-through of labour cost into inflation has weakened over time (Peneva and Rudd, 2017). Bobeica et al. (2019) find that labour costs have some forecasting power in the largest economies of the euro area. IMF (2019) finds that the pass-through from labour costs to consumer prices has weakened since 2009 in Europe and expects the recent pickup in wage growth to have a more muted impact on inflation than in the past.

2.3. EXISTENCE OF THE PHILLIPS CURVE IN IRELAND

Before Ireland's accession to the Economic and Monetary Union (EMU), most of the literature saw Irish inflation as determined by external factors, with little role for domestic excess demand. This was attributed to the small open nature of the Irish economy, and its particularly close links with the UK (Gerlach et al., 2016). However, more recent studies suggest the existence of a well-defined Phillips curve in Ireland, implying that accession to the EMU might have changed the inflation process. Anthony (2010) and Bermingham et al. (2012) find a role for unemployment or the unemployment gap. Gerlach et al. (2016), using annual data up to 2012, find that the unemployment gap (the difference between the unemployment rate and the NAIRU), as well as import prices, drive consumer prices. However, these studies do not rely on recent data and do not examine why robust employment and wages growth have not passed through to inflation in recent years.

2.4. NON-LINEARITIES IN THE PHILLIPS CURVE

Several theoretical models of price-setting behaviour suggest that the sensitivity of inflation to cyclical conditions may be non-linear (see Dupasquier and Ricketts, 1998, for a literature review).

Most of these models imply convexity, with inflation increasingly sensitive to excess demand. The capacity constraint model (Macklem, 1997) supposes that some firms cannot increase their capacity to produce in the short run when an economy experiences strong aggregate demand. Hence, if aggregate demand increases during recessions–as a result possibly of expansionary monetary policy–firms would be able to satisfy the additional demand by producing more and see little incentive to raise prices. By contrast, during times of expansion, firms produce closer to their capacity constraint and would react by raising prices. The downward nominal wage rigidity model (Akerlof et al., 1996) suggests that workers are more reluctant to accept a decrease in their nominal wages than a decrease in their real wages, implying that in a low-inflation environment, wages (and thus costs) could adjust more slowly. Ball and Mankiw (1994) assume that, in the presence of menu costs, not all firms adjust their prices in response to a demand shock.

By contrast, the model of monopolistic competition suggests a concave relationship (Stiglitz, 1997). During boom times, firms might be reluctant to raise prices, with the aim of keeping out potential new competitors.

The empirical literature examining non-linearities in the euro area Phillips curve remains scarce. Semmler and Gross (2017), using regime-switching Phillips curves, find a convex relationship, with prices reacting more strongly to a positive output gap than to a negative output gap. By contrast, Onorante et al. (2019) do not find evidence of non-linearities. To our knowledge, this paper is the first to investigate the existence of non-linearities in the Irish Phillips curve.

2.5. GLOBAL DRIVERS OF INFLATION

Another strand of literature suggests that domestic inflation is increasingly sensitive to the global output gap, which might not only play an indirect role on domestic inflation (via its effect on import prices and domestic output gaps) but also a direct one. One explanation is that globalisation has rendered domestic inflation less responsive to domestic capacity constraints, either because a sudden demand shock would bolster imports rather than increase prices, or because exposure to foreign competitors curtails increases in the price of domestic tradable products (Guerrieri et al., 2010). However, empirical evidence is mixed. Auer et al. (2017) argue that, as participation in global value chains increases, exposure to foreign competitors makes domestic inflation more sensitive to the global output gap and less sensitive to domestic cyclical conditions. By contrast, Mikolajun and Lodge (2016) do not find a direct effect of global slack on domestic inflation in advanced economies. Similarly, McCoy et al. (2019) do not find evidence that measures of domestic cyclical conditions are superseded by global output gap variables in the euro area. Ciccarelli and Mojon (2010) find that including a measure of global inflation improves national inflation forecasts for OECD countries.Medel et al. (2014) find that gains in forecasting accuracy are modest.

3. DOES THE PHILLIPS CURVE EXIST IN IRELAND?

3.1. MEASURES OF CYCLICAL CONDITIONS

While assessing the cyclical position in real-time is difficult for any economy, several features of the Irish economy pose additional challenges (Casey, 2019). National accounts figures are volatile owing to the activities of large foreign-owned multinational enterprises. Estimates of spare capacity in the Irish economy are thus subject to high uncertainy. We therefore consider a number of alternative indicators of cyclical conditions, presented below.

3.1.1. Output gap and unemployment gap

- ✓ **Unemployment gap:** difference between the unemployment rate and the non-accelerating wage rate of unemployment (NAWRU) as estimated by the European Commission.

- ✓ **Output gaps and modified domestic demand gap**. Quantifying potential output, which is unobservable, and, by extension, the output gap, is subject to a significant margin of uncertainty (see Casey, 2019). Hence, we use a range of alternative estimation techniques and indicators as a robustness check. A first is a Hodrick-Prescott (HP) filter-based measure of the output gap, where the filter is applied to quarterly real GDP[ii]. Along with this purely statistical measure, we test the output gap as estimated by the European Commission (Havik et al., 2014), based on a production function-type approach. Thirdly, we apply a HP filter to modified domestic demand (MDD), an indicator developed by the Central Statistics Office that better reflects Irish domestic activity[iii] than GDP.

3.1.2. Labour market indicators

The Irish participation rate has sharply declined since 2008, suggesting that the ongoing decline in the unemployment rate may overstate the improvement in labour market conditions. Hence, we test alternative indicators of labour supply.

- ✓ **The non-employment index (NEI)** distinguishes between short-term and long-term unemployed, discouraged workers and passive job seekers (Byrne and Conefrey, 2017). It includes tailored weights that reflect the probabilities of these groups of transitioning from non-employment into work. An increase in the NEI suggests more slack in the economy. We test both the impact of changes in the NEI and of the level of the NEI gap, computed as the difference between the NEI and its long-term average.

- ✓ **Potential labour force**. The potential additional labour force is made up of two groups of people not in employment. First, the available potential jobseekers, i.e. the persons available for work but not seeking a job, who are not recorded as unemployed because they are not actively looking for a job, and second, the unavailable jobseekers, i.e. the persons seeking a job but not immediately available, who do not qualify as unemployed because of their limited availability to start in a new job. The Labour Force Survey provides indicators of the potential additional labour supply, such as unemployed persons plus discouraged workers (PLS1) and unemployed persons plus potential additional labour force (PLS2). The PLSs gaps are computed as the difference between these indicators and their long-term averages.

- ✓ **Changes in the Irish labour force** is tested as a proxy of cyclical condition, as labour force tends to react with a lag to the cycle. The labour force tend to increase in periods of expansion, as labour demand is high, and to decrease in recessions, as discouraged workers quit the labour force and students stay longer in education.

We test whether short- and long-term unemployment exert different pressures on inflation with the following indicators:

- ✓ **Short- and long-term unemployment:** quarterly change in the unemployment rate with a duration of up to one year and over one year, respectively.

- ✓ **Short- and long-term unemployment gaps:** difference between the levels of these unemployment rates and their long-term averages.

We test the impact of domestic labour cost for different economic sectors (by NACE code). Some services sectors, which have recently experienced strong wage growth, are dominated by multinational enterprises. Testing for the impact of sector-specific labour costs provides an indicator of how multinational firms could impact the aggregate price level[iv].

3.1.3. Migration and cyclical conditions in Ireland's major economic partners

The openness of the Irish labour market and the high mobility of labour may add to difficulties in discerning a stable relationship between unemployment and inflation. During the economic boom (1995-2007), wage pressures could have been higher in the absence of high net inward migration. Since 2015, net inward migration has been contributing significantly to the increase in the labour force. The additional labour supply prompted by migration can limit the wage pressures that may arise in a tightening labour market.

A number of studies dating back to the 1990s highlight an equilibrium unemployment gap between Ireland and the UK (Gerlach et al., 2015), whereby cross-border labour mobility ensures that the Irish unemployment rate adjusts to labour market conditions in the UK. However, Meyler (1999) concludes that this unemployment gap does not drive Irish inflation.

To account for fluctuations in the Irish labour force and cyclical conditions in Ireland's trading partners, we test the following indicators of cyclical conditions:

- ✓ **Difference in unemployment rates** between Ireland and the UK and between Ireland and the euro area;

- ✓ **Net migration flows and net migration** as a percentage of the labour force;

- ✓ **The UK and the euro area output gaps**, computed with two different methods (the European Commission production function approach and a HP filter).

3.2. BASELINE SPECIFICATION

Following Gordon's triangle model (Gordon, 1988), inflation is modelled as a function of three sets of determinants: inertia, demand factors, reflecting the state of resource utilisation, and supply factors, such as large changes in commodity prices. Our preferred specification[v] is the following:

$$\pi_t = \alpha + \rho\pi_{t-1} + \beta \underset{j\in\{0;1\}}{y_{t-j}} + \sum_{i=1}^{Max\ I=2}\sum_{l=0}^{Max\ L=4}\gamma_{i,l}\,\Delta z_{i,t-l} \qquad (1)$$

Where $\pi_t$is the inflation rate, computed as the first difference in the logarithm of the HICP[vi], y is a measure of cyclical conditions[vii], introduced either contemporaneously or lagged, and z corresponds to an indicator of external price movements. International prices can impact domestic prices directly, through the price of imported final consumption goods, and indirectly, through the price of imported intermediate goods. The inclusion of a lagged inflation term captures backward-looking inflation expectations[viii] and other sources of persistence in price setting. The optimal lag order is selected on the basis of the Akaike information criteria. Given our relatively short sample, we test up to two indicators of external price and up to four lags for z. We estimate the models by OLS on quarterly data. The starting point of our sample (1999-2018) corresponds to the introduction of the euro, and hence, to a new regime for Irish inflation.

3.3. LINEAR REGRESSIONS

3.3.1. Headline inflation

In this section, we examine whether domestic cyclical conditions drive Irish headline inflation. We test several indicators of demand, while controlling for two measures of external prices (Equation 2): the quarterly change in the euro/sterling exchange rate (reflecting Ireland's reliance on goods imported from the UK[ix]) and the quarterly change in oil prices, which reflects fluctuations in prices of internationally traded goods.

$$\pi_t = \alpha + \rho\pi_{t-1} + \beta \underset{j\in\{0;1\}}{y_{t-j}} + \gamma\Delta oil\ prices_t + \delta\Delta sterling_t \qquad (2)$$

Table 1 shows that a large number of indicators of cyclical conditions are statistically significant[x]. The conclusion that inflation reacts to domestic cyclical conditions is robust to a range of indicators, such as the output gap, labour costs, or adjusted measures of unemployment[xi]. Indicators reflecting cyclical conditions in Ireland's main economic partners, such as the output gaps in the UK and the euro area, are also significant.

Inflation is very persistent, as indicated by a high (between 0.6 and 0.7) and statistically significant coefficient of lagged inflation.

Estimates of the slope of the Phillips curve depend on the indicator of cyclical conditions. A 1% increase in the output gap, implying less slack in the economy, is for instance associated with a 0.06% increase in HICP. This value is consistent with the literature. Semmler and Gross (2017) find a coefficient of 0.03 for Ireland on monthly data for a sample covering 1999 to 2016. The long-term impact of the output gap —computed as the short-term coefficient of slack divided by one minus the coefficient of lagged inflation— is 0.15.

Table 1. **Linear estimates for headline HICP (1999Q2-2018Q3)**

Model	AR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
constant	0.05	0.14***	0.02	0.20**	0.09*	0.16**	0.12**	0.01	0.11**	0.04	0.05
π_{t-1}	0.56***	0.58***	0.69***	0.70***	0.72***	0.65***	0.70***	0.69***	0.68***	0.70***	0.70***
π_{t-3}	0.24***										
$\Delta sterling_t$		-0.03**	-0.04***	-0.03**	-0.03**	-0.04**	-0.03**	-0.04***	-0.03**	-0.02*	-0.02
$\Delta oil\ prices_t$		0.01***	0.02***	0.01***	0.01***	0.01*** ***	0.01***	0.02***	0.01***	0.01***	0.01***
$output\ gap\ IE_{t-1}$		0.06***									
$\Delta labour\ cost\ \ BS_{t-1}$			0.11**								
$UR_t - UR\ UK_t$				-0.03**							
$NEI\ gap_t$					-0.14**						
$output\ gap\ EA_{t-1}$						0.06**					
$output\ gap\ UK_{t-1}$							0.05*				
$\Delta labour\ cost\ \ GN_{t-1}$								0.13***			
$UR < 1\ year\ gap_t$									-0.13**		
$\Delta labour\ force_{t-1}$										0.19***	
$\Delta employment_t$											0.11***
Observations	78	78	78	78	78	78	78	78	78	78	78
R2	0.55	0.67	0.72	0.69	0.69	0.68	0.68	0.74	0.69	0.69	0.66
Adjusted R2	0.53	0.65	0.70	0.67	0.68	0.66	0.66	0.72	0.67	0.67	0.64
Estimation window:						**RMSE**					
40 quarters	0.32	0.23	0.23	0.26	0.24	0.21	0.23	0.24	0.24	0.22	0.26
50 quarters	0.29	0.18	0.19	0.18	0.20	0.16	0.17	0.21	0.21	0.16	0.21
60 quarters	0.34	0.20	0.20	0.21	0.23	0.20	0.22	0.19	0.24	0.21	0.26
65 quarters	0.10	0.08	0.09	0.09	0.11	0.10	0.10	0.08	0.11	0.12	0.12

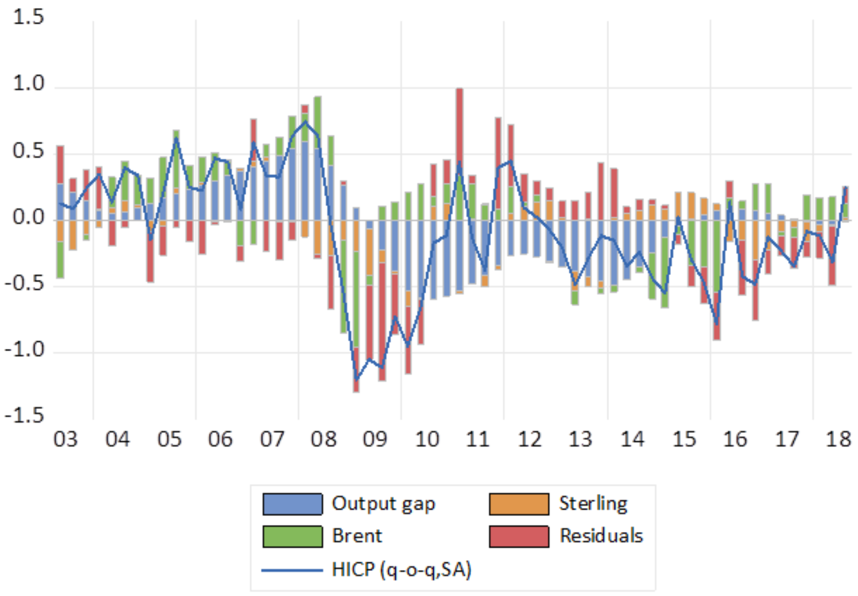
Notes: *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively. Grey shaded cells highlight the lowest RMSE. RMSE for one-quarter ahead forecasts are computed on rolling estimation windows of up to 65 quarters.

π: quarterly change in the logarithm of HICP; *Labour cost BS and GN*: labour costs in Nace activities B to S (whole economy) and G to N (services); *UR <1 year gap*: difference between the short-term unemployment rate and its long-term average; *UR-UR UK*: difference between the Irish and the UK unemployment rates; *Output gap IE, EA and UK*: Irish, euro area and UK output gaps; *Employment*: number of jobs.

Sources: CSO, Eurostat, European Commission and author's calculations.

Based on Model 1 in Table 1, Graph 1 shows the contributions of the main drivers of inflation in terms of deviations from their historical averages. At the onset of the crisis, inflation was above its historical average, bolstered by buoyant demand, as the economy grew above its potential during the construction boom. From 2009 to 2012, inflation was dampened by the increasing level of slack in the economy. The drag from domestic demand was partly offset by high oil prices between 2008 and 2011. Between 2010 and 2014, part of inflation is unexplained by its three drivers (cyclical conditions, the exchange rate and oil prices). The positive contribution from the residuals illustrates the "missing disinflation" episode, as inflation fell by less than suggested by the high level of slack.

Graph 1. **Contributions to headline inflation (%, q-o-q)**



Sources: Eurostat, European Commission and author's calculations.

The model explains inflation reasonably well. The relative importance of the drivers of inflation has changed throughout the sample. The drag from economic slack dominated the picture between 2009 and 2015, until spare capacity was absorbed. Low import prices contributed to low inflation between 2014 and 2017, as oil prices decreased and the depreciation of the sterling after 2016 made Irish imports from the UK cheaper. Since 2017, the negative contributions from the residuals illustrates the "missing inflation" puzzle, as inflation remains subdued despite the tightening of the labour market.

To determine the indicator of cyclical conditions most relevant for inflation, we compute the Root Mean Square Errors (RMSEs) for one-quarter-ahead forecasts. The RMSE corresponds to Equation 3, where $\pi_{t+1|t}$ is the pseudo out-of-sample forecast of π_{t+1} conditional on data at date t.

$$RMSE(t_1, t_2) = \sqrt{\frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} (\pi_{t+1} - \pi_{t+1|t})^2} \tag{3}$$

The model yielding the lowest RMSE varies depending on the estimation sample. As a robustness check, we compute RMSEs based on rolling estimation windows of different lengths (Table 1).

All Phillips curves specifications yield lower RMSEs than a "naive" autoregressive (AR) benchmark model[xii]. We examine whether Phillips curve specifications provide more accurate forecasts than the benchmark AR model by performing pairwise Clark-West tests (Clark and West, 2007). The test assesses whether additional parameters (such as external price pressures and domestic cyclical conditions) improve the accuracy of the forecast, compared to the more parsimonious AR benchmark[xiii]. We test the following null hypothesis: the AR benchmark performs as well as a Phillips curve model. The first column in Table 2 shows that the null hypothesis is systematically rejected, suggesting that all Phillips curve specifications yield more accurate forecasts than the AR model.

Table 1 shows that the RMSEs yielded by different Phillips curve specifications are close, suggesting similar forecasting performances. We perform the Diebold-Mariano test[xiv] (Diebold and Mariano, 1995) to assess whether differences in forecasting performances are statistically significant. We test the null hypothesis that the benchmark Phillips curve specification (in columns) performs at least as well as alternative Phillips curve models (in rows). Table 2 shows that we cannot reject the null hypothesis that Models 2, 7, 3 and 10 perform at least as well as the nine alternative models. These results suggest that these models, which rely, respectively, on domestic labour costs, the difference in unemployment rates between Ireland and the UK and changes in employment in Ireland, generate more accurate forecasts than alternative specifications. However, none of these four models outperforms the three others. By contrast, models 5 and 6, which rely on the output gap in Ireland's major partners, do not outperform models relying on some measure of domestic demand. This finding is consistent with Mikolajun and Lodge (2016) and McCoy et al. (2019), who do not find evidence that measures of domestic cyclical conditions are superseded by global output gap variables in the euro area.

Table 2. **Diebold-Mariano and Clark-West tests (p-values)**

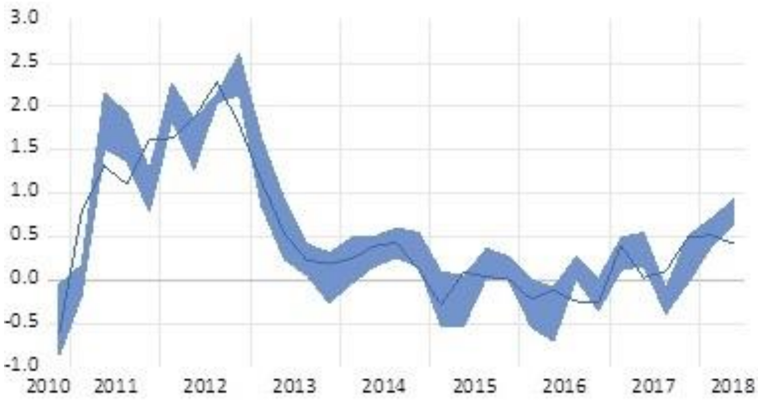
	Clark-West	Diebold-Mariano								
		Benchmark model								
Model	AR	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	0.00									
(2)	0.00	0.01								
(3)	0.00	0.04	0.77							
(4)	0.00	0.85	0.99	0.95						
(5)	0.00	0.65	0.96	0.87	0.37					
(6)	0.00	0.16	0.96	0.79	0.05	0.15				
(7)	0.00	0.08	0.24	0.23	0.05	0.07	0.13			
(8)	0.00	0.87	0.97	0.93	0.60	0.63	0.91	0.96		
(9)	0.00	0.71	0.94	0.92	0.45	0.53	0.79	0.92	0.40	
(10)	0.00	0.58	0.84	0.79	0.40	0.48	0.66	0.87	0.35	0.35

Note: Models are estimated on 40-quarter rolling windows. Forecast errors are computed over 38 observations. Grey shaded cells highlight situations in which the null hypothesis is rejected at the 10% level for the following hypotheses: the AR model performs as well as a Phillips curve model (Clark-West test); the benchmark Phillips curve specification (in columns) performs at least as well as the alternative Phillips curve models in rows (Diebold-Mariano test). Hence, a p-value of 0.01 indicates that we reject the null hypothesis that models 1 performs as well as model 2 at the 1% level.

Source: author's calculations.

We observe how the best-performing models behaved in recent years by producing dynamic pseudo-out-of-sample forecasts, conditional on the actual paths for the exogenous variables. The models capture rather well the dynamics of inflation (Graph 2). All forecasts are relatively close to actual inflation, regardless of the measure of slack used.

Graph 2. **Out-of-sample forecasts for HICP inflation (%, y-o-y)**



Note: dynamic pseudo out-of-sample forecasts, with the forecast range derived from the four specifications in Table 1 yielding the lowest RMSE.

Sources: Eurostat and author's calculations.

3.3.2. Robustness check: the price of services

As a robustness check, we focus on the price of non-tradable products, proxied by the services component of HICP. As most services are produced domestically and intensive in labour, inflation in services might better illustrate the relationship between domestic demand and inflation[xv]. In Ireland, the price of services is mainly driven by rents and accommodation and restaurant services. Hence, our specifications for HICP services include the lagged dependent variable, an indicator of cyclical conditions and lagged changes in house prices, which are highly correlated to rents. Neither the bilateral euro/sterling exchange rate nor commodity prices are statistically significant for services. Our results confirm the significant impact of domestic cyclical conditions on the price of services.[xvi]

4. IMPACT OF EXTERNAL PRICE PRESSURES

In this section, we focus on the impact of external price pressures on headline inflation. We test a number of indicators: bilateral and effective exchange rates, import prices, commodity prices and indicators of global inflation, such as inflation in the euro area and in the UK.

In the light of the UK's withdrawal from the EU, we pay particular attention to the impact of price pressure from the UK, a major economic partner for Ireland. According to Reddan and Rice (2017), imports from the UK dominate extra-euro area imports in Ireland in the categories contributing most to Irish consumer goods inflation (manufacturing and food). Fitzgerald and Shortall (1998) highlight the role of UK-based retail firms in the Irish market. The price of these affiliate retail companies is often set by parent companies in the UK, suggesting that Irish consumer prices may be highly correlated to UK consumer or producer prices. We test the impact of producer prices in the UK to determine whether Irish prices are driven by production costs similar to those observed in the UK owing to the close integration of the two economies.

We estimate Phillips curve specifications augmented with two indicators of external price pressures. As a robustness check, we use two different indicators of cyclical conditions: the Irish output gap (Equation 4) and domestic labour costs (Equation 5), one of the best performing demand indicator identified in Section 3.

$$\pi_t = \alpha + \rho\pi_{t-1} + \beta\ output\ gap\ IE_{t-1} + \sum_{i=1}^{Max\ I=2} \sum_{l=0}^{Max\ L=4} \gamma_{i,l}\ \Delta z_{\ i,t-l} \quad (4)$$

$$\pi_t = \alpha + \rho\pi_{t-1} + \beta\ \Delta labour\ cost\ BS_{t-1} + \sum_{i=1}^{Max\ I=2} \sum_{l=0}^{Max\ L=4} \gamma_{i,l}\ \Delta z_{\ i,t-l} \quad (5)$$

We compare the pseudo-out-of-sample forecasting performance of different specifications with alternative indicators for z.

The Diebold-Mariano test suggests that a Phillips curve augmented with the bilateral euro/sterling exchange rate, in conjunction with an indicator of commodity prices, import prices, or lagged inflation in the euro area, generates more accurate forecasts than alternative specifications[xvii]. This result is consistent with Reddan and Rice (2017), who find that Irish consumer prices are predominantly exposed to the euro/sterling exchange rate[xviii], rather than to the effective exchange rate.

Following Stock and Watson (2008), we calculate (bi) weighted rolling estimates of the RMSE (BRMSE hereafter), based on a weighted centred 15-quarter window (Equation 6). Bigger weights are given to errors close to the centre of the window.

$$BRMSE(t) = \sqrt{\frac{\sum_{s=t-7}^{t+7} K\left(\frac{|s-t|}{8}\right)(\pi_{s+1} - \pi_{s+1|s})^2}{\sum_{s=t-7}^{t+7} K\left(\frac{|s-t|}{8}\right)}} \quad (6)$$

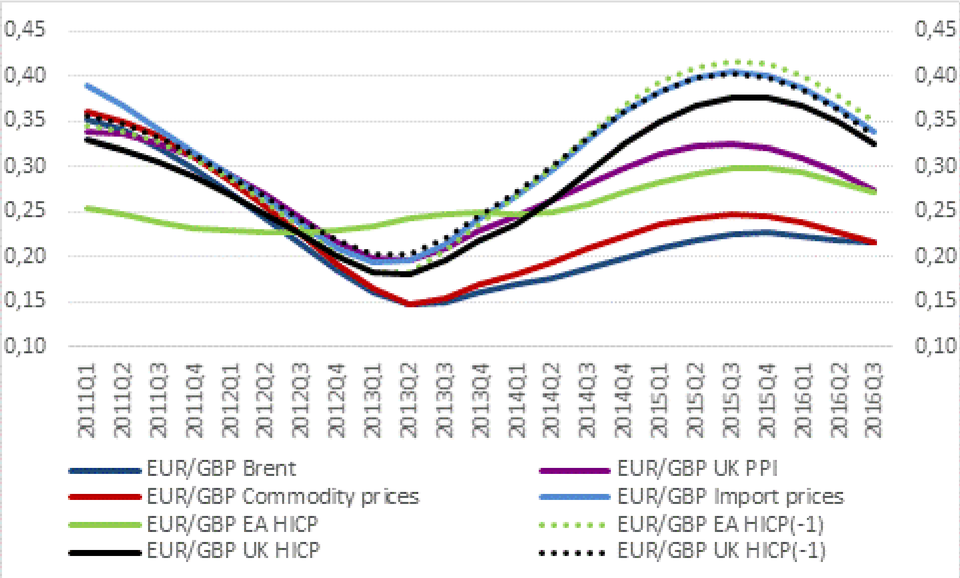
Where K is the biweight kernel:

$$K(x) = \frac{15}{16}(1 - x^2)^2 \mathrm{I}_{\{|x|<1\}} \quad (7)$$

The rationale for using BRMSE is the following. Our sample includes episodes of important volatility in the price of oil, the 2009 recession and the sovereign debt crisis, characterised by large fluctuations in the euro exchange rate. These events might have altered the link between external price pressures and domestic inflation. BRMSE highlight the forecasting performance at the centre of the window and hence, the models yielding the lowest BRMSE for any specific event.

Until 2012, the best performing model included inflation in the euro area (Graph 3). More recently, the correlation between inflation in the euro area and in Ireland has decreased. Since 2012, models yielding the lowest BRMSE include the euro/sterling exchange rate, in conjunction with commodity prices. By contrast, specifications based on UK producer or consumer prices do not outperform other models.

Graph 3. **BRMSE for Phillips curve specifications with different indicators of external price pressures**



Note: The date on the time axis represents the centre of the 15-quarter rolling window. Models are estimated on 40-quarter rolling windows, based on Equation 4. BRMSE are computed for one-quarter-ahead forecasts.

Sources: Eurostat and author's computations.

5. TIME-VARIATION AND NON-LINEARITIES

Linear Phillips curves with a constant slope estimated in Sections 3 and 4 illustrate the average relationship between cyclical conditions and inflation over the last two decades. However, the slope could have changed over time, which may explain why inflation remains subdued despite the economic recovery. The Phillips curve could also be non-linear, with different sensitivity of inflation to different positions in the economic cycle.

In this section, we investigate time-variation and non-linearities in the relationship between cyclical conditions and inflation. We use different approaches to ensure the robustness of our results.

5.1. ROLLING LINEAR REGRESSIONS

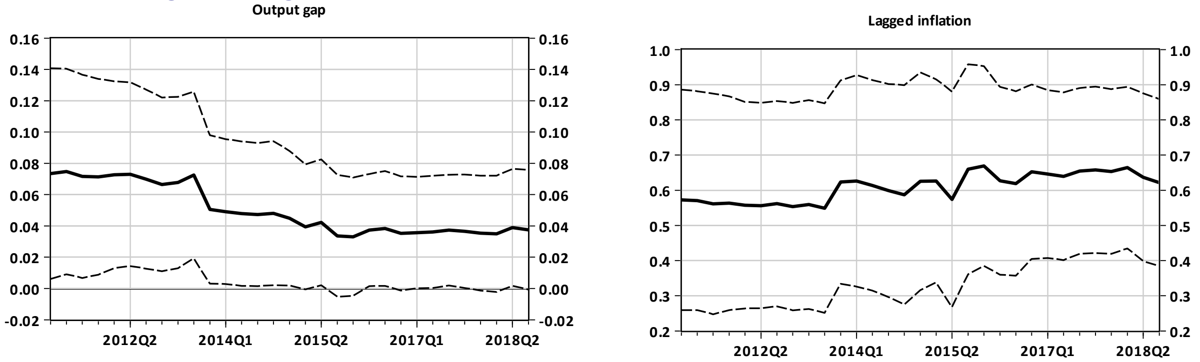
We estimate rolling linear regressions to illustrate possible changes in the relationship between cyclical conditions and inflation. Models are estimated over a fifty-quarter rolling window, which we consider a sufficiently long sample to provide robust coefficients.

The coefficient of the output gap has halved since 2009 (Graph 4), while controlling for the impact of oil prices and exchange rates, suggesting that the Phillips curve might have flattened in Ireland. This seemingly reduced sensitivity of headline inflation to economic conditions suggests that the recent pickup in activity could have a more muted inflationary impact than in the past. The flattening of the Phillips curve is observed in other advanced economies (e.g. Ball and Mazumder, 2011). Possible causes include better-anchored inflation expectations, increased globalisation and global competition, which may have made inflation less responsive to domestic demand, lower and less volatile inflation, which may have induced less frequent price changes by firms, and increased volatility of supply shocks relative to demand shocks (see Occhino, 2019 for a literature review).

In addition, rolling regressions for headline inflation suggest that inflation persistence has slightly increased in recent years (Graph 4), which may explain why inflation has remained low despite improved cyclical conditions: higher persistence suggests that following a prolonged period of subdued inflation and weak demand, it will take a longer period of strong demand to pass through to prices. By contrast, the coefficients on oil prices and the exchange rate have remained stable.

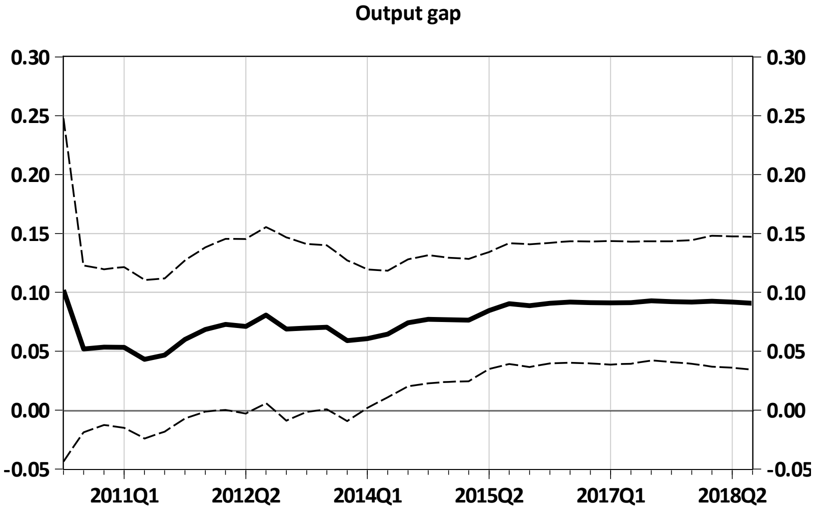
However, the finding that the Phillips curve slope has flattened is sensitive to the indicator of cyclical conditions and to the measure of inflation. Rolling linear regressions for HICP services suggest a stable coefficient on the output gap (Graph 5). Hence, the finding that the Phillips curve has flattened might depend on including goods that are primarily influenced by non-cyclical factors in the price index.

Graph 4. **Rolling linear regressions (HICP)**



Note: rolling regressions with a constant number of 50 observations, using the 1999Q2-2011Q2 window as the starting estimation window, and then rolling the window one quarter at the time. The solid line represents the point estimate. The dotted lines represent the associated +/-2 standard errors confidence bands.
Sources: Eurostat and author's caluclations.

Graph 5. **Rolling linear regressions (HICP services)**

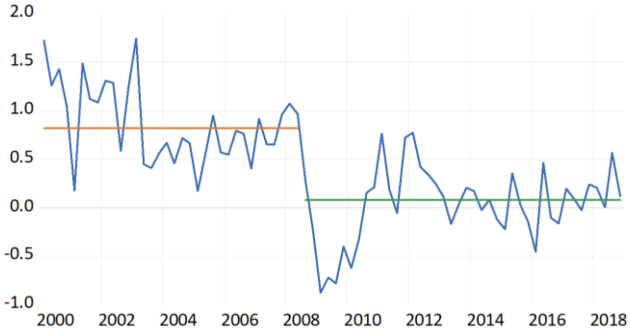


Sources: Eurostat, author's calculations.

5.2. REGIME SWITCHING REGRESSIONS

Graph 6 shows that the average quarterly growth rate of HICP has sharply decreased in Ireland, from 0.8% on average between 1999 and 2008 to 0.1% over the past decade. The existence of different regimes of inflation suggests that non-linear modelling may be appropriate to analyse inflation in Ireland.

Graph 6. **Quarterly growth rate of HICP (%)**



Note: Solid lines represent the average inflation rates between 1999 and 2008 and between 2009 and 2018.
Sources: Eurostat and author's calculations.

5.2.1. Headline HICP

In this section, we analyse the relationship between inflation and its determinants with Markov-switching dynamic regressions. We allow for the slope of the Phillips curve, inflation persistence and the coefficients on variables capturing imported inflation to be time-varying, with non-linearities arising from discrete changes in regime.

Equations are estimated using a standard Expectation-Maximisation (EM) algorithm. Transition probabilities are assumed to be constant. The initial regime probabilities are set to the ergodic (steady state) values implied by the Markov transition matrix. The error variance is allowed to switch regimes to allow for heteroscedasticity.

In a first step, we allowed all coefficients to be time-varying. However, after performing the Wald test, we could not reject the hypothesis of equality of the coefficients of oil prices and the exchange rate across regimes. We subsequently set these two regressors as non-switching.

Table 3 shows estimation results from linear and regime-switching Phillips curves. Our results suggest the existence of a regime (Regime 1) under which the output gap has no impact on inflation, corresponding to a flat Phillips curve, whereas under Regime 2, the Phillips curve is steeper than the linear model. Assuming that a Markov-switching process better captures inflation, the linear Phillips curve would tend to overestimate inflation when the economy is experiencing Regime 1 and underestimate it when the economy is experiencing a period of relatively higher inflation. However, this finding is not robust to all indicators of cyclical conditions. For all indicators except the Irish output gap, the Wald test null hypothesis of equality of the coefficient of slack across regimes was not rejected.

5.2.2. The price of services

As a robustness check, we also estimated Markov-switching regressions for HICP services. The identification of distinct regimes conditional on cyclical conditions is robust to a larger range of indicators of demand (Table 3). The price of services is a priori less impacted by external price shocks than headline inflation, which may explain why the identification of different regimes is easier for HICP services.

On average across specifications, the coefficient under Regime 1 is about 4 to 5 times larger than under Regime 2. We performed the Wald test and found that the null hypothesis of equality of the coefficient of cyclical conditions across regimes is rejected for most specifications.

Overall, Markov-switching regressions suggest the existence of different regimes of inflation, especially for the price of services. However, this conclusion is not robust to all indicators of demand. Moreover, our results should be interpreted with caution given the relatively small size of the sample.

Table 3. **Parameters estimates: linear v Markov-switching (MS) specifications (1999Q2-2018Q3) and Wald test for equality of coefficients across regimes**

	Cyclical conditions	Constant	π_{t-1}	Slack	Long-term
		HICP			
Linear model	output gap IE_{t-1}	0.14***	0.58***	0.06***	0.14
MS Regime 1		0.10	0.43***	0.01	
MS Regime 2		0.16**	0.70***	0.09***	0.30
Wald test p-value		0.45	0.12	0.03	
		HICP services			
Linear model	output gap IE_{t-1}	0.41***	0.43***	0.09***	0.16
MS Regime 1		0.68***	0.04	0.05**	0.05
MS Regime 2		0.75*	0.15	0.27***	0.32
Wald test p-value		0.87	0.72	0.00	
Linear model	Δlabour cost BE_{t-1}	0.26***	0.48***	0.11***	0.21
MS Regime 1		0.07**	0.40***	0.01	
MS Regime 2		0.25***	0.54***	0.16***	0.35
Wald test p-value		0.02	0.10	0.00	
Linear model	$UR_t - UR\ UK_t$	0.55***	0.48***	-0.06***	-0.12
MS Regime 1		0.76***	0.12	-0.04**	
MS Regime 2		0.80***	0.43**	-0.20***	-0.35
Wald test p-value		0.90	0.19	0.01	

Notes: *, ** and *** denote statistical significance at 10%, 5% and 1% levels, respectively. The long-term effect corresponds to the coefficient of slack divided by one minus the coefficient of lagged inflation. It is not computed when the coefficient of slack is not statistically significant. Non-switching regressors are not reported. Grey shaded cells highlight situations in which the null hypothesis of equality of coefficients across regimes is rejected at the 10% level. *Labour cost BE*: labour costs in Nace activities B to E (manufacturing).

Sources: Eurostat, author's calculations.

We compare the forecasting performances of linear and Markov-switching regressions. We produce dynamic pseudo-out-of-sample forecasts for HICP, conditional on the actual data for the exogenous variables. We perform the Diebold-Mariano test to assess whether differences in forecasting accuracy are statistically significant. Table 4 shows that in most cases, non-linear specifications yield more accurate forecasts than linear specifications.

Table 4. **Diebold-Mariano test (p-values): linear v Markov-switching specifications**

	Rolling estimation window	
Indicator of demand	60 quarters	65 quarters
	HICP	
output gap $\mathbf{IE_{t-1}}$	0.01	0.01
	HICP services	
output gap $\mathbf{IE_{t-1}}$	0.01	0.01
$\mathbf{\Delta}$labour cost $\mathbf{BE_{t-1}}$	0.14	0.47
$\mathbf{UR_t - UR\ UK_t}$	0.01	0.00

Note: The null hypothesis is that forecasts generated by linear specifications are at least as accurate as forecasts from Markov-switching specifications. The alternative hypothesis is that Markov-switching specifications yield more accurate forecasts. Grey shaded cells highlight situations in which the null hypothesis is rejected at the 10% level. Models are estimated on two rolling windows (60 and 65 quarters), which are relatively large to benefit from a sufficient number of observations. Forecast errors are computed over respectively 18 and 13 observations.

Sources: Eurostat, European Commission, author's calculations.

5.3. THRESHOLD EFFECTS

While Section 5.2 focuses on non-linearities that might arise from discrete changes in regime where the sample separation into regimes is not observed, this section focuses on the role of potential threshold effects, where slack needs to fall below or rise above a certain critical level before driving significant movements in inflation. We test two approaches, which can fit both convex and concave non-linear relationships between inflation and cyclical conditions[xix].

5.3.1. Dummy variables

Dummy regressions provide a simple way to test whether the nature of the relationship between inflation and an activity variable such as the output gap may change according to whether the gap lies above or below a particular value. We use arbitrarily-defined thresholds (x) for different indicators of cyclical conditions (y), using an indicator function $\mathbb{1}(.)$ which takes the value 1 if the expression is true and 0 otherwise (Equation 8).

$$\pi_t = \alpha + \rho\pi_{t-1} + \beta_1\, y_t \mathbb{1}_{\substack{y_{t-j} \leq x \\ j\in\{0;1\}}} + \beta_2\, y_t \mathbb{1}_{\substack{y_{t-j} > x \\ j\in\{0;1\}}} + \delta\Delta brent_t + \chi\Delta sterling_t \quad (8)$$

We set different thresholds depending on the indicator of cyclical conditions. For the output gap and the unemployment gap between Ireland and the UK, the dummy variable is set to 1 when gaps are positive, 0 otherwise. Similarly, the dummy variable is set to 1 when the growth rate of wages is positive, 0 otherwise. The threshold for the Irish unemployment rate corresponds to levels observed during periods of full-employment. The dummy variable is set to 1 when the unemployment rate exceeds 5%. Results should be interpreted with caution given the small number of observations for which the unemployemnt rate was below 5%.

Regarding headline inflation, Table 5 shows that coefficients on dummy variables are significant for the Irish and the euro area output gaps. The output gap only affects inflation significantly when it is positive ($\boldsymbol{\beta_1}$), suggesting that in the presence of a large amount of slack, prices change more slowly than in periods of expansion, making the Phillips curve convex. However, coefficients on dummy variables are not significant for other indicators of cyclical conditions.

Table 5. **Parameters estimates: linear v dummy regressions (1999Q2-2018Q2)**

y	x	Model	Constant	ρ	β	β_1	β_2	R2	Adj. R2
				HICP					
output gap IE_{t-1}	0	Linear	0.14***	0.58***	0.06***			0.67	0.65
		Dummy	0.07	0.61***		0.08**	0.03	0.71	0.68
output gap EA_{t-1}	0	Linear	0.14**	0.65***	0.06**			0.69	0.67
		Dummy	0.09	0.65***		0.11*	0.03	0.69	0.67
				HICP services					
output gap IE_{t-1}	0	Linear	0.40***	0.43***	0.08***			0.56	0.55
		Dummy	0.37***	0.43***		0.10**	0.07*	0.56	0.55
ΔUR_{t-1}	5	Linear	0.23***	0.67***	-0.12			0.50	0.49
		Dummy	0.22***	0.67***		-0.14	-0.17*	0.51	0.49
ΔLabour cost BS_{t-1}	0	Linear	0.23***	0.51***	0.17**			0.59	0.57
		Dummy	0.17*	0.50***		0.20**	-0.10	0.58	0.56
$UR_t - UR\ UK_t$	0	Linear	0.55***	0.48***	-0.06***			0.56	0.53
		Dummy	0.48***	0.41***		-0.04***	-0.55**	0.56	0.54

Note: *, ** and *** denote statistical significance at 10%, 5% and 1% levels, respectively.
Sources: Eurostat, European Commission and author's calculations.

Estimations for services also suggest a convex relationship. The Irish output gap has a slightly larger effect on inflation when it is positive (Table 5). Changes in the Irish unemployment rate affect inflation more strongly when the labour market is close to full-employment compared to the linear model. By contrast, changes in the unemployment rate do not affect inflation when the unemployment rate is high. Similarly, increases in labour costs have a significant impact on inflation, whereas the coefficient is not significant when wages decrease. The unemployment gap between Ireland and the UK has a larger impact on inflation when labour market conditions are better in Ireland, i.e. when the unemployment rate differential is negative.

5.3.2. Threshold regressions

After testing dummy variables with arbitrarily-defined thresholds, we examine whether non-linearities might occur when the indicator of cyclical conditions crosses an unknown threshold. We use the threshold regression model, which describes a simple form of nonlinear regression featuring piecewise linear specifications and regime switching that occurs when an observed variable crosses an unknown threshold.

Assuming an observable threshold variable q_t (the indicator of cyclical conditions) and strictly increasing threshold values ($\gamma_1 < \gamma_2 < \cdots < \gamma_m$) such that we are in regime j if $\gamma_j \leq q_t < \gamma_{j+1}$, we estimate the following single threshold, two-regime model for headline inflation:

$$\pi_t = \alpha + \rho\, \pi_{t-1} + \beta_1\, y\ _{\substack{t-j \\ j\in\{0;1\}}} + \delta\, \Delta brent_t + \chi\, \Delta sterling_t \qquad \text{if} \qquad \gamma_1 \leq q_t < \gamma_2$$

$$\pi_t = \alpha + \rho\, \pi_{t-1} + \beta_2\, y_{\underset{j\in\{0;1\}}{t-j}} + \delta\, \Delta brent_t + \chi\, \Delta sterling_t \qquad \text{otherwise} \tag{9}$$

We assume that the slope of the Phillips curve can change according to whether the indicator of cyclical conditions lies between or outside the threshold values. If the indicator of cyclical conditions is between the lower threshold γ_1 and the upper threshold γ_1, then the coefficient $\beta_1$measures the slope of the Phillips curve in this interior region. By contrast, if the indicator of cyclical conditions lies below the lower threshold or above the upper threshold, the coeffi cient β_2 measures the slope of the Phillips curve in either exterior region.

The parameters and the threshold values γ are estimated by non-linear least squares. The Wald test null hypothesis of equality of coefficients across regimes is only rejected for β. Hence, the coefficient on cyclical indicators, β, is regime-specific, whereas other coefficients are invariant. In other words, it is assumed that the other variables in the model do not produce threshold effects on the infl ation process.The threshold variable q corresponds to the lagged indicator of demand, y. We test similar specifications for HICP services, but without the indicators for external price pressures, which are not statistically significant.

Table 6. **Parameters estimates: linear v discrete threshold regressions (1999Q2-2018Q2)**

Cyclical conditions	Model	Threshold (q)	β	R2	Adj. R2
		HICP			
output gap IE_{t-1}	Linear		0.06***	0.67	0.65
	$y < q$	-1.9	0.01	0.70	0.68
	$y \geq q$		0.12***		
output gap EA_{t-1}	Linear		0.06**	0.68	0.66
	$y < q$	-0.9	0.01	0.69	0.66
	$y \geq q$		0.14**		
output gap UK_{t-1}	Linear		0.05*	0.68	0.66
	$y < q$	-1.0	0.00	0.69	0.66
	$y \geq q$		0.19***		
$UR_t - UR\ UK_t$	Linear		-0.03**	0.69	0.67
	$y < q$	3.8	-0.15***	0.69	0.67
	$y \geq q$		-0.04*		
		HICP services			
output gap IE_{t-1}	Linear		0.08***	0.58	0.57
	$y <$q	-2.2	0.05	0.60	0.57
	$y \geq$q		0.12***		

output gap EA_{t-1}	Linear		0.10***	0.57	0.55
	y <q	-2.2	0.05	0.58	0.56
	y ≥q		0.14***		
output gap UK_{t-1}	Linear		0.06*	0.54	0.52
	y <q	-0.9	0.04	0.54	0.52
	y ≥q		0.14*		
ΔLabour cost BS_{t-1}	Linear		0.13**	0.56	0.54
	y <q	1.6	0.11	0.54	0.51
	y ≥q		0.29***		
ΔLabour cost BN_{t-1}	Linear		0.16***	0.58	0.56
	y <q	1.2	0.10	0.57	0.55
	y ≥q		0.24***		
ΔLabour cost GN_{t-1}	Linear		0.16***	0.58	0.56
	y <q	1.3	0.10	0.58	0.55
	y ≥q		0.22***		

Note: *, ** and *** denote statistical significance at 10%, 5% and 1% levels respectively. *Labour cost BS, BN, GN*: labour costs in Nace activities B to S (whole economy), B to N (manufacturing, construction and private sector services) and G to N (private sector services).

Sources: CSO, Eurostat, European Commission and author's calculations.

The results reported in Table 6 show that cyclical conditions only affects headline inflation in a statistically significant way beyond a certain threshold. For instance, the first line shows that threshold Phillips curve model allows the trade-off between headline inflation and cyclical conditions to depend on the level of the output gap. The output gap does not have a significant impact on inflation when it is highly negative. Similarly, results for the price of services suggest that increases in labour costs have a higher inflationary impact when wage pressures are already high, implying that the slope of the Phillips curve depends on the degree of labour market tightness.

Overall, threshold regressions suggest that the Phillips curve may be flatter in times when excess capacities are high and turn steeper as slack is eliminated. The existence of non-linearities may lead to a more sudden rise in inflation than suggested by a linear Phillips curve as inflation becomes more sensitive to slack beyond a certain threshold. Hence, a linear model may over-predict inflation at times of recession and underestimate it during times of expansion. Assuming that a convex Phillips curve better captures inflation dynamics than a linear model, during boom times, linear models would tend to under-predict inflation and provide policy-makers with insufficient incentives to curb demand, increasing the risk of overheating. However, our findings are not robust to all indicators of demand and should be interpreted with caution given the relatively small size of the sample.

We compare the forecasting performance of linear Phillips curve specifications to that of threshold regressions. We produce dynamic pseudo-out-of-sample forecasts for inflation, conditional on the actual data for the exogenous variables.

Table 7 shows that for some indicators of cyclical conditions (the output gap and the unemployment rate gap between Ireland and the UK), threshold regressions yield more accurate forecasts than linear specification. However, threshold regressions do not systematically outperform linear specifications.

Table 7. **Diebold-Mariano test (p-values) linear v threshold regressions**

	Rolling estimation window (quarters)			
Cyclical conditions	50	60	65	70
		HICP		
output gap $\mathbf{IE_{t-1}}$	0.69	0.07	0.23	0.93
output gap $\mathbf{EA_{t-1}}$	0.16	0.93	0.43	0.14
output gap $\mathbf{UK_{t-1}}$	0.47	0.13	0.59	0.38
$\mathbf{UR_t - UR\ UK_t}$	0.04	0.05	0.16	0.12
		HICP services		
output gap $\mathbf{IE_{t-1}}$	0.20	0.49	0.10	0.94
output gap $\mathbf{EA_{t-1}}$	0.05	0.09	0.12	0.82
output gap $\mathbf{UK_{t-1}}$	0.11	0.33	0.05	0.04
Δlabour cost $\mathbf{BS_{t-1}}$	0.27	0.55	0.39	0.05
Δlabour cost $\mathbf{BN_{t-1}}$	0.49	0.85	0.50	0.96
Δlabour cost $\mathbf{GN_{t-1}}$	0.92	0.33	0.99	0.88

Note: The null hypothesis is that forecasts generated by linear specifications are at least as accurate as forecasts from threshold regressions. The alternative hypothesis is that threshold regressions yield more accurate forecasts. Grey shaded cells highlight situations in which the null hypothesis is rejected at the 10% level. Models are estimated on 50, 60, 65 and 70 60-quarter rolling windows. Forecast errors are computed over respectively 28, 18, 13 and 8 observations. *Labour cost BS, BN, GN*: labour costs in Nace activities B to S (whole economy), B to N (manufacturing, construction and private sector services) and G to N (services).

Sources: CSO, Eurostat, European Commission and author's calculations.

6. CONCLUSION

In recent years, persistently low inflation despite considerable reductions in economic slack has cast doubt on the relevance of the Phillips curve relationship. This “missing inflation” puzzle has stirred debates on the measurements of economic slack and on possible non-linearities in the Phillips curve.

We find that the Phillips curve relationship between inflation and cyclical conditions remains valid in Ireland. Results are robust to a large range of alternative measures of demand and to different measures of inflation. Phillips curve specifications perform better than a simple AR benchmark. The forecasting performances of Phillips curves based on alternative measures of cyclical conditions are close, regardless of the indicator of cyclical conditions. In particular, models relying on the output gap in Ireland’s major partners do not outperform models relying on some measure of domestic demand.

We show that import prices play a significant role in driving Irish inflation and explain part of the subdued inflation observed in recent years. We compare the forecasting performances of Phillips curves augmented with alternative indicators of external prices and find that the best-performing model includes the euro/sterling exchange rate, in conjunction with an indicator of commodity prices. This result confirms the high exposure of Irish consumer prices to price shocks from the UK.

We also provide evidence in favour of the hypothesis that the relationship between inflation and slack may be convex, with inflation becoming increasingly sensitive to cyclical conditions as excess demand increases. This finding of convexity holds under a number of specifications.

For some indicators of cyclical conditions, Phillips curve models that take into account some form of non-linearities have a better fit than alternative linear specifications. As inflation becomes more sensitive to cyclical conditions as slack is eliminated, non-linearities in the Phillips curve suggest that inflation might rise faster than suggested by a linear model in the absence of major shocks on imported inflation. However, our results should be interpreted with caution, given the relatively small size of our sample.

The analysis in this paper can be further extended by considering other types of non-linearities. For instance, regime dependence on variables other than economic slack could be considered. Some of the theories that imply convexity in the Phillips curve (such as the costly adjustment model or the downward nominal wage rigidity hypothesis) could also be tested by conditioning the parameters of the Irish Phillips curve on the level or on the variance of inflation.

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[i] The analysis in this paper was carried out before the covid-19 outbreak.

[ii] The gap corresponds to the log difference between observed output and the trend estimate. To limit the “end-point problem” which, with some filters, may result in estimates that are highly biased at the ends of the sample, we extend historical data with forecasts from the European Commission.

[iii] Modified domestic demand is a measure of underlying economic activity which excludes leased aircraft and foreign owned intellectual property assets. The rationale for distinguishing between measures of slack in the domestic sector and multinationals-driven sectors is that multinationals are expected to be operating at full capacity, whereas capacity constraints are more likely to be binding in the domestic sector.

[iv] In this paper, changes in the labour cost refer to quarterly changes in nominal compensation per employee. Although wage inflation adjusted for productivity is a better proxy of the true cost pressure faced by firms, we do not adjust labour cost for productivity, as productivity is particularly difficult to measure in Ireland, with value added being inflated by the activity of multinationals.

[v] Other specifications were tested, including an accelerationist version of the Phillips curve with the sum of coefficients on lagged inflation constrained to unity. However, as the Wald test rejected the hypothesis of unity of the sum of coefficients on lagged inflation, we opted for a non-acceleratonist version of the Phillips curve.

[vi] HICP has been seasonally adjusted using the X-12 ARIMA procedure. Although year-on-year inflation has no seasonal pattern, using year-on-year growth rates may introduce a moving average component to inflation and complicate econometric inference, with auto-correlated residuals. For this reason, we rely on seasonally adjusted quarter-on-quarter inflation rates.

[vii] Stationary variables (such as net migration variables, indicators computed as gaps, or the differences in national unemployment rates) were introduced in levels, whereas non-stationary variables (such as the NEI and PLS indicators, labour cost indicators, unemployment rates and the global factors) were introduced in first differences.

[viii] Time series for the inflation expectations of firms and consumers are not available for Ireland. In the absence of forward-looking indicators, the lagged inflation term can be considered as a proxy for backward-looking expectations.

[ix] Reddan and Rice (2017) show that fluctuations in the sterling are of particular relevance for Ireland, a small open economy with a large share of trade outside the euro area, and advocate the consideration of bilateral exchange rates, rather than composite series such as nominal effective exchange rates.

[x] Table 1 reports only the specifications for wich the indidator of cyclical conditions was statistically significant.

[xi] Using the CPI as dependent variable as a robustness check provides similar results.

[xii] The appropriate lag length for the AR model was selected using the Akaike information criterion.

[xiii] The Diebold-Mariano test should not be applied to situations where the competing forecasts are obtained using nested models. Hence, we rather use the Clark-West test.

[xiv] We focus on one-sided tests to detect forecast superiority. The null hypothesis is that forecasts generated by model A are at least as accurate as forecasts generated by model B. The alternative hypothesis is that forecasts generated by model B are more accurate. Given the small size of the sample, we use the small-sample bias correction to the Diebold-Mariano test proposed by Harvey, Leybourne and Newbold (1997).

[xv] Methodological issues in the computation of the Irish HICP strengthens the case for focusing on services. The price of non-energy industrial goods has been on a declining trend since 2007, which partly reflects difficulties in measuring changes in quality in specific goods (clothing, footwear, computers and printers). In particular, the bridged overlap method used for these goods leads to a well-documented deflationary bias (Keating and Murtagh, 2018). This is the reason why we do not focus on core inflation, which includes non-energy industrial goods, but rather on the services component, which is immune from these methodological difficulties.

[xvi] Results are available upon request.

[xvii] As in Section 3, models are estimated on 40-quarter rolling windows and forecast errors are computed over 38 observations.

[xviii] By contrast, Reddan and Rice (2017) do not find a significant impact of the US dollar exchange rate on the price of non-energy consumer goods in Ireland, as a significant proportion of goods imported from the US (such as pharmaceutical products) are not sold to Irish consumers, but rather later exported from Ireland.

[xix] Quadratic slack terms, aimed at introducing convexity in the relationship between slack and inflation, were also tested, but were not statistically significant.

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