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The Phillips Curve at the ECB

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Abstract

We explain the role of the Phillips Curve in the analysis of the economic outlook and the formulation of monetary policy at the ECB. First, revisiting the structural Phillips Curve, we highlight the challenges in recovering structural parameters from reduced-form estimates and relate the reduced-form Phillips Curve to the (semi-)structural models used at the ECB. Second, we identify the slope of the structural Phillips Curve by exploiting cross-country variation and by using high-frequency monetary policy surprises as instruments. Third, we present reduced-form evidence, focusing on the relation between slack and inflation and the role of inflation expectations. In relation to the recent weakness of inflation, we discuss the role of firm profits in the pass-through from wages to prices and the contribution of external factors. Overall, the available evidence supports the view that the absorption of slack and a firm anchoring of inflation expectations remain central to successful inflation stabilisation.

JEL classification: E31, E52

Keywords: Inflation, Phillips Curve, Monetary Policy, European Central Bank

Non-technical summary

In this paper, our goal is to explain the role of the Phillips Curve in the analysis of the economic outlook and the formulation of monetary policy at the ECB.

Whereas the original contribution of Phillips (1958) identified an empirical relation between the level of unemployment and wage growth, nowadays we broadly think of the Phillips Curve as a structural relation between economy-wide slack and inflation. Central bankers rely heavily on the transmission mechanism by which monetary policy operates through the impact of financial conditions steered through both standard and non-standard monetary policies on the degree of economic slack in the economy, which in turn influences the evolution of wages and prices.

One contribution of the paper is to examine the structural Phillips Curve, which is embedded in the semi-structural models used at the ECB. The structural Phillips Curve specifies that deviations of inflation from its steady-state level are a function of: (i) the degree of slack in the economy; (ii) inflation expectations; and (iii) shocks to the mark-up over marginal cost in the prices set by firms.

Empirically, we identify the slope of the structural Phillips Curve following two approaches. The first approach uses country-level variation in slack within the euro area, while the second approach relies on high-frequency monetary policy surprises as external instruments. All in all, we find that the causal impact of slack on inflation, as captured by the structural estimates, is substantially higher than implied by reduced-form estimates.

However, reduced-form estimates also make a useful contribution to the suite of forecasting models used at the ECB. By considering a wide set of economic variables and econometric models, thick modelling and dynamic model averaging approaches provide robustness against measurement uncertainty and allow us to assess the contribution of slack and inflation expectations to inflation outcomes in the euro area in the past few years. Over the 2013-2017 period, the evolution of core inflation is largely attributable to the reduction in slack, which is partly offset by the drag from muted inflation expectations.

However, from late 2017 onwards, the thick modelling framework struggles to account for the persistent weakness of core inflation. We consider three potential explanations for the residuals. First, we examine the role of non-linearities and find that overall the evidence of non-linearities is stronger for the wage Phillips Curve than for the price Phillips Curve for the euro area. Second, we consider the missing pass-through from wage to price inflation and argue that a key factor contributing to the missing pass-through from wages to prices lies in the compression of the profit margins of firms: when wage and unit labour cost growth picked up strongly from mid-2017 onwards, firm profit margins compressed. The observed compression in firm profits may, in turn, relate to external factors, the structure of global goods markets and their implications for domestic pricing.

Third, we identify suggestive evidence for a link between the trade balance and domestic price pressures: over the recent period our battery of reduced-form models consistently reports substantially lower root mean squared forecasts errors for specifications that include a measure of the trade balance. This finding is consistent with the mechanics of the structural medium-scale ECB models, where the relation between the external economic environment and domestic inflation is modelled by assuming market power and sticky price setting in import (as well as export) markets, which generates a role not only for import prices but also for the trade balance.

Overall, we conclude that slack, which monetary policy can influence by changing financial conditions and thereby affecting consumption and investment, drives marginal costs (including wages) and transmits to inflation via the price-setting decisions of firms. Structural factors can generate headwinds that drive inflation away from the target for a long time, but not permanently. In the steady state (if policy is unconstrained), inflation is determined by the policy target.

It also matters that the structural relation between slack and inflation is dependent on expectations about future inflation: if expected future inflation is low, the impact of slack on wages and prices is attenuated. In addition, the relation can be time-varying and the reduced-form relation between slack and inflation depends on structural factors as well as the monetary policy response, which is necessarily less sharp in the neighbourhood of the effective lower bound. At the same time, further research is warranted on the drivers of the mark-ups that firms charge over their costs and the factors that give firms the confidence to raise their prices.

All in all, we consider the Phillips Curve framework to be a helpful way to understand the transmission of ECB monetary policy in recent years: the measures undertaken since the summer of 2014 have underpinned a sustained expansion and a substantial reduction in unemployment. In turn, the re-absorption of slack has been associated with a substantial positive shift in indicators of underlying inflation and in the distribution of inflation expectations from their previous historical lows. Looking to the future, further progress in raising inflation towards our aim can only be achieved by ensuring slack is sufficiently low and inflation expectations are sufficiently anchored.

1 Introduction

In this paper, our goal is to explain the role of the Phillips Curve in the analysis of the economic outlook and the formulation of monetary policy at the ECB.[1] While there is considerable debate about the conceptual and empirical links between activity and inflation, central bankers rely heavily on the transmission mechanism by which monetary policy operates through the impact of financial conditions on the degree of economic slack in the economy, which in turn influences the evolution of wages and prices. In normal times, central banks manage financial conditions through variations in short-term interest rates; in the neighbourhood of the effective lower bound, central banks use additional tools, such as forward guidance about the future path of interest rates, asset purchases and targeted lending schemes.

Whereas the original contribution of Phillips (1958) identified a relation between the level of unemployment and wage growth, we nowadays broadly think of the Phillips Curve as a structural relation according to which deviations of inflation from its long-run steady state are a function of: (i) the degree of slack in the economy; (ii) inflation expectations; and (iii) shocks to the mark-up over marginal cost in the prices set by firms.

This structural view of the Phillips Curve needs to be distinguished from the reduced-form view, which concentrates on the empirical relation between the measures of slack and inflation. Those questioning the "existence" of the Phillips Curve mostly refer to the challenge in identifying the reduced-form relation. Reduced-form estimates, however, cannot be expected to recover the policy-relevant structural parameters of the Phillips Curve, since these do not take into account the role of other parallel structural relations, such as the feedback from slack to the monetary policy stance. At the same time, the reduced-form estimates also play a role in the policy process. First, reduced-form estimates may provide a useful lower bound to estimates of the slope of the Phillips Curve. Second, the reduced-form empirical relation between slack and inflation provides a helpful contribution to the suite of forecasting models that we use at the ECB.

The paper is structured as follows. Section 2 introduces the policy context in which the ECB operates and outlines the current challenges to inflation stabilisation. Section 3 revisits the structural Phillips Curve, introducing its main components: slack; inflation expectations; and mark-ups. It also describes key factors that determine the strength of the relation and can drive its time variation, while also highlighting the challenges in recovering structural parameters from reduced-form estimates. This section also relates the simple Phillips Curve to the (semi-) structural models regularly used at the ECB for policy analysis.

Section 4 empirically identifies the slope of the structural Phillips Curve using two approaches:

[1] Comprehensive accounts of the ECB's monetary policy are available in Hutchinson and Smets (2017), Hartmann and Smets (2018) and Rostagno et al. (2019).

exploiting cross-country variation and relying on high-frequency monetary policy surprises as external instruments. Section 5 considers the reduced-form evidence, focusing on the relation between slack and inflation and the role of inflation expectations. This section also discusses the most important un-settled issues, including the role of profits in the pass-through of wage to price inflation, as well as the potential contribution of external factors. Section 6 concludes.

Overall, the message of this paper is that the available evidence supports the view that the absorption of slack and the robust anchoring of inflation expectations remain central to successful inflation stabilisation.

2 The ECB's policy context

Before the global financial crisis, headline inflation and inflation expectations were broadly aligned with the ECB's inflation aim. In the wake of the global financial crisis and the euro area debt crisis, headline inflation embarked on a notable downward trajectory from mid-2011 onwards. Initially, this largely reflected base effects due to receding energy prices, with measures of underlying inflation that strip out the volatile food and energy components remaining not too far from 2 percent. However, although emerging from contractionary territory, economic performance remained lacklustre in the following three years, while measured and trend inflation were both on a downward path, with significant risks of deflation priced in by the end of 2014.

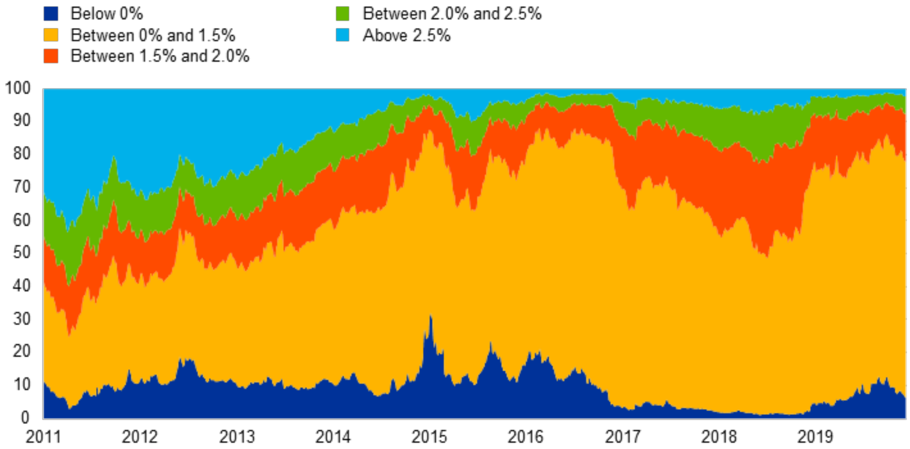
In the proximity of the effective lower bound on interest rates, and with a view to overcoming potential impairments of the monetary policy transmission process, the ECB has deployed an innovative, multi-pronged approach in the design of its policy stance.[2] The policy mix of measures undertaken since the summer of 2014 includes four main elements: (i) pushing the policy rate into negative territory; (ii) forward guidance on the future policy path; (iii) large-scale outright purchases in the form of the ECB's asset purchase programme (APP); and (iv) TLTROs (targeted long-term collateralised loans to banks that incentivise lending to the non-financial sector). These measures have worked as a package, with significant complementarities across the different instruments.

In combination, these measures led to a substantial easing of financial conditions. Both through decreases in the deposit facility rate (which anchors the key money market interest rates in an environment of abundant excess liquidity) and forward guidance on future policy rates, forward rates of short-term interest rates and the expectations component of longer-term yields declined. Furthermore, the asset purchases compressed term premia, thereby further reducing longer-term yields: Eser et al. (2019) estimate that the asset purchase programme lowered term premia by around 100 basis points.[3] Altogether Rostagno et al. (2019) find that the ECB's policy package

[2] For more details, see Hartmann and Smets (2018), Lane (2019) and Rostagno et al. (2019).

[3] The effects of non-standard monetary policy measures on the monetary policy stance are also captured in

Figure 1: Option-implied distribution of average inflation over the next five years



Probabilities implied by five-year zero-coupon inflation options are smoothed over five business days. Risk-neutral probabilities may differ significantly from physical, or actual, probabilities. The sample is from 8 January 2011 to 17 December 2019. Data from Bloomberg, Thomson Reuters and ECB calculations.

as a whole contributed 2.5 percentage points to euro area real GDP between 2015 and 2018 and 1.2 percentage points to inflation.

The easing in financial conditions contributed to a sustained recovery and subsequent expansion, with 26 consecutive quarters of positive growth. At the same time, the unemployment rate declined from its peak in the second quarter of 2013 to a level of 7.4 percent in December 2019.[4] The steady expansion of domestic demand and re-absorption of economic slack have been associated with a substantial positive shift in the distribution of inflation expectations since the end of 2014 (Figure 1). Importantly, measures of underlying inflation shifted upwards from their previous historical lows (see Figure 2).

This episode provides basic support for a connection between reducing economic slack (supported by accommodative monetary policy) and raising inflation momentum. However, despite the noticeable pick up in wage inflation (Figure 3), the recovery in measures of underlying price inflation has been more muted.

Indicators of inflation expectations also declined, both at long and at short horizons. At the same time, looking at the correlation between the one-year and five-year ahead SPF inflation expectations, it does not seem that the dynamics of inflation expectations by 2019 were similar to that of 2014-2015, when this correlation had become significant. As explained in Ciccarelli and Osbat (2017), a significant correlation between long-term inflation expectations and short-term ones (or current inflation) can be interpreted as a sign of de-anchoring of long-term expecta-

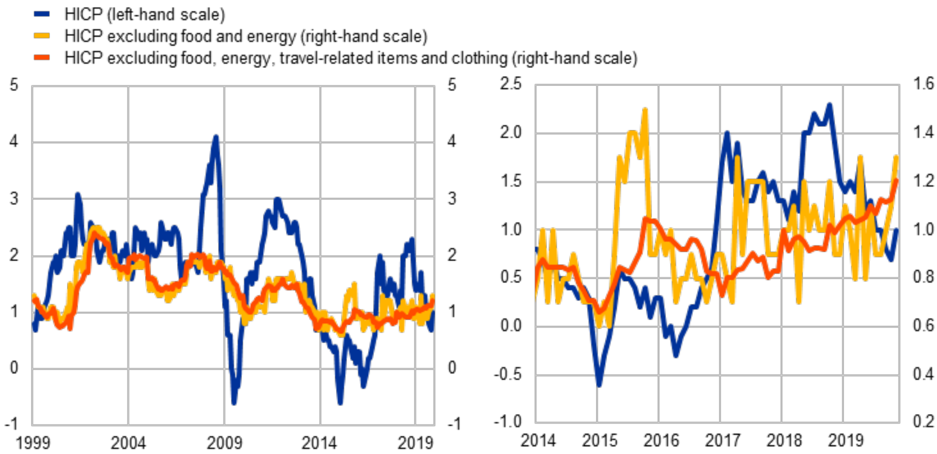
models calculating a shadow short-term interest rates, as for example Krippner (2015) and Lemke and Vladu (2017).

[4]Total hours worked have only recently recovered to their pre-crisis level.

tions.

Even if the signs of de-anchoring seem lower than before the start of the ECB's package of unconventional measures, inflation remains below target.[5] More generally, inflation pressures have remained largely subdued around the world, so that there continues to be a vigorous debate about the nature of the inflation process. Against this background, we next review the theoretical underpinnings of the structural Phillips Curve, its implications for reduced-form estimates, as well as evidence about the power of slack in forecasting inflation.

Figure 2: Inflation development



The left panel shows the full sample from January 1999 to November 2019 and the right panel shows a sub-sample from January 2014 to November 2019. Data source: Eurostat.

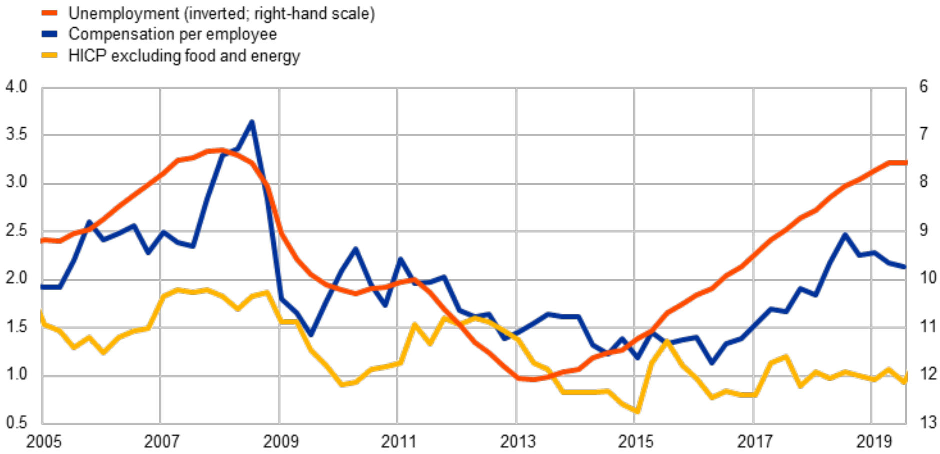
3 The structural Phillips Curve

The structural Phillips Curve is a key element in our thinking about the transmission of monetary policy. It describes a causal relation between economy-wide slack and inflation. Slack, which monetary policy can influence by changing financial conditions and thereby affecting consumption and investment, drives marginal costs (including wages) and transmits to inflation via the price-setting decisions of firms.

We present a stylised structural framework, which helps us to: (i) introduce the main elements of the structural Phillips Curve: slack, inflation expectations and mark-ups; (ii) describe key factors that determine the strength of the relation and can drive its time variation; and (iii) highlight the challenges in recovering structural parameters from reduced-form estimates.

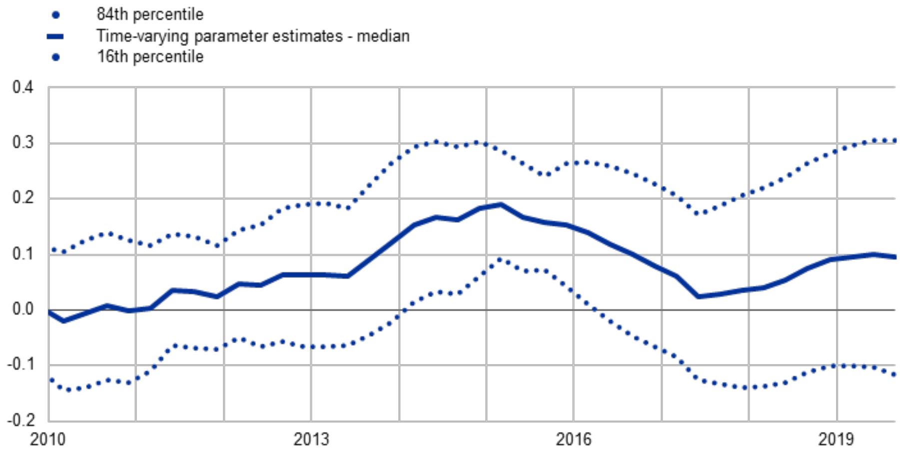
[5] For discussions of the anchoring of inflation expectations see e.g. Corsello et al. (2019) or Byrne and Zekaite (2019).

Figure 3: Inflation, wage growth, and unemployment (inverted scale)



Both the HICP excluding food and energy and the unemployment rate are converted to quarterly data. The sample is from 2005Q1 to 2019Q3. Data from Eurostat.

Figure 4: Pass-through of short-term to long-term inflation expectations



The chart shows estimated coefficient in regression of five-year ahead on one-year ahead inflation expectations from the ECB's SPF. Sample is from 1999Q1 to 2019Q2. Data from ECB, ECB Survey of Professional Forecasters (SPF), and ECB calculations.

3.1 The New Keynesian Phillips Curve

The particular formalisation of the structural Phillips Curve that we outline in this section is the New Keynesian Phillips Curve. The New Keynesian Phillips Curve forms the backbone of the structural framework that underlies the family of DSGE models used regularly at the ECB. The framework introduces realistic price and wage stickiness into a general-equilibrium business-cycle model with optimising households and firms.[6] The price and wage stickiness can

[6]Structural models in which agents are optimising have an important role in policy analysis by offering protection against the critique of Lucas (1976), according to which reduced-form relations are not invariant to the

lead to inefficient business cycle fluctuations, which monetary policy can partially offset.

While we describe the elements of the basic New Keynesian model, we will also refer to two more complex structural models that we regularly use in the projection exercises for forecasting and in monetary policy analysis.[7] These are: the New Area-Wide Model II (Coenen et al., 2018), which is the most recent version of an open-economy medium-scale DSGE model of the euro area, estimated as a system using Bayesian methods in the tradition of Smets and Wouters (2003, 2007); and the ECB-BASE model (Angelini et al., 2019), which is a new incarnation of a semi-structural model of the euro area, in a similar vein to the FRB/US model of the US Federal Reserve. Both models rely on the New Keynesian paradigm, but the semi-structural model aims to achieve better data fit by: (i) relaxing some of the cross-equation parameter restrictions of the New Keynesian model; (ii) implementing a more flexible lag structure; and (iii) replacing rational expectations with a more empirical (VAR-based) approach that relies on the observed evolution of survey expectations.

The Phillips Curve is a central equation in the New Keynesian framework.[8] The price Phillips Curve links the deviation of domestic inflation (GDP deflator) from its long-term steady-state value ($\hat{\pi}_t^{\text{GDP}}$), which we label the "inflation gap", to three terms: the output gap ($\tilde{y}_t$), a theoretical measure of economy-wide slack; the lagged ($\hat{\pi}_{t-1}^{\text{GDP}}$) and expected future inflation gaps ($E_t\left\{\hat{\pi}_{t+1}^{\text{GDP}}\right\}$); and innovations in desired mark-ups (φ_t). Formally,

$$\hat{\pi}_t^{\text{GDP}} - \gamma\hat{\pi}_{t-1}^{\text{GDP}} = \kappa\tilde{y}_t + \beta\left[E_t\left\{\hat{\pi}_{t+1}^{\text{GDP}}\right\} - \gamma\hat{\pi}_t^{\text{GDP}}\right] + \varphi_t, \tag{1}$$

where γ, β and κ are constants.

In an open economy setting, consumer-price inflation (π_t, CPI) is different from domestic inflation, as it also depends on the exchange rate and the evolution of import prices. Among import prices, the oil price is particularly salient in the euro area. The sensitivity of the CPI to these factors depends on the openness of the country, in particular the share of imported goods in consumption. The relation can be formalised as $\hat{\pi}_t = \hat{\pi}_t^{\text{GDP}} + \nu/(1-\nu)\Delta q_t$, where $\hat{\pi}_t$ is the consumption inflation gap, Δq_t is the change of the real exchange rate, which depends on both the import prices and the nominal exchange rate, and ν is a parameter capturing the degree of openness.

Without going through the details of the derivation of equation (1), it is useful to highlight its

policy regime.

[7]There are many more structural models of the euro area developed and maintained by ECB researchers that are part of the suite of models we use for particular policy exercises. See, amongst others, Christiano et al. (2010); Darracq Pariès and Kühl (2016); Mendicino et al. (2019). In terms of the Phillips Curve, these models are similar to the description in the main text.

[8]The models at the ECB augment the benchmark Phillips Curve with backward indexation, while also taking into account wage stickiness and open economy dimensions. For ease of presentation, we relegate to the appendix the description of the impact of wage stickiness. We return to open-economy issues in section 5.4.3.

micro foundations and the origins of its main components.[9] The relation is the outcome of the optimal price-setting choices of firms, in the presence of constraints on flexible price adjustment. The benchmark framework we outline here introduces price stickiness through the popular Calvo (1983) framework, which assumes that in every period a fixed share of firms adjust their prices. This assumption implies infrequent and staggered price adjustment, which are realistic features confirmed by price-setting micro-data.[10] The firms have pricing power in the markets of the specialised goods that they produce. If they set prices flexibly, they would simply set it at a mark-up over their marginal costs. With sticky prices, their choices become dynamic.[11]

3.1.1 Slack

The output gap ($\tilde{y}_t$), which measures output relative to its natural level, appears in equation (1) because it drives the marginal cost of production. When the output gap is positive, the extra production reduces efficiency and increases marginal costs. It also requires additional labour input, which households are only willing to provide for higher wages, leading to cost increases for firms. The natural level of output has a clear definition in the framework: it is the counterfactual level of output that would prevail if prices were flexible. Under flexible prices, the level of output would be at its efficient level. Furthermore, and this is a key insight of the framework, the distance from this level determines the relevant measure of slack, which is the key driver of inflation dynamics. The natural level of output is not constant; rather, it fluctuates with structural shocks (such as technology shocks) around the long-term steady-state value.

A long-standing challenge to the New Keynesian Phillips Curve concerns the independence of the natural level of output from monetary policy and, more generally, other demand-side factors. In particular, some researchers have argued that the standard models need to be extended to explicitly take into account hysteresis effects, whereby serious downturns have persistent or even permanent effects on the natural level of output and the natural rate of unemployment (Blanchard and Summers, 1986; Comin and Gertler, 2006; Galí, 2015). In our reading, these approaches tend to accept the usefulness of the Phillips Curve and the output gap as a driver of inflation, but argue that policy needs to take into account its potentially long-lasting effect

[9] See Woodford (2011) and Galí (2015) for textbook treatments.

[10] Alternative frictions can also generate the structural Phillips Curve. Relevant examples are quadratic adjustment costs (Rotemberg, 1982), noisy (Woodford, 2009; Mackowiak and Wiederholt, 2009) and sticky (Mankiw and Reis, 2002) information, small fixed (menu) costs of price adjustments (Gertler and Leahy, 2008), and control costs of timing and size of price changes (Costain et al., 2019). Although there are important differences between the details of these models, these all imply Phillips Curves that are broadly in line with the augmented Phillips Curve described above. With this, we do not want to imply that the current framework - which predominantly relies on costs of adjustment - cannot be improved through further work, which, for example, combine realistic sources of price-setting frictions, such as those with information and menu costs suggested by Alvarez et al. (2011). See also Alvarez (2008).

[11] The recent contributions by Rubbo (2020) and Höynck (2020) examine the possible implications of multiple sectors for the Phillips Curve.

on the natural level of output.[12]

Four sets of factors influence the slope of the structural Phillips Curve (κ):

1. First, the slope is flatter, the stickier are prices: with more firms keeping their price unchanged, the current level of slack has a smaller impact on inflation. Furthermore, adjusting firms set prices for multiple periods, taking into account an average anticipated slack over this period. If prices are stickier, the planning horizon increases, which mechanically reduces the impact of current slack on pricing decisions.

2. Second, the slope is flatter, the more severe are real rigidities. Real rigidities are factors that provide incentives for a firm to keep its prices close to the prices of its competitors. For instance, a firm might want to avoid setting its price much lower than its competitors since this could increase the demand for its product and the costs of extra production could cut too much into its profits. Other factors can play similar roles, such as increasing global competition, which raises the elasticity of demand. In terms of the wage Phillips Curve, the declining power of trade unions increases competition in the labour market. These factors reduce the impact of current slack on inflation, since the adjusting firms keep their prices closer to their non-price-adjusting competitors instead of responding to aggregate conditions.

3. Third, the slope is flatter, the less sensitive are marginal costs to the output gap. For instance, wages can stay subdued despite disappearing slack if labour supply responds elastically to wage increases, which is true if there are a lot of underemployed people or people out of the labour force, who are ready to re-enter.

4. Fourth, the slope is flatter, the more open is the country and the more substitutable are imports to domestic goods. Globalisation and the increasing role of global value chains therefore make inflation less sensitive to local slack and more sensitive to global conditions.[13] These open-economy aspects are discussed in Section 5.4.3.

3.1.2 Inflation expectations

Expectations about future inflation appear in the Phillips Curve equation, since firms set their prices in advance for multiple periods. This price-setting assumption is in line with observations from micro-data, which consistently find across various countries and sectors that consumer and producer prices stay unchanged for multiple quarters (see Bils and Klenow, 2004; Alvarez et al.,

[12] Alternatively, other researchers challenge the usefulness of the concept of the natural level of output and natural rate of unemployment, emphasising the primary role of animal spirits in determining fluctuations in output (Farmer and Nicolò, 2018).

[13] See, for example, Gilchrist and Zakrajšek (2019) on the impact of trade openness on the US Phillips Curve and Forbes (2019) on evidence that global trade integration has made global factors more important for inflation across many advanced and emerging economies.

2006). If prices are set for multiple periods, firms need to plan forward by taking into account the future evolution of their costs, mark-ups and the price-setting of their competitors. Indeed, as we iterate the equation forward, we see that the inflation gap reacts not only to the current level of slack, but also to the present discounted value of its future dynamics:

$$\hat{\pi}_t^{\text{GDP}} - \gamma \hat{\pi}_{t-1}^{\text{GDP}} = \sum_{i=0}^{\infty} E_t \beta^i \left[\kappa \tilde{y}_{t+i} + \varphi_{t+i} \right]. \tag{2}$$

This expression captures that monetary policy influences inflation not only through its impact on current slack, but also through its impact on future anticipated slack. It follows that transparency about future policy, through clarity about the monetary policy reaction function and forward guidance, can improve the effectiveness of monetary policy. At the same time, the expression also implies that the reduced-form relation between inflation and current slack will not describe the structural relation between the two variables, unless we control for the future expected evolution of slack. This also means that the measured relation will vary with the persistence of an underlying shock, as well as with how policy is expected to react in the future.

The source of the impact of the lagged inflation gap $\hat{\pi}_{t-1}^{\text{GDP}}$ in the Phillips Curve is backward-looking indexation. The idea is that those firms that are not re-optimising their prices do not keep their prices constant, but adjust them partially (with a proportionality term γ) to past inflation. This term is not without controversy. On the one hand, automatic indexation does not seem to show up in micro-level price-setting data. On the other hand, adding the term improves the empirical fit of the model by introducing stickiness to inflation (not just to the price level as the benchmark New Keynesian Phillips Curve does).

This might be one of the areas where better micro-foundations of the currently applied New Keynesian models are required. Models with frictions in information acquisition or information processing, for example, are prime candidates to explain why some firms might rely on past information when they reset their prices. Research that improves our understanding of the key factors determining the expectations of firms and the impact of these expectations on price setting are essential to help us bridge this micro-macro dichotomy (see Coibion and Gorodnichenko, 2015).

3.1.3 Mark-ups

Time variation in desired mark-ups (through the term φ_t) can give rise to variation in optimal prices and inflation that are independent of the level of slack.[14] In estimated models, fluctuations

[14] In more complex models this also applies to cost-push shocks, of which desired wage or price mark-ups are a subset.

in mark-ups play an important role in accounting for the variation in inflation.[15] The prominence of residual mark-up shocks is not a problem so long as these collect the impact of factors that are independent of monetary policy. Their prominent role is problematic, however, and might call for further work to insert them more directly into our analyses, if we think that monetary policy can have a relevant impact on their evolution, or that their fluctuations signal some underlying change in the pricing decisions of firms.

3.2 Policy feedback

The structural Phillips Curve does not fully describe the co-movement between inflation and economic slack, which form the basis of reduced-form analysis. For this, we also need to consider the role of additional feedback mechanisms in the economic system. In particular, we need to assess: (i) how economic slack is influenced by monetary policy; and (ii) how monetary policy itself is conducted.

First, monetary policy affects financial conditions, which influence economic slack by changing consumption and investment decisions. This complex relation can, in the most simple model, be illustrated by the dynamic IS equation:

$$\tilde{y}_t = -\frac{1}{\sigma}\left(i_t - E_t\{\pi_{t+1}\} - r_t^n\right) + E_t\{\tilde{y}_{t+1}\}, \tag{3}$$

where i_t is the policy rate, σ is a parameter, and r_t^n is the natural rate of real interest.[16] In similar vein to the natural level of output, the latter is the counterfactual real interest rate under flexible prices, which depends on the household discount rate and innovations in the economy. Equation (3) captures the inter-temporal decision of the representative consumer: intuitively, policy easing reduces the real interest rate, which increases aggregate consumption and therefore reduces current slack.

In the NAWM II and the ECB-BASE models, the transmission of monetary policy to economic slack is more multi-dimensional. Among other channels, these models take into account the impact of monetary policy on investment, the exchange rate and trade, while also incorporating key aspects of fiscal policy and the impact of financial frictions on policy transmission. While these complications do not qualitatively modify the key transmission channel outlined above (policy affects aggregate demand and the economic slack through its impact on financial conditions), these additional factors matter for quantitative assessments.

Second, we turn to monetary policy. In the benchmark New Keynesian model, policy is for-

[15] In some sense, these are a residually-determined measure of the limitations of our models to include all relevant factors that might influence observed inflation.

[16] In the NAWM II and ECB-BASE the Taylor rule is specified in terms of HICP.

malised in terms of a Taylor-type interest-rate feedback rule

$$i_t^* = \rho + \pi^* + \phi_\pi (\pi_t - \pi^*) + \phi_y \tilde{y}_t + \eta_t, \tag{4}$$

where $\rho = -\log(\beta)$ is the discount rate, π^* is the central bank's inflation objective, $\phi_\pi > 1$, and $\phi_y > 0$ are parameters and η_t is a temporary deviation of the rule from the modelled systematic factors. The feedback rule is constrained by the effective lower bound of the interest rate $i_t = \max(i_t^*, \underline{i})$.

Such a policy rule is a simplified description of the decision-making process in a central bank, but it emphasises a couple of cornerstones of actual policy-making. First, the central bank is committed to achieving its inflation objective (π^*). Second, it adjusts its policy rate sufficiently vigorously to contain the variability of inflation around its objective. Third, it also puts some weight on stabilising output around its efficient natural rate, and, fourth, its instruments face constraints. Importantly, the medium-scale models at the ECB expand the set of available instruments: in particular, these give an explicit role to unconventional monetary policies, such as forward guidance and quantitative easing.

The long-term steady-state inflation rate ($\overline{\pi}$) is not determined by the New Keynesian Phillips Curve. Rather, the latter just describes the determinants of the inflation gap (the difference between inflation and its long-term rate). In this sense, the Phillips Curve only offers a framework for the stabilisation of inflation around its long-term level, but not about the determinants of the long-run level itself. The steady state inflation, instead, is pinned down by the central bank's inflation objective (π^*). The real interest rate is defined by the Fisher equation as $r_t = i_t - E_t\{\pi_{t+1}\}$. In the steady state, the real interest rate equals to $\bar{r} = \rho$, so by equation (4), steady-state inflation is equal to the central bank's objective.

It might be worth emphasising here that this Fisher effect, which is the one-to-one long-run relationship between nominal interest rates and inflation rates, is an inherent feature of the New Keynesian model. Neo-Fisherian frameworks, even if these focus on the potential of the Fisher equation in guiding optimal interest rate policies, do not challenge the role of the Phillips Curve in short-term inflation stabilisation.[17]

[17] The neo-Fisher effect, which finds that a permanent nominal interest rate increase can coincide with an increase in the short-term inflation rate, is also consistent with the standard New Keynesian model, as shown by Uribe (2018). In the model, the permanent change is caused by a fully-credible increase in the central bank's inflation objective. This credible increase raises inflation expectations and therefore inflation through a Phillips Curve relation. This allows the central bank to achieve its new higher inflation objective without a short-term cut in the nominal interest rates. Even although the result is conceptually interesting, it is difficult to envisage scenarios in which the change in the target can be communicated with perfect credibility, as in Erceg and Levin (2003).

3.3 Implications for the reduced-form Phillips Curve

In this section, we use the structural model outlined in Section 3 to describe some of the reasons why reduced-form estimates cannot be expected to reveal the slope of the policy-relevant structural Phillips Curve. In addition, we consider factors that could contribute to shifts in the intercept and slope of reduced form estimates.

Let us first consider the slope. The reduced-form estimation approach regresses inflation ($\pi_t = \hat{\pi}_t + \bar{\pi}$) on the output gap ($\tilde{y}_t$). Temporary demand shocks, such as innovations in r_t^n, move the output gap and affect inflation proportionally to the structural Phillips slope coefficient κ. If only these shocks were present, the structural coefficient could be recovered by the reduced-form estimates. However, temporary mark-up shocks φ_t shift the Phillips Curve and move the equilibrium output gap and inflation in opposite directions, which confounds their structural relation. Notably, if only mark-up shocks existed (or these were sufficiently dominant), the estimated relation between inflation and the output gap would turn negative, even though the structural relation is positive. This is a standard problem of estimating structural relations within a simultaneous system.

The estimated slope is also not independent of the conduct of monetary policy. Through adjusting its commitment to inflation stabilisation ϕ_π, the central bank can modify the relative volatility of the inflation and the output gap. If inflation stabilisation increases without limit ($\phi_\pi \to \infty$), the reduced-form Phillips Curve becomes flat (Bullard, 2018).

Under optimal discretionary policy, the situation is even starker (McLeay and Tenreyro, 2019). In this case, monetary policy optimally offsets all demand shocks, but since mark-up shocks drive inflation and the output gap in opposite directions monetary policy partly accommodates their impact. It follows that the shock and the slack will co-move. This introduces a simultaneity bias: the error term in the Phillips Curve (φ_t) is not independent of the slack $\tilde{y}_t$.[18]

The outcome here is a negative slope in the reduced-form Phillips Curve, despite the positive slope in the structural relation. It should be noted that these issues remain even if one controls for the presence of lagged inflation and inflation expectations in the reduced-form equations. These are relevant problems, and the increased focus of central banks on inflation stabilisation and improved credibility of policy making could have played some role in the secular decline in the estimated slope of reduced form Phillips Curves since the 1980s (see also Bank for International Settlements (2017), Figure I.3).

One of the goals of the joint estimation of the full system, as is done in the structural NAWM II model and in the price-wage block of the semi-structural ECB-BASE models, is to overcome this identification challenge. As long as the models are not (too) mis-specified, these can recover the

[18]Related evidence is provided by Geerolf (2020) who shows that a consistent negative relation holds between the relative price of non-tradables to tradables and unemployment across exchange rate regimes but that a relation between overall inflation and unemployment is not observed for flexible exchange rate regimes.

policy-relevant slope of the structural Phillips Curve. As we show in Section 4, an alternative identification of the structural slope can also be achieved without a full model through identifying independent variation in slack, which is unrelated to systematic monetary policy.

Table 1 lists some parameters of the estimated Phillips Curves in the NAWM II model, the ECB-BASE model and the average of a set of reduced-form equations (see Section 5). The parameters are not directly comparable since these use somewhat different measures for inflation, the output gap and inflation expectations, but are still indicative of relevant differences between the reduced-from and structural estimates.[19]

Our focus is on comparing the estimates of the slope coefficients in the (semi-)structural models to the reduced-form estimates. In particular, we are interested whether the structural estimates imply a higher slope coefficient than the reduced-form estimates, in line with predictions outlined above. However, the slope coefficients cannot be assessed independently of the estimated coefficient of the forward-looking term (the discount rate $\hat{\beta}$), since equation (2) shows that current inflation is a function of the present discounted value of current and anticipated output gaps. If the change in the output gap is persistent, then anticipated future changes of the output gap - and thereby the discount rate - play a role in determining the pass-through of the change to the inflation rate. When the Phillips Curve is very forward looking ($\hat{\beta}$ is high), then the anticipated future output gaps play a much more important role relative to the current output gap, than when the curve is less forward looking. An upper-bound of the effect is simple to calculate: $\hat{\kappa}/(1-\hat{\beta})$ measures the maximum effect as the change in output gap approaches to stay permanent.

A key difference between the structural NAWM II model and the semi-structural ECB-BASE model is that, while the former restricts the coefficient of the forward-looking term to its theoretical value ($\hat{\beta} = 0.998$), the latter estimates this parameter (still assuming model-consistent, rational expectations) and obtains a much lower estimate ($\hat{\beta} = 0.63$). The reduced-form estimates use different survey-based expectations and estimate an even lower forward-looking term ($\hat{\beta} = 0.18$).[20] The differences in the coefficient estimates of the forward-looking terms show up inversely in the estimated backward-looking terms: the reduced-form models assign it most

[19] The relevant dependent variables are the GDP deflator in the NAWM II and the ECB-BASE, and HICP inflation excluding energy and food (HICPx) in the reduced-form regressions. The output gap measures are also different, but related: while NAWM II uses the potential output estimate of the European Commission as one of its observables, the ECB-BASE and the reduced-form estimates use the ECB's internal potential output and output gap estimates. The sample period also varies across estimations.

[20] The reduced-form equations regress current HICPx inflation on backward- and forward-looking (headline HICP) inflation terms and a slack measure. The structural Phillips curve (equation 1) is expressed in terms of the deviation of current inflation from the indexation term ($\hat{\pi}_t - \gamma\hat{\pi}_{t-1}$) and not directly in terms of the current inflation gap: indeed, current inflation appears in both sides of the equation. After rearranging terms, the structural Phillips curve can be expressed in terms of the inflation gap as

$$\hat{\pi}_t^{\text{GDP}} = \frac{\gamma}{1+\beta\gamma}\hat{\pi}_{t-1}^{\text{GDP}} + \frac{\kappa}{1+\beta\gamma}\tilde{y}_t + \frac{\beta}{1+\beta\gamma}\left[E_t\left\{\hat{\pi}_{t+1}^{\text{GDP}}\right\}\right] + \frac{\beta}{1+\beta\gamma}\varphi_t.$$

From the reduced form estimates, it is straightforward to recover the implied values of γ and β.

weight, then the ECB-BASE model and finally the NAWM II model assigns the smallest weight to backward-looking terms.

Taking the impact of the forward-looking terms into account, we find that the differences in forward-looking terms can be very important: even although the slope estimate of the structural NAWM II model is lower than both the ECB-BASE model and the reduced-form estimates, as a result of the strong forward-looking term, the effect of a persistent shock is estimated to have a stronger effect than in the other models. The size of the slope coefficients can also be compared in terms of the impact of a simulated monetary policy shock in the ECB-BASE and the NAWM II models. We find that the effect is larger in the NAWM II model despite its lower slope coefficient estimate (see Figure 5). The explanation is that the larger forward-looking term more than compensates for the lower slope coefficient.

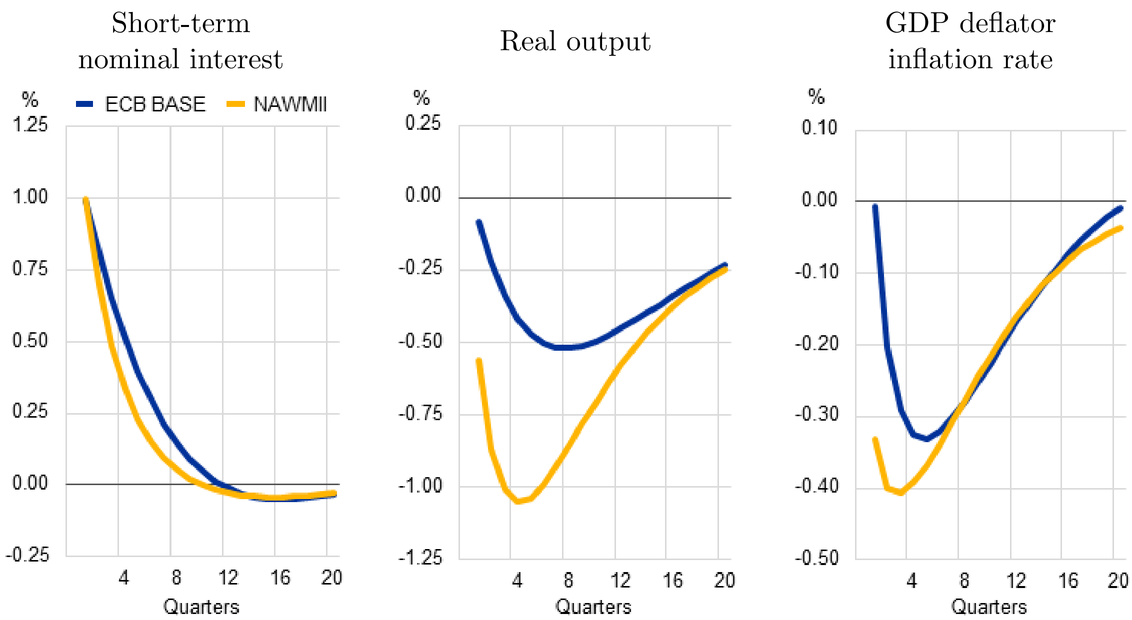
All in all, we find that the causal impact between slack and inflation as revealed by the structural estimates is substantially higher than implied by the reduced-form estimates. This is in line with arguments outlined above, which imply that the presence of mark-up shocks and the impact of monetary policy impart a downward bias on the slope coefficient estimates in reduced-form models.

Table 1: Estimated Phillips Curve parameters

Coefficients	Notation	NAWM II	ECB-BASE	Reduced-form
Slope	$\hat{\kappa}$	0.0084	0.12	0.02
Forward term	$\hat{\beta}$	0.998	0.63	0.18
Indexation term	$\hat{\gamma}$	0.230	0.39	0.51
Maximum multiplier	$\hat{\kappa}/(1-\hat{\beta})$	4.200	0.33	0.02
Sample		1985Q1-2014Q4	2000Q1-2017Q4	1995Q1-2019Q2
Type of model		Structural	Semi-structural	Reduced-form

Estimated Phillips Curve parameters of a structural open-economy DSGE model (New Area-Wide Model II), a semi-structural model (ECB-BASE) and an average of a suite of reduced-form estimates. The reduced-form estimation uses the core HICP excluding food and energy index as the dependent variable, the internal output-gap estimate of the ECB as a slack measure and various inflation expectations. The table reports a maximum output-gap multiplier, which obtains as the change in the output gap approaches becoming permanent.

Figure 5: Impulse responses to monetary policy shocks in the NAWM II model and the ECB-BASE model



The figure shows the impulse responses to a one percentage point monetary policy shock in the structural New Area-Wide Model II model and the semi-structural ECB-BASE model.

Finally, let us turn to the determinants of the intercept of the reduced-form Phillips Curve. These are the factors that influence the level of consumer-price inflation that are unrelated to the economy-wide slack:

- The intercept is influenced by the perception of the central bank's long-term inflation aim π^*, which drives its interest-rate and non-standard policies. Both the NAWM II model and the ECB-BASE model incorporate some uncertainty about the public perception of the central bank's long-term inflation objective. In particular, the perceived target is a (very) slow-moving function of the past perceived target and current inflation rates (Gürkaynak et al., 2005). In the NAWM II model, the evolution of the perceived target is disciplined by the observed evolution of the long-term inflation expectations in the Survey of Professional Forecasters (SPF).
- Even under full credibility of the central bank's inflation aim, uncertainty about the effectiveness of non-standard policy instruments, when standard interest rate policy is constrained by its effective lower bound, might open up a negative expected inflation gap.[21]
- Declines in the inflation rates of major trading partners and in commodity price inflation can reduce the intercept through their impact on import prices.
- The impact of the backward-looking term ($\hat{\pi}_{t-1}$) in the New Keynesian Phillips Curve can reduce the intercept following a stream of below-target inflation rates.
- Secular developments in mark-ups would also show up in the intercept of the reduced-form Phillips Curve. In contrast to the United States, we do not see substantial secular increases in mark-ups in the euro area; rather, if anything, mark-ups have marginally decreased (McAdam et al., 2019).

4 Identifying the slope of the structural Phillips Curve

In this section, we present two approaches that seek to identify the structural slope of the Phillips Curve without specifying a full model of the economy. The first approach uses country-level variation in slack within the euro area, as suggested by McLeay and Tenreyro (2019). If countries are small relative to the aggregate monetary union, the common monetary policy is arguably independent of country-level variation, so that the estimates sidestep the bias caused by the endogenous feedback of monetary policy.[22]

[21] Ciccarelli and Osbat (2017) find that uncertainty about the transmission of monetary policy increased in the aftermath of the European sovereign debt crisis. Similarly, Dovern and Kenny (2017) find a change towards a more uncertain and negatively skewed distribution of SPF expectations across forecasters, which can be interpreted as agents still learning about the effectiveness of the new instruments. On the other hand, Locarno et al. (2017) find that, if expectations drift away from target for a long time, monetary policy may become less effective. See also Corsello et al. (2019).

[22] This identification method is also used by Lane and Stracca (2018).

Following Barnichon and Mesters (2019), the second approach relies on proxies for monetary policy shocks η_t: the structural relation between unemployment and inflation (the "Phillips multiplier") is recovered by regressing inflation on a measure of slack using these proxies as instruments.

4.1 Using cross-country variation for identification

McLeay and Tenreyro (2019) discuss the problem of uncovering the Phillips Curve when monetary policy is successful at undoing demand shocks and leans against supply shocks. One approach to overcoming this identification problem is to use data from euro area countries, since the idiosyncratic national shocks that are not undone by the common monetary policy will make identification possible.

Table 2: Identifying the Phillips Curve slope using cross-country variation: benchmark euro area equation

Variables	(1) Euro area	(2) Euro area	(3) Euro area
Lagged inflation	0.904	0.892	0.884
	(0.000)	(0.000)	(0.000)
Output gap	0.008		
	(0.000)		
Unemployment rate		-0.010	
		(0.000)	
Unemployment gap			-0.011
			(0.001)
Constant	0.033	0.134	0.042
	(0.011)	(0.000)	(0.004)
Observations	81	80	81
R^2	0.899	0.892	0.891

Estimation using HICP excluding food and energy (y-o-y) and output gap, unemployment gap or unemployment rate. Output gap and unemployment gap are based on estimates from the European Commission. Estimation uses robust standard errors; p-values in parentheses. The sample is from 1999Q1 to 2019Q2.

We ran panel regressions using quarterly data on HICP excluding energy and food (year-on-year growth rates) and three measures of economic slack: the output gap, the unemployment gap and the unemployment rate. Table 2 reports the results from a simple regression that uses euro area data only, while Table 4 shows those obtained running dynamic panel fixed effects regressions on data from 18 euro area countries.[23] The data are normalised to facilitate comparison with the results shown in Table 1.

The estimates of the slack coefficient are significant in all regressions, including those run only on euro area data. Across panel specifications, the slope estimates based on the output gap and unemployment gap are remarkably stable across the three specifications (pooled, country fixed effects and time fixed effects), while those based on the unemployment rate double and their significance increases further when using fixed effects.

All estimates are in the range of those from the structural NAWM II and the reduced-form model, even if the estimated indexation term is larger.[24] With the exception of the pooled specification that uses the unemployment rate, the estimated slack coefficients are larger in the panel than in the aggregate euro area data, which is consistent with endogeneity bias in the aggregate data.

Table 4: Identifying the Phillips Curve slope using cross-country variation

Variable	(1) Pooled	(2) Pooled	(3) Pooled	(4) FE	(5) FE	(6) FE	(7) FE + TE	(8) FE + TE	(9) FE + TE
Lag	0.868	0.903	0.878	0.854	0.865	0.862	0.861	0.865	0.865
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Y gap	0.013			0.015			0.014		
	(0.000)			(0.000)			(0.000)		
U rate		-0.005			-0.011			-0.010	
		(0.004)			(0.000)			(0.001)	
U gap			-0.014			-0.017			-0.014
			(0.008)			(0.004)			(0.004)
Constant	0.053	0.079	0.051	0.059	0.152	0.059	0.006	0.099	0.021
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.850)	(0.016)	(0.487)
Obs.	1,457	1,436	1,457	1,457	1,436	1,457	1,457	1,436	1,457
R^2	0.896	0.883	0.887	0.888	0.878	0.878	0.903	0.898	0.898
Country FE	NO	NO	NO	YES	YES	YES	YES	YES	YES
Time FE	NO	NO	NO	NO	NO	NO	YES	YES	YES
N	18	18	18	18	18	18	18	18	18

Dynamic panel estimation using HICP excluding food and energy (y-o-y) and output gap, unemployment gap or unemployment rate. Output gap and unemployment gap are based on estimates from the European Commission. Estimation uses robust standard errors clustered at the country level; p-values in parentheses. Sample: unbalanced panel, minimum starting date: 1999Q1. Last observation: 2019Q2.

[23] All countries in the euro area except for Slovakia due to limited data availability.

[24] This might reflect the unavailability of inflation expectations as a control in the panel regressions (see Table 1).

4.2 Using monetary policy shocks as external instruments

Another approach to the identification of the causal impact of slack on inflation uses the exogenous variation in slack caused by monetary policy shocks (Barnichon and Mesters, 2019). As argued in the previous section, a monetary policy shock (denoted by η_t) is a particular type of demand shock that moves the economy along the Phillips Curve. It follows that the evolution of slack and inflation conditional on a monetary policy shock can help us identify the causal relation. In this section, we first show the dynamic response of unemployment and inflation to an identified monetary policy shock in the euro area. Next we turn to our estimate of the Phillips multiplier proposed by Barnichon and Mesters (2019), which is a non-parametric estimate of the dynamic relation between cumulative unemployment and inflation conditional on a monetary policy shock.

We assess the dynamic impact of monetary policy shocks on inflation and unemployment using the local projection method proposed by Jordà (2005). The local projection framework puts minimal structure on the data generating process. We use changes in the 3-month-ahead overnight indexed swaps in a 30-minute window around ECB Governing Council press statements and press conferences as proxies for monetary policy shocks (Gertler and Karadi, 2015). So long as financial markets incorporate all available information into asset prices before the announcement, the change in the price is proportional to the size of the policy surprise. Furthermore, the narrow window is intended to ensure that no other economic shock systematically contaminates the measure. We restrict our attention to announcements where the interest rate surprise and the STOXX50 price index moved in the opposite direction over the same time frame. As argued by Jarociński and Karadi (forthcoming), such co-movement is indicative of a dominant monetary policy shock, when the impact of the central bank's contemporaneous announcements about the economic outlook played a minor role. We transform these surprises to monthly variables by simply summing up monetary policy surprises within each calendar month.

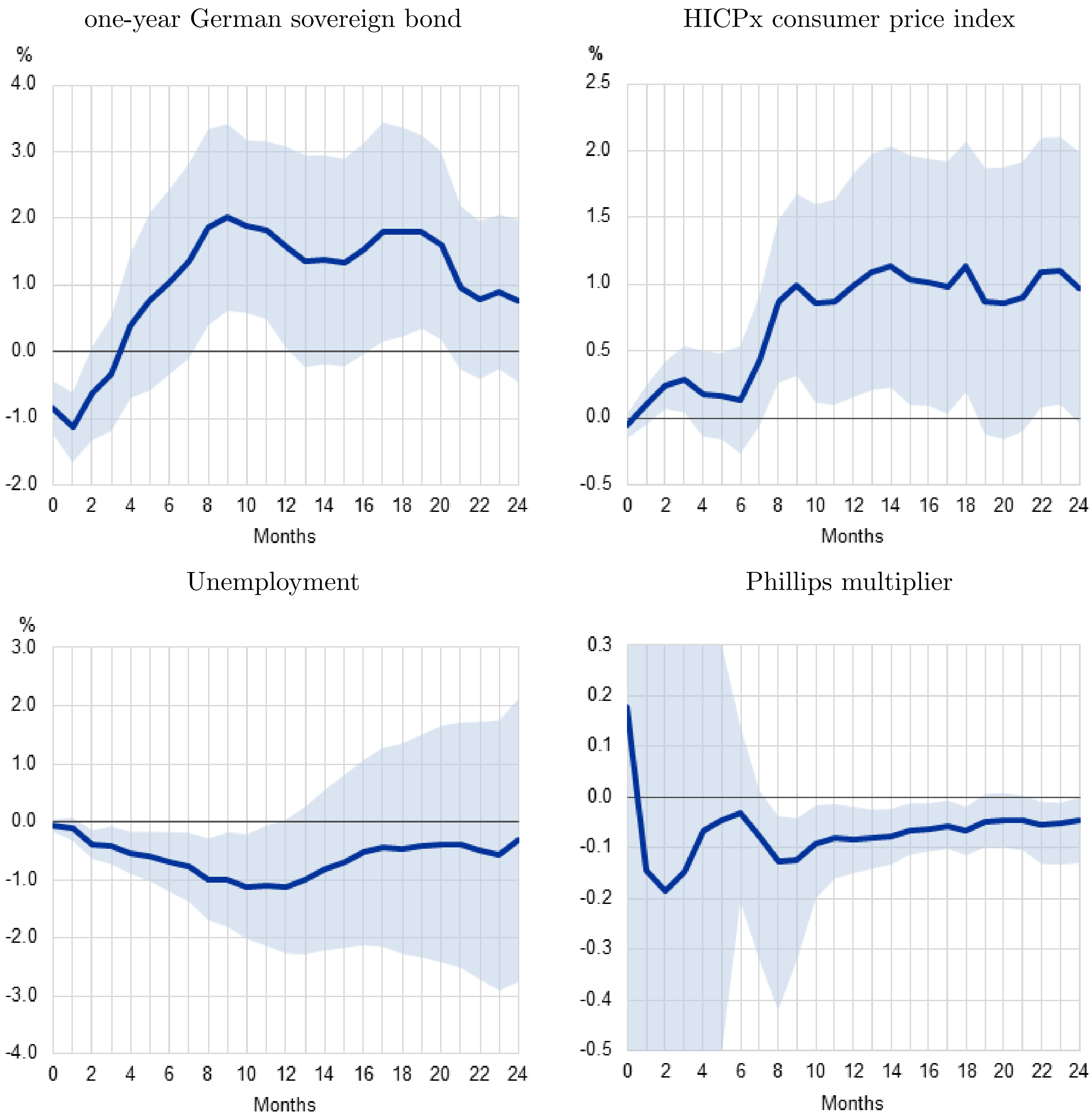
We run a series ($h = 0, \ldots, 24$ months) of regressions of the form:

$$x_{t+h} - x_t = \alpha_h + \beta_h \Delta i_t + \Gamma_h \Phi(L) X_t + u_{t,h}, \quad (5)$$

where x_t is the variable of interest and Δi_t is our proxy for a monetary policy shock. The local projections also include a set of controls $\Gamma_h \Phi(L) X_t$, where Γ_h is a vector of parameters for each h, X_t is a vector of control variables and $\Phi(L)$ is a lag polynomial. We use 12 lags of the one-year German sovereign bond yield, the (log) core HICP, and the (log) industrial production as controls.

The key object of interest is the coefficient β_h. In the first three panels of Figure 6 below, we plot β_h, $h = 0, 1, \ldots, 24$ along with 68 percent confidence bands.

Figure 6: Impulse responses of key macroeconomic variables to a monetary policy easing



Local-projection estimates (solid lines) of the dynamic impact of a surprise monetary policy easing on the one-year German sovereign yield, the core HICPx consumer price index, and the unemployment. The Phillips multiplier measures the dynamic causal impact of the cumulative unemployment on the cumulative inflation conditional on a monetary policy shock. Surprise monetary policy easing is measured as changes in the 3-month-ahead overnight indexed swaps in a 30-minute window around ECB Governing Council press statements and press conferences on days when interest rates and stock markets moved in opposite directions. The regressions include 12 lags of the one-year German sovereign bond yield, the (log) HICPx, and the (log) industrial production as controls. The figures report 68 percent confidence intervals (shaded area). Sample: 1999:01 to 2016:12.

Figure 6 plots the impulse response of some key macroeconomic variables to the monetary policy shock. In particular, we plot the response to the one-year German sovereign bond yield, the response to the logarithm of the harmonised index of consumer prices excluding food and energy and the response of the unemployment rate. Since monetary policy shocks do not influence the natural rate of unemployment, variation in unemployment equals the variation in the unemployment gap. A surprise monetary policy easing, which eases financial conditions, causes a hump-shaped temporary decline in unemployment and a delayed rise in consumer prices.

The results indicate a negative relation between the unemployment gap and HICPx inflation. Barnichon and Mesters (2019) suggested to measure the strength of this relation using the Phillips multiplier: it (κ_h) can be estimated from a series of regressions ($h = 0, 1, \ldots, H$) of the form

$$\sum_{i=0}^{h} \pi_{t+i} = \kappa_h \sum_{i=0}^{h} u_{t+i} + \Gamma_h \Phi(L) X_t + e_{t,h}, \tag{6}$$

where the cumulative unemployment ($\sum_{i=0}^{h} u_{t+i}$) is instrumented by a proxy of the monetary policy shock. As our monetary policy shock does not reject the hypothesis of weak instruments, we use Anderson-Rubin confidence sets and plot 68 percent bands. At horizons between 6 and 18 months the Phillips multiplier is estimated to be negative, in line with theory, with a coefficient between -0.05 and -0.1.[25]

5 Reduced-form evidence

As discussed in Section 3, the reduced-form view of the Phillips Curve concentrates on the empirical relation between measures of slack and inflation and has been the subject of intense policy debate in recent years (Gordon, 2013; Blanchard, 2016; Coibion et al., 2019). For the reasons highlighted above, reduced-form regressions cannot be expected to recover the structural relation between slack and inflation and so cannot be used to confirm or reject the existence of the structural Phillips Curve in the euro area. Nonetheless, such regressions are informative: whatever the underlying structural relation, the policymaker is also interested in whether measures of economic slack have predictive power for inflation. For this reason, reduced-form models are also part of the toolbox of central banks.

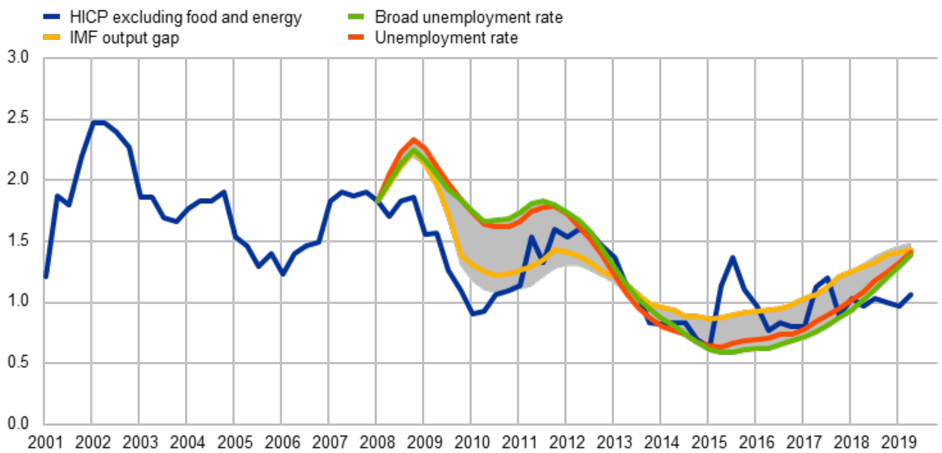
5.1 A simple exercise

In order to evaluate the predictive power of slack for inflation we first carry out a simple exercise in the spirit of Giannone et al. (2014). We estimate a series of simple bivariate Bayesian Vector Autoregressions (BVARs), each containing HICPx inflation and one measure of real activity

[25]The Phillips multiplier is not well defined and estimated with wide confidence bands at short horizons.

over the pre-crisis sample 2000q1-2007q4. Next, we perform conditional forecasts over the period 2008Q1-2019Q2. Figure 7 displays the actual path of HICPx (blue line) and the median forecast of HICPx inflation conditional on the latest vintage of the output gap estimated by the IMF (yellow line), the unemployment rate (red line) and the ECB's broad measure of unemployment (green line).[26] Despite some overshooting slack measures provide a reasonable conditional forecast of the HIPCx measure. Nevertheless, it is not surprising that such a simple model is not able to fully capture the dynamics of inflation and other variables need to be included to explain the dynamics of inflation better, as we explore in the next sections.

Figure 7: Conditional forecasts for two alternative indicators of economic conditions.



The range is obtained using alternative indicators of slack: unemployment rate, unemployment gap (the difference between unemployment and NAIRU), broad unemployment rate (U6), output gaps estimated by the OECD, IMF and European Commission. The sample is from 2001Q1 to 2019Q2 for HICP excluding food and energy and 2008Q1 to 20019Q2 for the rest. Data from Eurostat, IMF, OECD, European Commission.

5.2 Measuring slack

In investigating the predictive power of slack for inflation, the first challenge is that many measures of slack are not directly observable and their appropriate measurement is uncertain. Further specification issues arise in terms of the list of control variables to include, such as measures of inflation expectations and global factors, as detailed by Forbes (2019).[27] Section 5.3 addresses some of these specification issues by employing two variants of a "thick modelling"

[26] Although we present the results using only three measures of slack, we obtain similar results when estimating conditional forecasts using the output gaps estimated by the OECD and the European Commission and the unemployment gap (the difference between unemployment and NAIRU). The shaded area in Figure 7 indicates the range of results using all the slack measures.

[27] Bobeica and Sokol (2019) discuss in greater detail the main specification choices in this context.

approach: that is, combining the results of many models, each using different combinations of explanatory variables, rather than picking one single specification.[28]

The choice of the slack measure warrants some further discussion. "Gap" measures, based on some notion of equilibrium unemployment or potential output, are subject to both conceptual and empirical issues: these range from the appropriate definition of equilibrium to well-known problems with statistical filtering techniques, to timely data availability and subsequent data revisions (for a short overview, see Szörfi and Tóth (2018)). A recent innovation in this field is offered by Jarociński and Lenza (2018), who exploit the Phillips Curve relation in order to develop measures of the euro area output gap explicitly required to have predictive power for inflation. These authors find that, to achieve the best prediction of inflation, their model indicates a much larger degree of slack in the more recent period (see Figure 8).[29]

For all labour-market-based measures, one issue is the representativeness of standard unemployment measures, especially during protracted periods of low growth. For example, Ball and Mazumder (2019a) suggest that short-term unemployment has a stronger impact on wage growth.[30] Moreover, there is also evidence that the quality of jobs created could also be an issue. In fact, when using broader measures of labour market slack (which include the unemployed, underemployed and those marginally attached to the labour force), the Phillips Curve models appear to be more successful in predicting inflation (Cœuré, 2017). Finally, broader developments, including globalisation, could all play an important role (on the latter, see Borio and Filardo, 2007; Auer et al., 2017; ECB, 2017; Forbes, 2019).

5.3 Thick modelling and dynamic model averaging

Once we add more determinants to a naive Phillips Curve regression we are faced with the choice of which additional factors to include and which measure to choose for each factor. We do this in two ways: by constructing thick modelling sets and by using Bayesian dynamic model averaging (DMA). Thick modelling, as articulated by Granger and Jeon (2004), aims at keeping many alternative specifications instead of choosing the best one according to an in- or out-of sample prediction criterion. The specifications can then be pooled using weights that can be simply equal to $1/N$, where N is the number of models, or where the weights are optimised according to some prediction error criterion.

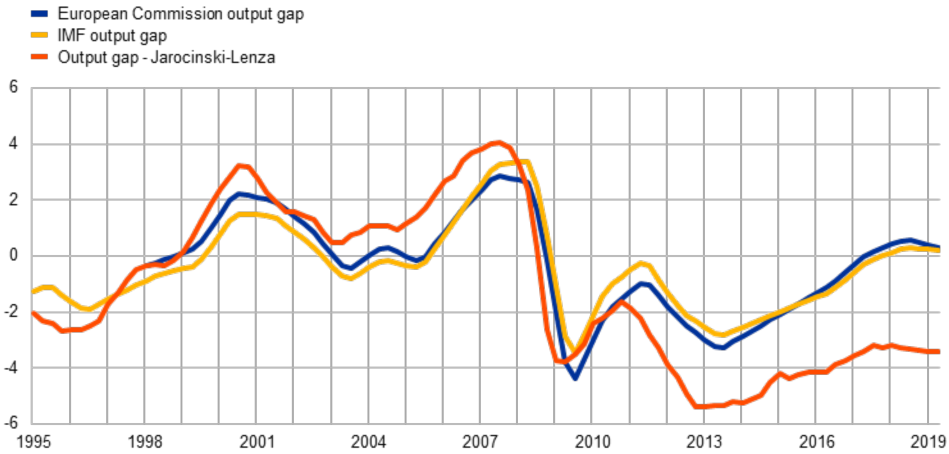
In the first exercise we limit ourselves to showing the range of median parameter estimates across models. In the case of Bayesian DMA the weights on each model (which are based on

[28]The concept was articulated by Granger and Jeon (2004), who also discussed previous empirical applications to the Phillips Curve by Stock and Watson (1999).

[29]By contrast, for the United States Del Negro et al. (2020) find less a role for "hidden slack" and point to a flattening of the Phillips Curve.

[30]However, Kiley (2015) found no significant difference between the impact of short- and long-term unemployment.

Figure 8: Comparison of official and alternative slack measures



Data from Eurostat, European Commission, IMF, and calculations based on Jarociński and Lenza (2018). The IMF and the EC output gap are depicted based on quarterly linear interpolation on annual data. The sample is from 1995Q1 to 2019Q2.

the posterior predictive distribution) are allowed to change over the sample. Each approach has advantages: looking at the whole "thick" set gives a visual indication of the model uncertainty, while dynamic model averaging gives an idea of the time variation in the predictive content of the various drivers of inflation. Both approaches to thick modelling are non-structural: these provide empirical evidence about conditional correlations and can be used for conditional forecasting.[31] Moreover, these approaches provide robustness against measurement uncertainty. A reduced-form version of equation (1) can be estimated for the euro area taking into account the uncertainty about how to measure economic slack, inflation expectations and other relevant drivers of inflation.[32] For instance, in order to take into account an external source of cost-push shocks, import prices or commodity prices can also be added to the specification. The range of coefficient estimates from all models can be used to assess the strength of the empirical relation between slack and inflation, to gauge whether some forms of naive Phillips Curve can explain past inflation developments, or to produce conditional projections.

The starting point in this exercise is an econometric specification of the form:

$$\pi_t = \mu + \rho\pi_{t-1} + \kappa\tilde{y}_{t-1} + \beta E_t(\pi_{t+h}) + \theta\Delta p_t^{foreign} + \varepsilon_t, \tag{7}$$

where iterating over all alternative measures of slack, expectations at many horizons from various sources (surveys, markets) and foreign prices yields a set of estimates for μ, ρ, κ, β and δ. The specifications iterate across the following twelve measures of slack: (1) model-based output gap

[31] See Dotsey et al. (2011) and Ciccarelli and Osbat (2017) for a discussion of how well a Phillips Curve can conditionally predict inflation.

[32] See Mavroeidis et al. (2014), Abbas et al. (2016) or Bobeica and Sokol (2019) for an overview of the specification choices for empirical New Keynesian Phillips Curves.

estimate; (2) IMF output gap; (3) European Commission output gap; (4) OECD output gap; (5) unemployment rate; (6) model-based estimate of the unemployment gap; (7) IMF unemployment gap; (8) European Commission unemployment gap; (9) OECD unemployment gap; (10) short-term unemployment rate; (11) U6 unemployment measure; (12) Jarociński and Lenza (2018) output gap.[33] We combine these with nine measures of inflation expectations based on surveys (at 1 to 6 quarters ahead from Consensus Economics and at 1, 2 and 5 years ahead from the SPF) plus 4 market-based ones (1y1y, 1y2y, 5y5y and 5y10y inflation linked swaps), and five measures of external prices.[34]

The rationale for looking at all available measures of inflation expectations is provided by Meyler and Grothe (2015), who find that both types of expectations are useful in forecasting euro area inflation. This is one reason why the ECB routinely monitors a broad range of inflation expectations, as recently emphasised by Cœuré (2019).

At the same time, we have to account for the fact that inflation expectations reflect a wide set of information relevant to inflation and exhibit significant covariation with current and past inflation, especially at shorter horizons.[35] To separate the backward-looking part of inflation expectations from the purely forward-looking part, we perform an auxiliary regression of the fourteen measures of expectations on a constant and lagged annual headline HICP inflation. The result confirms that short-term inflation expectations are highly influenced by past inflation, while longer-term expectations are quite stable (see Figure 9). To filter out the dependence on past inflation we rely on the residuals from these auxiliary regressions.

For indicators of market-based inflation expectations we also take into account the fact that these include a "genuine" inflation expectations component and risk premia, where we rely on the methodology of Joslin et al. (2011).

Starting with the reduced-form estimates of the slope of the Phillips Curve, the median estimate across 780 specifications for the coefficient on slack lies in the range of 0.09 to 0.24. The largest slope coefficient is estimated using the Jarociński and Lenza (2018) measure for slack, which signals a relatively high degree of slack.[36] This is to be expected, since that measure is constructed to maximise inflation prediction performance.

The battery of thick models allows us to assess the contribution of slack and expectations to inflation in the euro area in the past few years. Figure 11 shows the average contributions

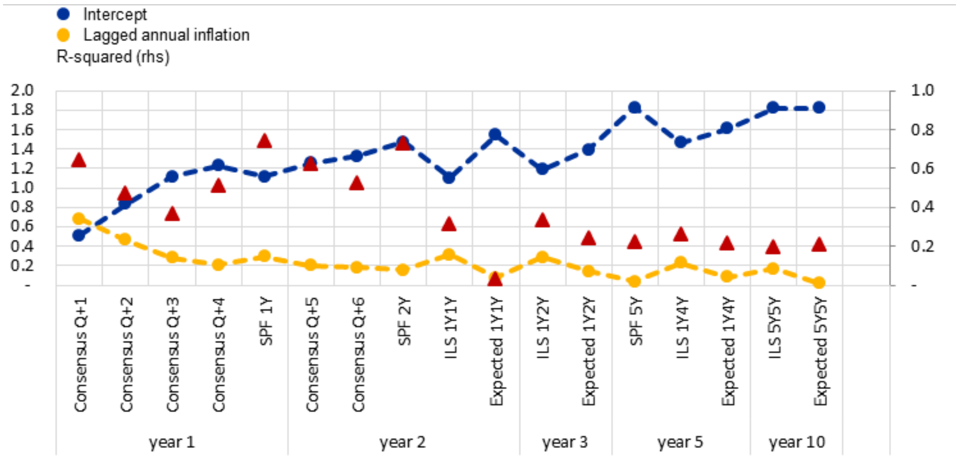
[33] The slack variable is introduced with a lag rather than contemporaneously to allow for a delayed effect on inflation.

[34] The external price measures are extra-EA import prices (quarter-on-quarter changes), the oil price in euro (quarter-on-quarter changes), a 4-quarter moving average of the oil price in euro, global quarterly headline and core consumer price inflation.

[35] For instance, Coibion and Gorodnichenko (2015) document an increased sensitivity of inflation expectations to oil price news. As a result, the additional information content of inflation expectations over and above data related to oil prices can be limited.

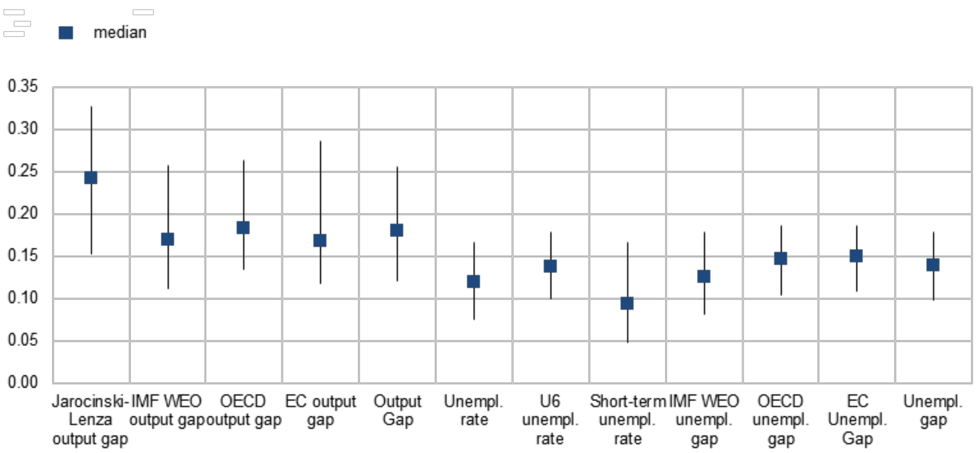
[36] For comparability we standardise the slack measures, as described in the notes to Figure 10.

Figure 9: Estimates of intercept and lagged HICP inflation in expectations equation



For market-based measures we use both the data as they are and the expectations part, filtering out risk premia. The sample is from 1999Q1 to 2019Q2 for specifications that include survey measures of expectations, and 2005Q2 to 2019Q2 for specifications that include market-based measures.

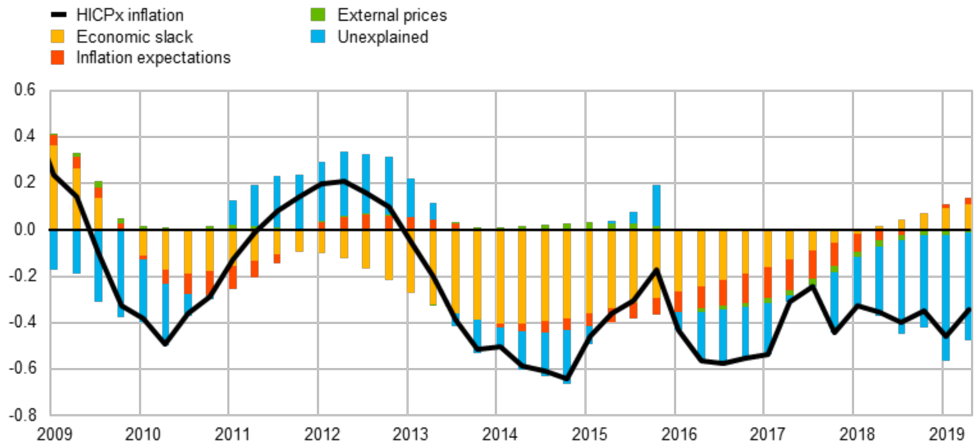
Figure 10: Estimated Phillips Curve slope across all specifications



The coefficients for unemployment rates/gaps have been inverted. The measures of slack have been standardised prior to estimation for comparability. The vertical bars show the range of coefficients across all specifications including a particular measure of economic slack. The sample is from 1999Q1 to 2019Q2 for specifications that include survey measures of expectations, and 2005Q2 to 2019Q2 for specifications that include market-based measures. Data from European Commission, Eurostat, IMF, OECD.

to HICPx of slack, expectations and external prices across all 780 specifications, relative to their historical averages.[37] Broadly speaking, one can distinguish three phases. The first half of the picture is dominated by the global financial crisis and its immediate aftermath, with HICPx first somewhat lower, then later higher, than could be accounted for by the explanatory variables included. Second, over the 2013-2017 period, the evolution of HICPx inflation is largely accounted for by a large, albeit declining, contribution from slack, and as this started to dissipate a drag from inflation expectations. Third, from late 2017 onwards the thick modelling framework struggles to account for the persistent weakness of HICPx inflation, since the drag from inflation expectations and slack progressively turns positive but large negative residuals emerge.[38] In looking at the contribution of inflation expectations in this decomposition it is important to keep in mind two issues: first, our measure for inflation expectations is the purely forward-looking component of expectations that is orthogonal to lagged (headline) inflation; and, second, the chart shows contributions in deviation from their historical mean.

Figure 11: Thick modelling: Phillips Curve-based decomposition of HICPx inflation



Average of contributions across 780 specifications. The sample is from 1999Q1 to 2019Q2 for specifications that include survey measures of expectations, 2005Q2 to 2019Q2 for specifications that include market-based measures. All series are in deviation from their sample averages.

As a complement to thick modelling and to address the fact that the importance of different types of shocks changes over time, we also apply a dynamic model averaging approach. DMA allows us to remain agnostic about the specification but to attach a weight to each model that depends on its predictive power. This is done dynamically over time, allowing the posterior estimates and inclusion probabilities of the coefficients to change as the sample increases. This makes it possible to uncover the relative importance of different regressors over time.

Following Moretti et al. (2019), we estimate a battery of 810 reduced-form Phillips Curve models, which include a measure of slack and a permutation of at most one variable taken from

[37] This an updated version of the figure discussed in Bobeica and Sokol (2019).

[38] Some studies put forward explanations based on combinations of "hidden slack" and a steeper Phillips Curve slope in the euro area (Cordemans and Wauters, 2018; Stevens and Wauters, 2018).

the inflation expectations, external factors and labour market indicators group.[39] The results, reported in appendix B, confirm the analysis using thick modelling and provide further information on the relative importance over time of the different groups of variables for predicting inflation.

5.4 Explaining the residuals

The Phillips Curve based decomposition of HICP inflation presented in Figure 11 points to a considerable contribution from unexplained factors since 2017. We consider three potential explanations for the residuals: (i) non-linearities; (ii) the missing pass-through from wage to price inflation; and (iii) the role of external factors.

5.4.1 Non-linearities

The empirical approaches presented so far assume that the Phillips Curve is linear. In principle a number of factors can give rise to non-linear effects. For example, the strength of the relation between slack and the inflation gap can vary with the state of the economy (boom versus recession), as well as with the magnitude of the slack (in a mild downturn versus in a severe recession).

A prominent factor that may generate non-linearity in the wage Phillips curve is the downward rigidity of nominal wages (Tobin, 1972; Daly and Hobijn, 2014). The pervasiveness of rigid wages is likely to have contributed to the missing wage and price deflation during the recent recessions in both the United States and the euro area. The "pent-up" wage deflation, in turn, led to a delay in the pick-up of wage growth during the early stages of the recovery. For wages to increase, the labour market needs to be sufficiently hot. This is partly because a prolonged downturn discourages workers, and attracting them back to the market demands extra effort. Furthermore, firms need sufficient assurances of a robust recovery to start raising wages if they know that there are constraints of future wage cuts.

Empirically, there is evidence from the euro area supporting non-linearities in the wage Phillips Curve, with a stronger impact of slack on wage inflation once the labour market becomes sufficiently hot (Byrne and Zekaite, 2020). This finding is in line with evidence from the Unites States, where Leduc and Wilson (2018) identify non-linearities based on the cross-geographical wage Phillips Curve. Babb and Detmeister (2017) also find in the US metropolitan area data

[39] The measures of slack include the output gap estimated by the OECD, the IMF and the European Commission; the unemployment rate, the unemployment gap (the difference between unemployment rate and NAIRU) and a measure of broader unemployment. The inflation expectations group includes both survey measures (Consensus forecast 4 and 6 quarters ahead; SPF 1 year, 2 years and 5 years ahead) and the genuine inflation expectations component of market-based measures of expectations (1 year-in-1 year, 1 year-in-2 years and 5 years-in-5 years inflation linked swaps).

that the impact of unemployment on inflation is twice as large when it is low than when it is large.

In relation to price inflation, the case for non-linearities is less clear cut. In terms of the structural price Phillips Curve, non-linearities can arise if the share of prices that is adjusted in a given period is state-dependent rather than constant, as in the simple case we have considered above. However, the sign of the non-linearity is ambiguous: on the one side, when the inflation rate is persistently below target, as it tends to be true in recessions, the share of price adjustments can decline, as price dispersion is lower (Costain et al., 2019). This implies a flatter Phillips Curve. On the other side, higher volatility of firm-level fluctuations, which also characterise recessions, should raise the share of price changes (Vavra, 2013). This channel should make the aggregate price level more flexible in recessions and the Phillips Curve steeper.[40]

It therefore comes as no surprise that the empirical evidence on non-linearities in the price Phillips Curve for the euro area is mixed. Gross and Semmler (2019) find some evidence of non-linearity, with firms more likely to raise prices in response to a boost in aggregate demand if facing capacity constraints than if there is spare capacity. However, in recent work Moretti et al. (2019) do not find that non-linearity terms in the Phillips Curve help in forecasting euro area inflation. Looking more broadly, the cross-country panel evidence suggests that the relation between slack and price inflation is steeper if an economy is operating above potential (Forbes et al. (2020)). Ultimately, the search for non-linearity in the price Phillips Curve may suffer from the same identification problem as discussed above: it is difficult to identify the underlying structural relation from the reduced-form evidence.

Another type of non-linearity relates to the distribution of prices across different types of good. In this vein, Ball and Mazumder (2019a) and Ball and Mazumder (2019b) argue that the Phillips Curve holds for the weighted median of inflation measures – but not for the mean. That said, the euro area thick modelling exercises along the lines we present above yield similar results for inflation measures based on the median as for the mean.

Overall, the finding that the evidence of non-linearities is stronger for the wage Phillips Curve than for the price Phillips Curve for the euro area is in line with the analogous finding by Babb and Detmeister (2017) for the United States.

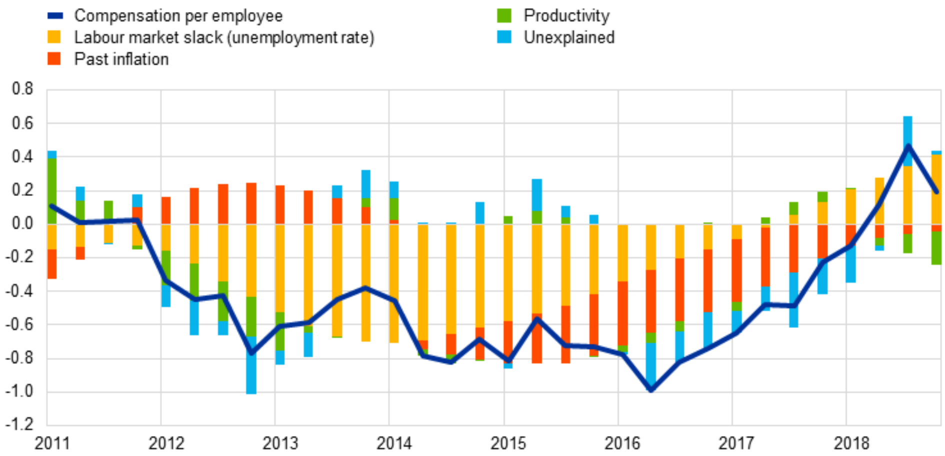
5.4.2 The missing pass-through of wage growth to inflation

In the initial phase of the recovery, the hypothesis of "pent-up" wage deflation was prominent both in the United States and in the euro area to explain why wage growth was not picking up at a faster pace. However, wage inflation has picked up in recent years, in line with a robust

[40] Alternative channels that can induce non-linearity to the Phillips Curve include state-dependent elasticity of demand (Kaplan and Menzio, 2016; Lind and Trabandt, 2019; Stroebel and Vavra, 2019).

Phillips Curve relation for wages.[41] Nickel et al. (2019) consider the wage inflation in the euro area and find that a standard wage Phillips Curve shows smaller residuals than the price Phillips Curve. In fact, residuals in a simple specification that uses the unemployment rate as measure of labour market slack all but disappeared in 2018 (see Figure 12).

Figure 12: Decomposition of wage growth into its main drivers in the euro area



Contributions are derived as in Yellen (2015). The sample is from 2000Q1 to 2018Q4.

Whereas wage growth started to pick up in line with the recovery, the recovery in HICP inflation and in particular core inflation (measured by HICPx, which excludes food and energy) has been more muted (see Figure 3).

In principle, labour costs are a fundamental source of cost-push inflation. In particular, wage increases in excess of productivity gains would be expected to put pressure on inflation (especially the more "domestic" HICPx inflation). At the same time, an improvement in demand conditions in the economy could directly boost pricing power, with wage inflation even lagging price inflation (especially given the stickiness in wage dynamics).

Indeed, empirical results on the dynamic correlation of wage growth and inflation are often mixed. For instance, Gordon (1988) concluded that wage inflation does not cause price inflation, while Zanetti (2007) found that CPI inflation always causes wage inflation, with the reverse only true in sub-samples; in particular, this author finds that wage inflation does not pass through when price inflation is low and stable. Peneva and Rudd (2017) found little evidence that changes in labour costs over and above those in line with labour market slack had a relevant impact on inflation in recent years.

Recent work by ECB staff has deepened the analysis of the hypothesis that wage-price "pass-through" is state-dependent. These studies find that the impact of wage inflation on price inflation depends on the source of the shocks driving the economy at each point of time: wage

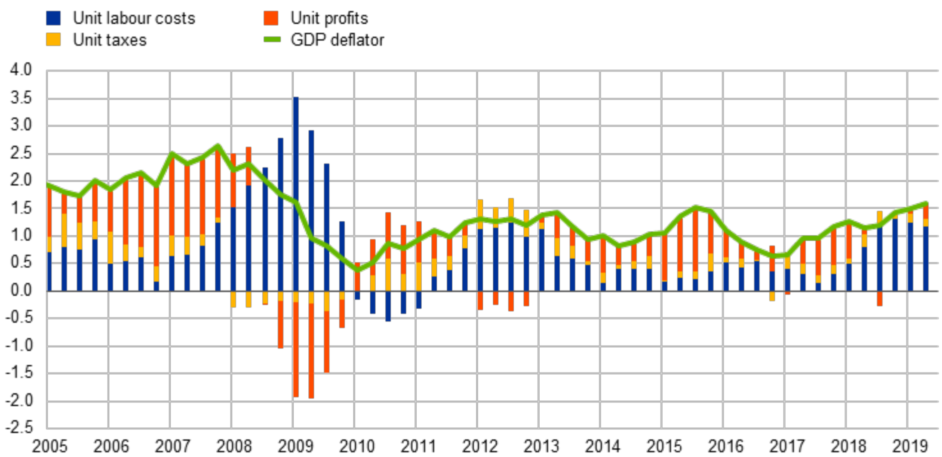
[41] Yellen (2015), for example, elaborated on this point.

increases pass through to inflation faster and to a larger extent following a demand shock than a supply shock (Gumiel and Hahn, 2018; Bobeica et al., 2019; Hahn, forthcoming).[42] Conti and Nobili (2019) also find that the pass-through of wages to prices depends on the nature of the shock hitting the economy. They also suggest that the positive contributions stemming from monetary policy and wage mark-up shocks were partially counterbalanced by downward pressures on consumer prices exerted by aggregate supply shocks.

One factor contributing to the missing pass-through from wages to prices lies in the compression of the profit margins of firms. Profits are not only an integral part of the transmission mechanism of economic conditions to prices, but also constitute the empirical counterpart to mark-ups in the structural models discussed above - even if firm profits are endogenous to the state of the economy rather than driven by exogenous mark-up shocks.

On aggregate, the profit share has been on an upward trend since the 1980s, before declining during the crisis and then stabilising at levels that were relatively high but lower than before the crisis. When wage and unit labour cost growth picked up strongly from mid-2017 onwards, the growth in firm profit margins compressed further, as is shown in Figure 13. At least in an accounting sense, the reduced profit margins restrained the increase in domestic price pressures. In turn, the observed compression in firm profits may relate to external factors, the structure of global goods markets and their implications for domestic pricing, as explored further in the following section.

Figure 13: GDP deflator: annual growth and contributions



Sample: Q1 2014 to Q2 2019.

[42]Another source of state dependence is linked to the concept of wage gap explained in appendix A: if the wage gap is negative then the adjustment mechanism will tend to drive wage and price inflation in different directions. Empirically, this idea is challenging to test, however, since the "natural" wage level is not observable.

5.4.3 The role of external factors

The first external factor that we consider is import prices. In the micro-founded structural model discussed above, the consumer price inflation also depends on the exchange rate and the evolution of import prices, including the oil price, while the underlying structural behaviour of the economy is also affected by substitutability between home and foreign goods and the possibility of international financial trade.

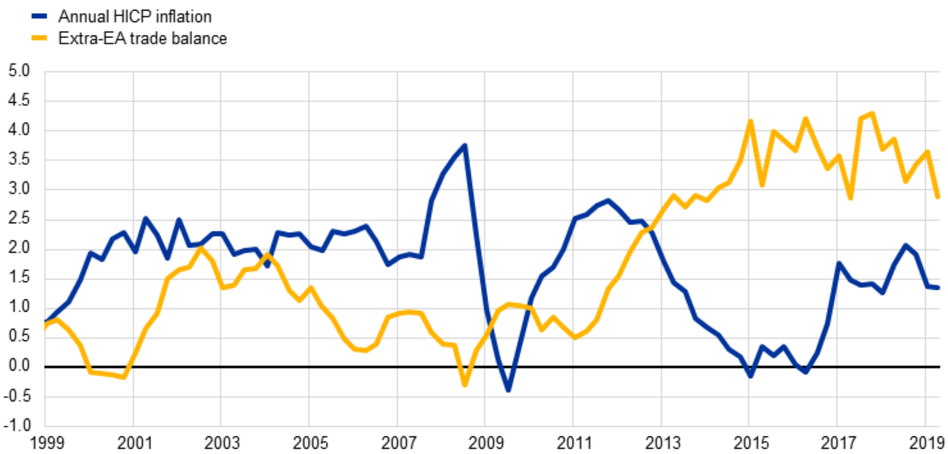
While the thick modelling described above focuses on different indicators of domestic slack and inflation expectations, each regression also includes an indicator of external inflationary pressure: extra-euro area import prices; the oil price; or the exchange rate. It follows that the substantial residuals that obtain despite the inclusion of import prices suggest that factors beyond these play a role.

Second, a role for global slack in the Phillips Curve can also be framed in terms of increased contestability of markets, especially labour markets. According to this line of argument, as the labour force of emerging market economies such as China and other large emerging markets became available to firms via global supply chain integration, wage pressure in advanced economies was contained and with it inflationary pressure. In this setting global slack is viewed as a supply factor, entering the domestic marginal cost over and above import prices. Empirically, Borio and Filardo (2007) found support for this mechanism, estimating a significant impact of global slack on inflation in a cross-section of advanced economies. Auer et al. (2017) argue that increasing global value chain integration is an important channel for the transmission of global slack on domestic inflation. The evidence on global slack remains mixed, however. For example, considering a sample of advanced economies Mikolajun and Lodge (2016) conclude that foreign slack has no significant impact in a Phillips Curve framework, which is also confirmed by Nickel (2017). Forbes (2019) emphasises that the most visible impact of globalisation on inflation is through the global factors determining commodity prices.

Third, there is some suggestive evidence that there could be a link between the trade balance and domestic price pressures. In the medium-scale ECB models the relation between the external economic environment and domestic inflation is modelled more realistically by assuming market power and sticky price setting in import (as well as export) markets. This generates a role not only for import prices but also for the trade balance. For instance, the forward-looking setting of import prices implies that future expected appreciation of the currency can have a negative impact on current import-price inflation by reducing the expected future marginal cost of foreign firms in domestic currency. A large surplus in the trade balance and the current account can generate such expectations about future exchange rate appreciation, with the corollary that the current trade balance (more precisely its gap from its flexible-price counterpart) can appear as a relevant open-economy slack measure in the import-price Phillips Curves, which can keep import-price inflation subdued (Ferrero et al., 2007).

Similarly, a direct role for the trade balance over and above that on marginal cost is also identified by Corsetti et al. (2010), as a result of various open-economy rigidities such as local currency pricing and incomplete international financial markets that affect the open-economy Phillips Curve. Empirically, however, it is difficult to bring such models directly to the data in a reduced-form setting, since these rely on unobservable concepts such as efficient relative demand and equilibrium exchange rates. However, such mechanisms could explain why the trade surplus of the euro area is correlated with inflation (see Figure 14). Historically, inflation stabilisation by monetary policy may have obscured this relation, but it may be more visible during phases when inflation deviates from the target level for an extended period, due to the constraints on monetary policy in the neighbourhood of the effective lower bound.

Figure 14: Inflation and the trade balance in the euro area



HICP inflation, annual growth rate; extra-EA trade balance from BoP statistics and GDP from national accounts, both seasonally adjusted. Data from Eurostat.

Using a simple empirical approach, Galstyan (2019) includes in a Phillips Curve for the euro area the current account or trade balance as a measure of relative demand imbalance and finds a significant correlation between the trade balance and inflation also after accounting for the unemployment rate, inflation expectations, productivity growth and import prices.

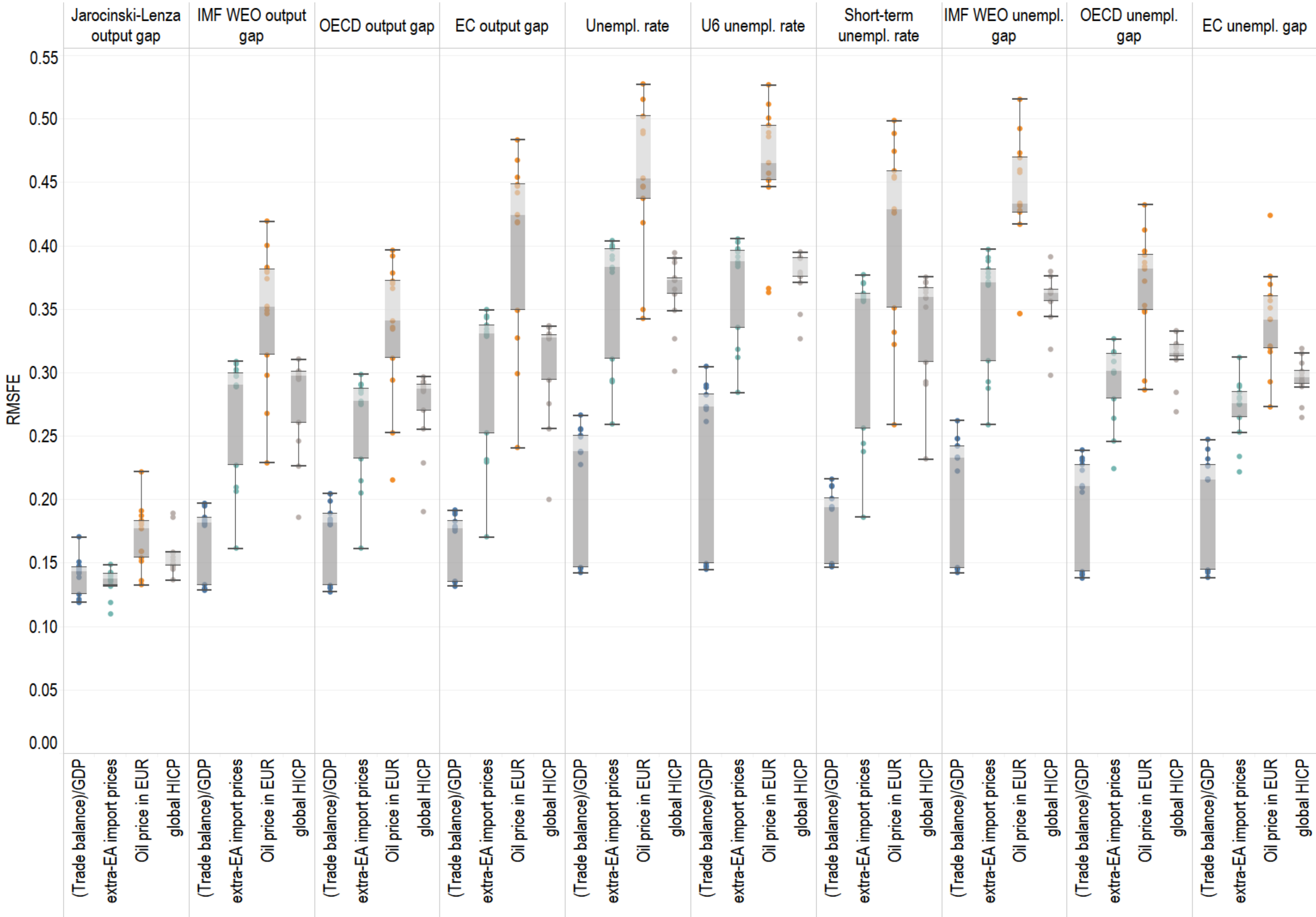
We obtain further tentative evidence on the role of the trade balance for domestic inflation by revisiting the thick modelling analysis presented in Section 5. To this end, we add the extra-EA trade balance as a ratio to GDP as an indicator of external price pressure. We then consider the root mean squared forecast error (RMSFE) that we obtain by estimating each of the 780 models that only include external prices and the 156 models that include the extra-EA trade balance up to Q4 2017 and then making conditional forecasts up to Q2 2019 based on the realised values of the regressors. This yields two observations that offer support for the hypothesis that the trade balance contains independent information about domestic inflation.

The first observation, based on Figure 15, is that the RMSFE from models that use the Jarociński and Lenza (2018) slack measure are systematically lower – and less dispersed across specifications – than that of any other model. In particular, it is notable that this factor model information set contains imports and exports, along with domestic variables such as other components of GDP, the unemployment rate, consumer confidence, capacity utilisation and inflation expectations. This tentative reduced-form evidence is consistent with the possibility that indicators of the trade balance can help to predict inflation.

The second observation from Figure 15 is that for most other indicators of slack the specifications that use the trade balance result in a substantially lower RMSFE over 2018 and 2019. This suggests that including the trade balance in the thick modelling goes some way in explaining the large residuals since 2018.

Overall, while we identify some evidence in favour of a role for the trade balance in lower-frequency inflation dynamics, this evidence remains tentative and further investigation of this link remains warranted, both theoretically and empirically.

Figure 15: Thick modelling: root mean squared forecast error over 2018-19



The figure shows the root mean squared forecast errors for a representative subset of the models discussed in section 5.3 Estimation sample: 1999Q1 to 2017Q4 for specifications that include survey measures of expectations, 2005Q2 to 2017Q4 for specifications that include market-based measures. TB stands for trade balance.More details on the variables is provided above, see equation 7.

6 Conclusion

Our goal in this paper has been to explain the role of the Phillips Curve at the ECB for the analysis of the economic outlook and the formulation of monetary policy.

The structural Phillips Curve, describing a causal relation between economy-wide slack and inflation, is a key element in our thinking about the transmission of monetary policy. Slack, which monetary policy can influence by changing financial conditions and thereby affecting consumption and investment, drives marginal costs (including wages) and transmits to inflation via the price-setting decisions of firms. Structural factors can generate headwinds that drive inflation away from the target for a long time, but not permanently. In the steady state (if policy is unconstrained), inflation is determined by the policy target. Crucially, the structural relation between slack and inflation is dependent on expectations about future inflation: if expected future inflation is low, the impact of slack on wages and prices is attenuated. In addition, the relation can be time-varying and the reduced-form relation between slack and inflation depends on structural factors as well as the monetary policy response, which is necessarily less sharp in the neighbourhood of the effective lower bound. At the same time, further research is warranted on the drivers of the mark-ups that firms charge over their costs and the factors that give firms the confidence to raise their prices.

Overall, we consider the Phillips Curve framework to be a helpful way to understand the transmission of ECB monetary policy in recent years: the measures undertaken since the summer of 2014 have underpinned a sustained expansion and a substantial reduction in unemployment. In turn, the re-absorption of slack has been associated with a substantial positive shift in indicators of underlying inflation and in the distribution of inflation expectations from their previous historical lows. Looking to the future, further progress in raising inflation towards our aim can only be achieved by ensuring slack is sufficiently low and inflation expectations are sufficiently anchored.

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A New Keynesian wage Phillips Curve

The standard New Keynesian Phillips Curve expresses economy-wide slack in terms of the output gap. In more realistic models (including the medium-scale structural models at the ECB) that incorporate wage rigidities as well as price rigidities, one can express slack in terms of the unemployment gap: the difference between observed unemployment and its natural rate (Galí (2011)). In these models, the market power of unions raises wages above the marginal rate of substitution between consumption and employment, which determines labour supply. Therefore, labour supply exceeds labour demand. If wages were flexible, this would result in unemployment at its natural rate. Similarly to the natural rate of output, this rate is not constant, but varies around a long-term steady state value in line with fluctuations in the desired wage mark-up. Under sluggish wage adjustment, unemployment deviates from its natural rate, and it can be expressed as a linear combination of two terms: the output gap and the real wage gap. The latter is the difference between the real wage and its flexible price counterpart. In this model, therefore, the $\kappa\tilde{y}_t$ forcing variable in the benchmark Phillips Curve is replaced by $-\kappa_1\hat{u}_t + \kappa_2\tilde{\omega}_t$, where κ_1, κ_2 are positive parameters.

Wage stickiness also generates a wage Phillips Curve, which takes the form

$$\hat{\pi}_t^w - \gamma_w \hat{\pi}_{t-1} = \kappa_w \hat{u}_t + \beta E_t \left\{ \hat{\pi}_{t+1}^w - \gamma_w \hat{\pi}_t \right\} + \varphi_t^w, \tag{8}$$

where $\hat{\pi}_t^w$ is the deviation of wage inflation from its steady-state value, γ_w, κ_w are positive parameters and φ_t^w are wage mark-up shocks. Wages are partially indexed to past inflation. The slack is not unidimensional any more, because not only prices but also wages are sticky. Part of the real wage adjustment is achieved through inflation (changing the denominator of the real wage), therefore a below natural real wage exerts a negative impact on inflation over and above the impact of the unemployment rate. Postponed wage increases in the past, through this term, can contribute simultaneously to positive wage pressure as well as negative price pressure.

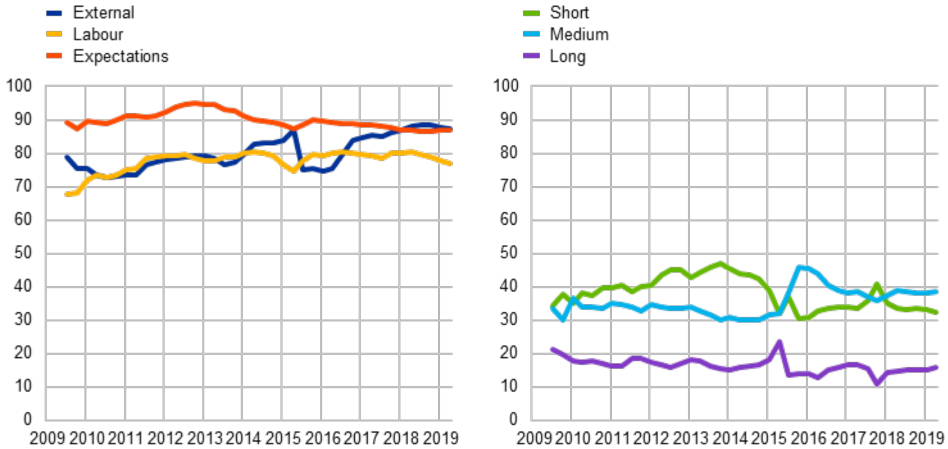
B Results of the DMA analysis

DMA allows us to assess the role of each group of variables used in the estimation of the Phillips Curve. Figure 16 shows the relative importance over time of inflation expectations (red line), external factors (blue line) and domestic factors (proxied by labour market indicators, yellow line). While external variables are important over the sample, their weight starts increasing after 2016. More importantly, the inclusion probability of inflation expectations is 90 percent or higher in (almost) the entire sample. To analyse further the role of inflation expectations, Figure 16 highlights the importance of short-term measures of inflation expectations, with a recent increase in the importance of medium-term expectations.

The DMA analysis can provide a decomposition into the factors driving inflation in similar manner as we show above for the thick-modelling approach. Figure 17 presents the contribution of the different groups of variables to the dynamics of HICPx, using optimal model weights.

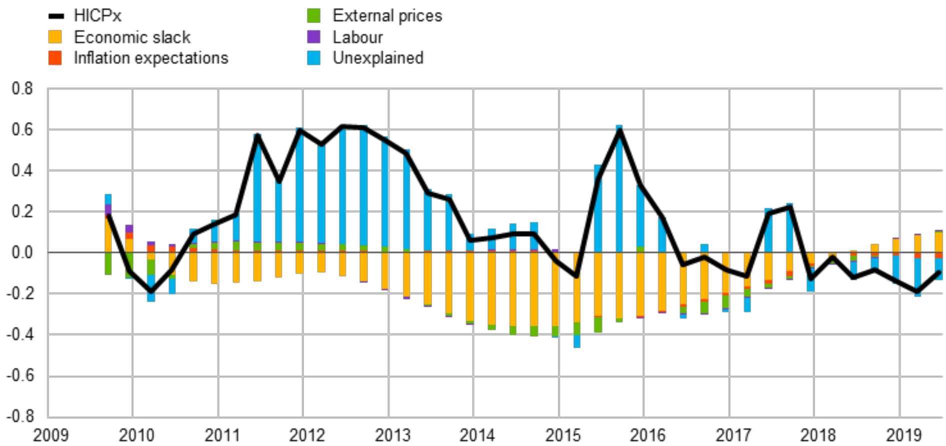
Overall, the message of the thick modelling approach is confirmed by the DMA analysis: slack accounts for a large part of the dynamics of HICPx inflation in the 2012-2017 period, while the contribution of purely forward-looking expectation is relatively constant, and hence comes out as only a minor factor in the decomposition.

Figure 16: Dynamic model averaging: inclusion probability of the different groups of variables (left), short vs medium vs long term expectations (right)



Sample 2009Q2 to 2019Q2. External factors include real effective exchange rate, oil prices, world IP, and import price deflator; labour market indicators include compensation per employee and total unit labour cost; inflation expectations include SPF (1, 2 and 5-year ahead), 1y1y, 1y2y and 5y5y ILS, and Consensus forecasts (4 and 6-quarter ahead).

Figure 17: Dynamic model averaging: Phillips Curve-based decomposition of HICPx inflation



Sample: 2009Q3 to 2019Q2. Weighted average of contributions across 810 specifications.

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