The Slope of the Phillips Curve[*]

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Abstract

We review recent developments in the estimation and identification of the Phillips curve and its slope. We have three main objectives. First, we describe the econometric challenges faced by traditional approaches of estimating the Phillips curve, explain how new approaches address those challenges, and assess which limitations still remain. Second, we review the findings of those new approaches and examine the evidence regarding a potential flattening of the Phillips curve in the pre-pandemic period. Third, we provide an account of inflation dynamics in the post-pandemic period with a particular emphasis on the role of nonlinearities.

JEL Classification: C51, E24, E31, E52

1. Introduction

The Phillips curve has long served as the workhorse model of inflation and is used by economists to analyze and forecast the evolution of inflation. In its modern form, of which we give an example in equation (1), it posits that inflation π_t depends on a combination of future expected inflation $\mathrm{E}_t\pi_{t+1}$ and past inflation π_{t-1}, a measure of resource utilization (here the output gap $y_t - y_t^*$), and a variety of supply shocks u_t including those affecting the prices of food, energy and other commodities:

$$\pi_t = \gamma\pi_{t-1} + (1-\gamma)\,\mathrm{E}_t\pi_{t+1} + \kappa\,(y_t - y_t^*) + u_t. \qquad (1)$$

This particular specification, a hybrid between a traditional backward-looking Phillips curve and a forward-looking New Keynesian Phillips curve, is the starting point of many empirical explorations, and we therefore organize our discussion of the literature around it.

One parameter in equation (1) is the object of considerable attention: the coefficient attached to the measure of resource slack, κ, that is commonly known as *the slope of the Phillips curve*. There

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are two main reasons for this interest in κ. First, κ is a key determinant of the trade-off between inflation and real activity faced by the monetary authority. For example, a large κ implies that inflation can be reduced at little cost in terms of economic activity. Inversely, a small κ entails that large declines in output are necessary to obtain a significant reduction in inflation. Second, Phillips curves such as equation (1) are one of the main tools used in policy institutions to generate forecasts of inflation. In that regard, given an assessment of the value of the output gap $y_t - y_t^*$ and its likely evolution, knowing κ helps forecast the future trajectory of inflation.

While there are many important and interesting aspects of Phillips curves specification and estimation that deserve discussion, in this survey we narrowly focus our attention on estimates of the slope parameter κ.[1] We have three main objectives. First, we provide an update of new developments in estimation and identification methods since the authoritative survey of Mavroeidis, Plagborg-Moller and Stock (2014). In particular, we briefly describe the econometric challenges faced by traditional approaches of estimating the Phillips curve that are described in the aforementioned paper, explain how new approaches propose to address those challenges, and examine which limitations still remain. Second, we review the evidence regarding a potential flattening—a decrease in κ—of the Phillips curve in the pre-pandemic period. Third, we provide an account of inflation dynamics in the post-pandemic period and look into claims that the Phillips curve has steepened in recent years.

Aside from a narrow focus on the slope of the Phillips curve, we also had to make several other choices to keep this survey relatively short. First, we only consider certain approaches to estimating the Phillips curve. Notably, we do not review the evidence coming from full information analysis of general equilibrium models where the Phillips curve is only one of multiple structural equations within a simultaneous system. Second, we mainly focus on the price Phillips curve, although the econometric challenges and associated solutions that we describe also apply to the estimation of the wage Phillips curve. Third, although we mention some results for other countries, the evidence that we present is mainly centered on the United States (for a recent review of Euro Area evidence, see Eser et al., 2020).

The chapter is structured as follows. Section 2 delves into the interpretation of the parameter κ, what it tells us about monetary policy trade-offs, and how knowing its value can be useful from a forecasting standpoint. Section 3 describes the econometric challenges faced by traditional approaches of estimating the Phillips curve and examines how new approaches address those challenges. Section 4 reviews the evidence uncovered by these new approaches. Section 5 covers the recent post-pandemic period and examines whether it has revealed the existence of substantial Phillips curve nonlinearities. Section 6 concludes.

[1] For example, Coibion, Gorodnichenko and Kamdar (2018) discuss how incorporating survey data on inflation expectations can address a number of shortcomings of Phillips curves under full-information rational expectations.

2. A few theoretical considerations

Before we begin our survey of recent developments, we briefly discuss several points regarding the interpretation of the Phillips curve slope κ and its usefulness for forecasting and assessing monetary policy trade-offs.

The overwhelming majority of empirical explorations of the Phillips curve is based on a relationship between inflation and a measure of real economic activity such as the output gap or the unemployment gap. Such a specification also forms the basis of most policy discussions. However, in structural models, microfounded versions of the Phillips curve relate inflation to average real marginal cost mc_t as follows:

$$\pi_t = \gamma \pi_{t-1} + (1-\gamma)\,\mathrm{E}_t \pi_{t+1} + \psi mc_t + u_t. \tag{2}$$

In the three-equation New Keynesian model (Galí 2015), average real marginal cost is proportional to the output gap and the Phillips curve can therefore be expressed as in equation (1). However, only minor deviations from this baseline model, such as the introduction of nominal wage rigidity or capital accumulation, are sufficient to break such proportionality. Thus, in equation (1), the output gap should be seen as an imperfect proxy for real marginal cost, and we should keep in mind that κ combines information on the degree of pass-through from costs to prices (ψ) together with the elasticity of real marginal cost with respect to the output gap. While ψ is a structural parameter that captures, among other things, the degree of price stickiness and the extent of strategic complementarities in price setting, the elasticity of real marginal cost with respect to the output gap is a reduced-form object that can change depending on the shocks hitting the economy.[2] This elasticity also depends on the concept of the output gap under consideration. It is likely that marginal cost is more closely related to the deviation of output from its flexible-price level, which fluctuates substantially in response to supply shocks, than it is to the deviation of output from measures of potential output computed by, for example, the Congressional Budget Office or central banks and international organizations, which are generally estimated as rather smooth trend measures of GDP.

Another point worth nothing is that the slope of the Phillips curve κ provides only a partial characterization of the trade-offs faced by the monetary authority. In fact, it measures the *impact* response of inflation to a change in aggregate demand holding inflation expectations constant. Barnichon and Mesters (2021) propose a metric, the Phillips multiplier, which gives a more complete characterization of monetary policy trade-offs and is defined as follows:

$$P_h = \frac{\partial \left(\sum_{j=0}^{h} \pi_{t+j} \right)}{\partial \varepsilon_t^m} \Big/ \frac{\partial \left(\sum_{j=0}^{h} \left(y_{t+j} - y_{t+j}^{*} \right) \right)}{\partial \varepsilon_t^m}, h \geq 0 \tag{3}$$

At each horizon h, the Phillips multiplier P_h is equal to the cumulative response of inflation to a monetary policy shock divided by the cumulative response of the output gap to the same

[2] Many factors aside from price stickiness and strategic complementarities can affect ψ. For example, when steady-state inflation is positive, ψ becomes a function of trend inflation: see Ascari and Sbordone (2014). For empirical evidence on structural drivers of trend inflation, see Ascari and Fosso (2024).

shock. It summarizes what a central bank cares about: by how much inflation declines when a change in policy lowers the output gap by a given amount. In the context of the three-equation New Keynesian model, κ is equal to the Phillips multiplier only when shocks are independently and identically distributed. When shocks are persistent, the Phillips multiplier depends also on the persistence of the shocks. Away from the simple New Keynesian model, the Phillips multiplier depends on other features of the Phillips curve such as the importance of lagged inflation but also on features embedded in other equations of the model such as inertia in aggregate demand.

Finally, we noted in the introduction that information on the value of κ is often used as part of estimated Phillips curve relationships to produce forecasts of inflation in policy institutions. In practice, however, Phillips curve-based forecasts have been found inferior to the ones produced by simple univariate models of inflation, as shown by Atkeson and Ohanian (2001) and Dotsey, Fujita and Stark (2018). While this finding seems to suggest that Phillips curves should not feature prominently in the toolbox of forecasters, there are several reasons to be cautious in drawing such conclusions. A first reason that we elaborate on below is that the Phillips curve should not be expected to perform well unconditionally: indeed, the Phillips curve traces out the response of inflation to shifts in demand. If the data are instead driven by supply shocks, we should not expect to see the positive relationship between inflation and real activity that is characteristic of the Phillips curve. A second reason is that the aferomentioned studies do not attempt to address the many endogeneity issues that arise in the estimation of Phillips curves. We discuss those endogeneity issues next.

3. Econometric challenges and new approaches

3.1. Econometric challenges

This section discusses the different sources of endogeneity that are present in Phillips curve equations and the methods used to address endogeneity issues that were predominant in the literature until the survey of Mavroeidis, Plagborg-Moller and Stock (2014). The exposition here draws from Barnichon and Mesters (2020).

Note that the baseline Phillips curve, equation (1), includes two unobserved variables: expectations of future inflation $\mathrm{E}_t\pi_{t+1}$ and potential output y_t^*. A first step is therefore to reformulate equation (1) in terms of observables, where $\hat{y}_t^*$ is an observable proxy for potential output:

$$\pi_t = \gamma\pi_{t-1} + (1-\gamma)\,\pi_{t+1} + \kappa\,(y_t - \hat{y}_t^*) + \underbrace{u_t + (1-\gamma)\,(\mathrm{E}_t\pi_{t+1} - \pi_{t+1}) + \kappa\,(\hat{y}_t^* - y_t^*)}_{e_t}. \tag{4}$$

There are several potential sources of endogeneity in equation (4). First, the cost-push shock u_t may affect π_t and y_t simultaneously: $\mathrm{E}\,(y_t u_t) \neq 0$. For this to happen, it suffices that the increase in inflation induced by the cost-push shock leads to a shift in real interest rates (for example, because of the response of monetary policy to inflation) which, in turn, affects real activity (for example, because an IS-type relationship relates real interest rates to demand). Second, if an unexpected shock materializes between time t and time $t+1$, expected inflation $\mathrm{E}_t\pi_{t+1}$ will differ from realized inflation π_{t+1}, in which case we will have that $\mathrm{E}(\pi_{t+1}e_t) \neq 0$. Third, there might be measurement error in potential output, in which case we will have that $\mathrm{E}(\hat{y}_t^* e_t) \neq 0$.

To make it worse, endogeneity issues arising from the correlation between cost-push shocks and real activity are exacerbated by good monetary policy. Under optimal policy, a central bank will seek to fully stabilize inflation and the output gap in response to shocks that do not create a trade-off between those two objectives—this includes demand shocks as well as certain supply shocks. If the central bank is successful in doing so, the remaining variation in inflation and the output gap in the data will be dominated by cost-push shocks and will be characterized by the negative correlation that is typical of the optimal policy response to those shocks (for an exposition of this argument, see McLeay and Tenreyro (2019) and a related comment by Rognlie (2019)). Thus, a negative correlation in the observed *equilibrium* values of inflation and the output gap is not the sign of a flattening or disappearing Phillips curve; rather, it is the expected outcome if the underlying data generating process features a positively-sloped Phillips curve such as equation (1), and if monetary policy is conducted with the aims of stabilizing inflation and the welfare-relevant output gap.

Until recently, the standard approach for handling endogeneity issues in the estimation of the Phillips curve was to use lags of macroeconomic variables as instruments. For this approach to be successful, the instruments z_t used by the econometrician must be both exogenous with respect to the different elements of e_t and strongly correlated with π_{t+1} and y_t. In particular, the exogeneity condition is satisfied if the following conditions are met. First, cost-push shocks u_t must not be correlated with z_t, which happens if u_t has no serial correlation or if the instruments are sufficiently lagged. Second, z_t must not be correlated with the inflation forecast error $\mathrm{E}_t\pi_{t+1} - \pi_{t+1}$, which happens under the assumption of rational expectations since the inflation forecast error arises only because of time $t+1$ shocks that are orthogonal to z_t. Third, z_t must not be correlated with the measurement error in potential $\hat{y}_t^* - y_t^*$, which happens if the measurement error has no serial correlation or, again, if the instruments are sufficiently lagged.

Satisfying those exogeneity conditions is already a tall order. However, as the literature has shown, meeting the relevance condition—that is, finding instruments that are strongly correlated with π_{t+1} and y_t—is even more challenging.[3] Put differently, even if one finds instruments that satisfy the exogeneity conditions, those instruments are likely to be weak.[4] This weak instrument problem leads to large sampling uncertainty and, as Mavroeidis, Plagborg-Moller and Stock (2014) show, it can explain the large dispersion of results in the literature as seemingly innocuous and a priori reasonable specification changes can lead to big differences in point estimates. These authors conclude: *"...the literature has reached a limit on how much can be learned about the New Keynesian Phillips curve from aggregate macroeconomic time series. New identification approaches and new datasets are needed to reach an empirical consensus."*[5] In recent years, researchers have responded to this challenge by proposing new approaches, which we review in the next three subsections.

[3] To be precise, it is finding strong instruments for future inflation, not output, that is particularly challenging.

[4] Using longer lags of macroeconomic variables, which we suggested above as a way of meeting the exogeneity requirement, will only exacerbate the weak instrument issue.

[5] Such a pessimistic conclusion is challenged by Inoue, Rossi and Wang (2022) who propose a new flexible time-varying instrumental variable approach that passes several weak instruments tests.

3.2. New approach: conditioning on demand shocks

A first approach, put forward by Barnichon and Mesters (2020), consists in using sequences of independently identified structural demand shocks as instruments. To see how this approach works, denote by $\{\varepsilon^d_{t-h}\}^H_{h=0}$ a sequence of current and past structural demand shocks. As before, the instruments must verify both the exogeneity and the relevance conditions. Starting with the exogeneity condition, it is satisfied if the sequence $\{\varepsilon^d_{t-h}\}^H_{h=0}$ is orthogonal to all the elements of e_t in equation (4). To see how likely this is to happen, we evaluate the exogeneity conditions for each of the components of e_t one by one. First, as long as the demand shocks are properly identified, they should be orthogonal to the cost-push shock u_t and its lags. Second, under rational expectations, the forecast error for future inflation depends only on time $t+1$ shocks and is therefore orthogonal to demand shocks occurring at time t or before. Third, the measurement error in potential output must be independent of demand disturbances. If potential y^*_t is independent of demand factors, as commonly assumed in macroeconomic theory, this implies that economists must be able to parse demand from supply factors when constructing measures of potential output $\hat{y}^*_t$. As shown by Coibion, Gorodnichenko and Ulate (2018), commonly-used proxies for potential output do not verify this property. Instead, if y^*_t is not independent of demand factors, as in theories of hysteresis, this implies that the proxy for potential output $\hat{y}^*_t$ must react in the same way than potential output to demand disturbances. Turning to the relevance condition, Barnichon and Mesters (2020) establish that it holds if and only if the impulse responses of lagged inflation, future inflation, and the output gap to the identified structural shocks are not linear functions of one another, a condition that is likely to be met in practice.

Barnichon and Mesters (2020) use the externally identified monetary policy shocks of Romer and Romer (2004) and Gertler and Karadi (2015) as instruments. Inoue, Rossi and Wang (2022) extend their approach to a setting with time-varying parameters. A first limitation of this approach is that, because the role of central banks is to make monetary policy as endogenous to the state of the economy as possible, truly exogenous monetary policy shocks are small and constitute weak instruments, thus leading to large weak-IV robust confidence intervals for the parameters of equation (1). A second limitation relates to the uncertainty associated with the identification of the structural monetary policy shocks. While this survey is not the place to discuss the literature on the identification of monetary policy shocks, it is worth noting that both the speed and the magnitude of the effects of the identified shocks on inflation and real activity vary considerably depending on the methodology used.[6]

A related approach is to identify shocks in a structural Vector Auto Regression (VAR) model and estimate Phillips curves conditional on certain shocks. Galí and Gambetti (2020) identify shocks through a combination of zero and sign restrictions and estimate wage Phillips curves using times series of wage inflation, price inflation and unemployment that are purged from the component asso-

[6]Several recent studies (Jarociński and Karadi, 2020; Miranda-Agrippino and Ricco, 2021; Bauer and Swanson, 2023) argue that the standard high-frequency approach used by Gertler and Karadi (2015) mixes true monetary policy surprises with information about the state of the economy or about the central bank's reaction function disclosed through the policy announcement. After purging measures of monetary policy shocks from those information effects, these papers find larger and faster effects of monetary policy on inflation and, to a lesser extent, output.

ciated with wage-markup shocks. Del Negro et al. (2020) estimate price Phillips curves conditional on innovations to the excess bond premium of Gilchrist and Zakrajšek (2012), which they interpret as a proxy for demand shocks. Bergholt, Furlanetto and Vaccaro-Grange (2024) develop a bivariate VAR in inflation and the output gap, identify demand and supply shocks using sign restrictions, and compute inflation-output gap correlations conditional on demand shocks. These VAR studies have one potential advantage over the literature using monetary policy shocks as instruments: the shocks that they identify tend to explain a larger share of the variance in inflation and real activity in the data than monetary policy shocks. Nonetheless, we should point out that, in the case of sign restrictions, the models are only set-identified and the uncertainty around the estimates can therefore be considerable. Moreover, as was the case with monetary policy shocks, those VAR approaches are valid only insofar as the identifying assumptions are correct and sufficient to identify the shock of interest.[7]

Lastly, we should also mention the work of Angeletos, Collard and Dellas (2020), who provide evidence on the dynamic relationship between inflation and real activity conditional on a 'main business-cycle shock', identified as a shock that maximizes the contribution to the volatility of either GDP, unemployment, hours worked, or investment at business-cycle frequencies. These authors find that this shock accounts for a small share of fluctuations in inflation, which is suggestive of a flat Phillips curve. However, it is possible that the shock captures both supply and demand forces, in which case it would not necessarily be informative about the slope of the Phillips curve. Moreover, Bianchi, Nicolò and Song (2023) argue that fixed-coefficients VARs, such as the one used by Angeletos, Collard and Dellas (2020), may be unable to disentangle business-cycle variations from low-frequency movements over periods of time featuring structural breaks. When using instead a Trend-Cycle VAR, which separates trends from cycles prior to the identification of shocks, they find that the main shock driving cyclical fluctuations in unemployment or output is also an important driver of cyclical inflation.

3.3. New approach: regional data

A second approach developed in recent years is to estimate the Phillips curve using regional data. A non-exhaustive list of studies in this literature includes Kiley (2015), Babb and Detmeister (2017), McLeay and Tenreyro (2019), Beraja, Hurst and Ospina (2019), Hooper, Mishkin and Sufi (2020), Hazell et al. (2022), Fitzgerald et al. (2024), and Smith, Timmermann and Wright (2023). The motivation for using regional data is two-fold. First, there is potentially more variability in the regional data than in the aggregate data, which facilitates inference. Second, changes in the aggregate environment can be captured by time-fixed effects. As we show next, this eliminates the endogeneity bias induced by the response of monetary policy to cost-push factors (a point forcefully emphasized by McLeay and Tenreyro, 2019; Fitzgerald et al., 2024) and permits to control for time-

[7] In the case of sign restrictions, it is well known that linear combinations of other structural shocks can masquerade as the shock of interest and thus lead inference astray (Wolf, 2020). Similarly, one may be worried that financial market disruptions captured by shocks to the excess bond premium could have substantial supply-side implications and that, as a consequence, the estimated Phillips curve may not be particularly informative about the inflation-output trade-off faced by the monetary authority.

variation in aggregate inflation expectations and aggregate potential output. According to Hazell et al. (2022), this ability to use time-fixed effects to control for aggregate inflation expectations is the main advantage of using regional data. Indeed, they argue that the central issue with Phillips curve estimations is that shifts in inflation expectations correlated, but not necessarily causally related, with shifts in the output gap impart an upward bias on estimates of the slope of the Phillips curve.

We now explain in greater details how the use of regional data can help sharpen identification. The exposition draws from McLeay and Tenreyro (2019). Consider a monetary union composed of N regions indexed by i. We assume that, in each region, dynamics are similar and are governed by a Euler equation and a Phillips curve:

$$y_{i,t} - y^*_{i,t} = E_t y_{i,t+1} - E_t y^*_{i,t+1} - (i_t - E_t \pi_{i,t+1} - r_{i,t}), \tag{5}$$

$$\pi_{i,t} = \gamma \pi_{i,t-1} + (1-\gamma) E_t \pi_{i,t+1} + \kappa \left(y_{i,t} - y^*_{i,t}\right) + u_{i,t}, \tag{6}$$

where i_t is the nominal interest set by the monetary authority that is common across regions. The cost-push shocks $u_{i,t}$ and demand shocks $r_{i,t}$ are potentially autocorrelated. Furthermore, aggregate variables are a weighted average of region-specific variables $x_t = \sum_{i=1}^N \alpha_i x_{i,t}$ for $x_t = \pi_t, y_t$, where the region-specific weights α_i satisfy $\sum_{i=1}^N \alpha_i = 1$. This implies that we can aggregate equations (5) and (6) and come up with similar equations that hold in the aggregate. Notably, the aggregate Phillips curve is still given by equation (1): under the simple assumptions made here, the slopes of the regional Phillips curves and the aggregate Phillips curve coincide. The key to identification is to rewrite region-specific variables in deviation from the aggregate:

$$\begin{aligned}\pi_{i,t} - \pi_t = {} & \gamma (\pi_{i,t-1} - \pi_{t-1}) + (1-\gamma)(E_t \pi_{i,t+1} - E_t \pi_{t+1}) \\ & + \kappa \left(y_{i,t} - y^*_{i,t} - (y_t - y^*_t)\right) + u_{i,t} - u_t,\end{aligned} \tag{7}$$

$$\begin{aligned}y_{i,t} - y^*_{i,t} - (y_t - y^*_t) = {} & E_t y_{i,t+1} - E_t y^*_{i,t+1} - \left(E_t y_{t+1} - E_t y^*_{t+1}\right) \\ & + (E_t \pi_{i,t+1} - E_t \pi_{t+1} + r_{i,t} - r_t).\end{aligned} \tag{8}$$

The main thing to notice is that the policy rate i_t drops out of equation (8), which implies that the deviation of the regional output gap from the aggregate output gap $y_{i,t} - y^*_{i,t} - (y_t - y^*_t)$ is independent of monetary policy. This means that, although $y_{i,t} - y^*_{i,t} - (y_t - y^*_t)$ can still be correlated with $u_{i,t} - u_t$—if shocks to $u_{i,t} - u_t$ are persistent, they affect future expected inflation which, in turn, affects $y_{i,t} - y^*_{i,t} - (y_t - y^*_t)$ through equation (8)—, this correlation is not propped up due to the stabilizing behavior of the monetary authority.[8]

In practice, economists estimate equations of the type:

$$\pi_{i,t} = \alpha_i + \delta_t + \eta_1 \pi_{i,t-1} + \eta_2 E_t \pi_{i,t+1} + \eta_3 y_{i,t} + \varepsilon_{i,t}, \tag{9}$$

[8] Another potential source of correlation between $y_{i,t} - y^*_{i,t} - (y_t - y^*_t)$ and $u_{i,t} - u_t$ is if cost-push shocks $u_{i,t}$ and demand shocks $r_{i,t}$ are correlated.

where the time-fixed effects δ_t control for aggregate cost-push shocks, aggregate inflation expectations, and movements in aggregate potential output (or the aggregate natural rate of unemployment if the unemployment rate is the forcing variable) while the region-fixed effects control for time-invariant differences in regional natural output and regional inflation expectations. The equation is estimated either with ordinary least squares (OLS) or with two-stage least squares (2SLS) using instruments that capture regional demand shifts that correlate with $y_{i,t}$ but not with the regional supply shocks contained in $\varepsilon_{i,t}$.

Away from the simple case described above, several issues can arise. First, we simply posited that equations (5) and (6) held instead of deriving them from a fully-fledged model. Hazell et al. (2022) develop a two-region model of a monetary union with both tradeable and nontradeable goods and show that it is the slope of the regional Phillips for nontradeable goods that is informative of the slope of the aggregate Phillips curve. In practice, this implies that, if one estimates regional Phillips curves for overall regional inflation, estimates of the slope should be divided by the expenditure share on nontradeables to be comparable with estimates of the slope of the aggregate Phillips curve. Second, as in all the literature, we have assumed that the parameters governing the inflation process γ and κ are identical across regions, which implies that the parameters η_1, η_2, and η_3 in the estimation equation (9) should also be identical across regions. Canova (2024) shows that this assumption is problematic if the underlying inflation dynamics in the data are heterogeneous across regions (different $\gamma_{i,t}$ and $\kappa_{i,t}$ by region): indeed, in that case the error term is correlated with the regressor $y_{i,t}$, which implies that OLS estimation fails and that instruments correlated with $y_{i,t}$ are also correlated with the error term $\varepsilon_{i,t}$, thereby violating the exclusion restriction.[9]

3.4. New approach: detailed firm-level data

Some of the same advantages in terms of identification that one gains by using regional data can also be obtained by using firm-level data. Gagliardone et al. (2023) use detailed micro-data for the Belgian manufacturing sector at a quarterly frequency from 1999 to 2019 and rely on a bottom-up approach to estimating the slope of the Phillips curve.[10] Because they observe costs, prices, and quantities of production at the firm-product level, these authors can estimate dynamic pass-through regressions relating prices to measures of marginal costs at the firm level. The results from these regressions provide information on the degree of nominal and real rigidities in price setting that determine the slope of the aggregate Phillips curve. As with the regional data, time-fixed effects are used in those regressions to account for the effects of aggregate confounders such as shifts in inflation expectations. The estimates indicate a relatively high slope for the aggregate marginal cost-based Phillips curve in the range of 0.05 to 0.06. In addition, the authors find that the elasticity of marginal cost with respect to the output gap is low, which helps reconcile their results with the low slope estimates usually found in the literature estimating unemployment or output gap-based Phillips curves.

[9] Canova (2024) outlines other issues with the regional approach, notably the fact that abstracting from interdependencies across regions and ignoring common factors creates an omitted variable bias.

[10] A few previous papers used survey data to estimate the Phillips curve at the firm level: see Boneva et al. (2020) for the UK, Gaiotti (2010) for Italy, and Frohm (2020) for Sweden.

4. Pre-pandemic evidence on the slope of the Phillips curve

4.1. What is a reasonable estimate of the slope of the Phillips curve?

Table 1 provides a summary of recent estimates of the Phillips curve slope. As can be seen by the large differences in estimates across studies, it is surprisingly difficult to answer the question contained in the title of this subsection. In part, this is because those estimates, as well as most estimates found in the literature, are not directly comparable, for reasons we explain next.

Consider a purely forward-looking version of equation (1). Assuming that the dynamics of the forcing variable can be modeled by an AR(1) process with persistence ρ and iterating this equation h periods ahead gives:

$$\pi_t = E_t \pi_{t+h} + \sum_{j=0}^{h-1} \rho^j \kappa \left(y_t - y_t^*\right) + \sum_{j=0}^{h-1} E_t u_{t+j}. \tag{10}$$

This equation shows that, even if inflation expectations are directly observable and all other endogeneity issues are properly addressed, unless one includes one-period ahead inflation expectations in the regression, the estimated slope coefficient will not be equal to the true slope parameter κ but will instead reflect a convolution of κ and of the persistence parameter ρ. The longer the horizon of the inflation expectations included in the regression and the more persistent the forcing variable, the higher the slope estimate. In the regional approach, where movements in inflation expectations are partly captured by a combination of time and region-specific fixed effects, estimates similarly depend on the persistence of the forcing variable or on the persistence of the variable used to instrument for the forcing variable. Given those observations, it is perhaps not surprising to see in Table 1 that the studies with the lower slope estimates are those that either include inflation expectations at short horizons (Del Negro et al. 2020) or estimate directly a solved-forward version of the Phillips curve (Hazell et al. 2022).

4.2. Empirical evidence on a flattening of the Phillips curve in the pre-pandemic period

The decades preceding the start of the COVID-19 pandemic witnessed a dramatic reduction in the unconditional correlation between inflation and real activity and many evoked the possibility that the Phillips curve had flattened or even disappeared. Stock and Watson (2021) show that this finding of a decrease in the unconditional correlation between inflation and activity does not depend on using common proxies for slack such as the output gap or the unemployment gap. Indeed, the decrease in the correlation is still observed if one uses a wide array of other measures of real activity or capacity utilization. As we have discussed in section 3, such a decrease in the Phillips correlation over time is not necessarily indicative of a decrease in the slope of the structural Phillips curve: mismeasurement in the potential levels of output or unemployment, or confounding from time-varying inflation expectations and the presence of cost-push shocks could be at play. The new econometric approaches reviewed above attempt to control for those confounding factors in various ways. In this section, we review what they tell us about a potential flattening of the Phillips curve in the pre COVID-19 period.

Table 1: Summary of Phillips curve slope estimates

Paper	**Sample**	**Dependent variable**	**Forcing variable**	**Inflation Expectations**	**Slope point estimate**
Barnichon and Mesters (2020)	1990-2017	Quarterly change in core PCE inflation (annualized)	Quarterly unemployment rate in deviation from HP-filtered trend	Average over next 4 quarters + rational expectations	-0.24
Inoue, Rossi and Wang (2022)	1974-2007	Quarterly change in core PCE inflation (annualized)	Quarterly CBO unemployment gap	Three-quarter-ahead SPF forecast of GDP deflator	-0.6 in 1974, -0.25 in 2007
Del Negro et al. (2020)	1989-2019	Quarterly change in core PCE inflation (annualized)	Quarterly unemployment rate	One-quarter-ahead SPF inflation expectations	0
McLeay and Tenreyro (2019)	1990-2017	Semiannual change in core CPI (annualized)	Semiannual average of monthly unemployment rates	12-month inflation exp. from U. of Michigan by region + time fixed effects	-0.38
Fitzgerald et al. (2024)	1977-2018	Annual change in headline CPI	Semiannual average of monthly unemployment rates	Time and MSA fixed effects	-0.33
Smith, Timmermann and Wright (2023)	1980-2022	Annual change in headline CPI	Annual average of monthly unemployment rates	Time and MSA fixed effects	-0.29 pre 2000, -0.25 post 2000
Hazell et al. (2022)	1991-2018	Annual change in headline CPI	Discounted sum of current and future quarterly unemployment rates	Time and state fixed effects	-0.055

We start with studies that condition on particular shocks, notably demand disturbances. Barnichon and Mesters (2020) and Inoue, Rossi and Wang (2022) estimate price Phillips curves using monetary policy shocks as instruments and with the unemployment gap as the forcing variable. Barnichon and Mesters (2020) find that the slope of the Phillips curve has been cut in half between the samples 1960-2007 and 1990-2017. Inoue, Rossi and Wang (2022) find that the slope of the Phillips curve has been divided by a factor of two to three between 1975 and 2007. However, in both studies, the point estimate for the slope of the Phillips curve in a given sample is always contained within the 90 or 95 percent weak-instrument robust confidence interval of the alternative sample. Galí and Gambetti (2020) estimate a wage Phillips curve with unemployment as the forcing variable on data that is purged from the component associated with wage-markup shocks using a VAR model and find that the slope of the wage Phillips curve has been cut in about half between a pre-2007 sample and post-2007 sample. These estimates appear to be based on a particular draw from the posterior distribution satisfying the restrictions (possibly the median) and do not factor in the sampling and model uncertainty present in the VAR. Del Negro et al. (2020) estimate a price Phillips curve with unemployment as the forcing variable conditional on an innovation to the excess bond premium and find that, between a first sample running from 1974 to 1989 and a second sample going from 1990 to 2019, the posterior distribution of the slope parameter shifts substantially. Notably, over the first sample the posterior distribution is centered around negative values of the slope and has very little mass on zero while in the second sample the posterior distribution is (rather narrowly) centered around zero. Finally, Bergholt, Furlanetto and Vaccaro-Grange (2024) estimate correlations between inflation and the CBO output gap conditional on demand shocks identified through a bi-variate VAR and do not find that the conditional correlations have changed meaningfully between the samples 1968-1994 and 1995-2019.

Next, we review the regional evidence on the flattening of the Phillips curve. Hazell et al. (2022) estimate a price Phillips curve for the non-shelter portion of the consumer price index (CPI) with the unemployment rate as a forcing variable using state-level data.[11] Between a first sample running from 1978 to 1990 and a second sample going from 1991 to 2018, they find that the slope of the Phillips curve has been divided by two, although that difference is not statistically significant. Fitzgerald et al. (2024) estimate a price Phillips curve with the unemployment rate as the forcing variable using metropolitan statistical areas (MSA) data and find that the slope of the Phillips curve has modestly declined after 2000, although that decline is not statistically significant. Smith, Timmermann and Wright (2023) estimate price and wage Phillips with either the unemployment rate or the unemployment gap as the forcing variable using sectoral, state, or MSA-level data. They use Bayesian panel methods with breakpoints that allows them to estimate the timing of Phillips curve breaks instead of imposing them. In the sectoral data, they uncover a marked flattening of the price Phillips curve between a pre-2001 and a post-2001 sample.[12] However, the state-level data indicates that the slope of the wage Phillips curve has been relatively stable over time while the MSA-level data shows a similar result for the slope of the price Phillips curve.

We draw two main conclusions from this overview of the recent literature. First, once appropriate econometric techniques are used to address endogeneity issues in the estimation of the Phillips curve, the estimated decline in the slope of the Phillips curve appears much less dramatic than in the unconditional data. Second, the median estimate indicates that the slope of the Phillips has been divided by a factor of two between pre-1990 and post-1990 data, but this estimate is characterized by large uncertainty.

4.3. Theoretical reasons for a flattening

Many explanations have been proposed in the literature to rationalize the flattening of the Phillips curve. Because of constraints in space, we cannot hope to do justice to this literature. Our choice here is to briefly mention only a few recent papers, with the understanding that we are by no means exhaustive. Interestingly, many of the explanations put forward to account for the flattening of the Phillips curve have also been invoked to account for the decline of the labor share in the United States (for a horserace, see Bergholt, Furlanetto and Maffei-Faccioli, 2022).

One popular narrative is related to globalization. However, in theoretical models the effect of globalization on the slope of the Phillips curve is ambiguous. Guilloux-Nefussi (2020) introduces endogenous entry in the export market and heterogeneous productivity across firms in an open economy model. In her model, only the largest and most productive firms enter the export market

[11] In the regional literature, movements in the aggregate natural rate of unemployment are captured by time-fixed effects while time-invariant differences in the natural rate of unemployment across regions are captured by region-fixed effects

[12] Because unemployment rate data is not available at the sectoral level, the authors abstract from time-fixed effects and include the aggregate unemployment gap and a measure of aggregate inflation expectations in the sectoral specification. This means that the sectoral results are potentially affected by some the endogeneity issues described in Section 3.

and globalization favors concentration through the emergence of big players. This concentration force dominates the pro-competitive force present in previous papers (Guerrieri, Gust and López-Salido, 2010; Benigno and Faia, 2016, among others), and globalization reduces the slope of the Phillips curve.

Another possibility is that the flattening of the Phillips curve is due to an increase in market concentration. Such a mechanism is present in several models that depart from the standard monopolistic competition setup used in the New Keynesian model: see Fujiwara and Matsuyama (2022), Wang and Werning (2022), Heise, Karahan and Sahin (2021), and Baqaee, Farhi and Sangani (2022), among others.

Labor market trends could also be related to the decline in κ. Lombardi, Riggi and Viviano (2023) show that κ decreases in response to a decline in the bargaining power of workers in a model with two margins of labor adjustment (employment and hours). Ratner and Sim (2022) make a similar point in a Post-Keynesian model of inflation where inflation dynamics are the result of the class conflict between workers and capitalists. Basso and Rachedi (2024) show that the threat of automating labor tasks lowers workers' bargaining power in the data and reduces the sensitivity of price and wage inflation to unemployment. Furthermore, Siena and Zago (2024) relate job polarization, i.e. the disappearance of routine jobs, to the decline in the slope of the Phillips curve. They show that increasing labor market fluidity, i.e. higher hiring and separation rates, decreases κ. Given that non-routine jobs are more fluid, a shift towards those jobs triggered by job polarization flattens the Phillips curve.

Other slow moving trends could have an impact on κ, including demographic shifts (Ambrocio 2023) and changes in the network structure of the economy (Rubbo 2023). Lepetit (2023) relates the flattening of the Phillips curve to the rise in the importance of hysteresis effects documented in Furlanetto et al. (2024): indeed, in the presence of hysteresis, inflation is less sensitive to fluctuations in economic activity as the productive capacity of the economy responds endogenously to demand shocks.

5. Post-pandemic evidence: is the Phillips curve back?

The post-COVID data signal the return of inflation to levels that are unprecedented since the late 1970s. In part, the recent high levels of inflation reflect the energy shocks that have roiled the Euro Area and, to a lesser extent, the United States. However, core measures of inflation, which strip out volatile components such as food and energy, have also increased noticeably over the course of 2021 and 2022. In the United States, the four-quarter-change in core PCE inflation started rising in early 2021 and peaked at 5.5 percent in the first quarter of 2022. In the Euro Area, the four-quarter-change in core HICP inflation peaked at about the same value a year later. Since then, however, measures of core inflation have decreased rapidly despite the resilience in economy activity. In this section, we review explanations for the recent behavior of core inflation. We focus especially on evidence related to a potential steepening of the Phillips curve. This choice is guided by several observations. First, unlike in the 1970s, measures of long-run inflation expectations have stayed relatively stable over the pandemic. Second, in the United States the labor market was extremely tight and it is likely that this tightness was understated by the (already very low) level of the unemployment rate. Third, a key aspect of the experience of the last few years is that major and persistent shifts in the composition of demand led capacity constraints to bind in some sectors.

We first consider the pre-pandemic evidence on Phillips curve nonlinearities. Unconditional aggregate data indicates a modest degree of steepening of the price Phillips curve at low levels of the unemployment rate if the data extends back to the 1960s. There is, however, more robust evidence of nonlinearities in the wage Phillips curve (Hooper, Mishkin and Sufi 2020). The regional approach provides more decisive evidence of nonlinearities, in part because there are more episodes of tight labor markets at the state and metropolitan area level. Babb and Detmeister (2017) and Hooper, Mishkin and Sufi (2020) find robust evidence of a steeper price Phillips curve at low levels of unemployment in U.S MSA-level data. Smith, Timmermann and Wright (2023) confirm the results of these two papers and also uncover evidence of nonlinearities in the price Phillips curve in Euro Area country-level data and in the wage Phillips curve in U.S. state-level data.

Turning to the pandemic period, Cerrato and Gitti (2022) use MSA-level data and compare pre-COVID estimates with those obtained on a sample ranging from March 2021 to August 2022: they find that the slope of the Phillips curve has tripled between the former and latter sample. Boehm and Pandalai-Nayar (2022) use pre-pandemic industry-level data and document that industries' supply curves are convex. They develop a model to show that the convexity could be due to capacity constraints in production. This finding is particularly relevant in light of the major shifts in the composition of demand that occurred during the pandemic. Indeed, Guerrieri et al. (2021) show that a combination of a shift in the composition of demand and convexities in sectoral supply curves can give rise to aggregate cost-push shocks in the aggregate Phillips curve. The logic is as follows. Suppose that there is a shift in the composition of demand from sector A to sector B. Because of the supply curve convexity, in sector A declines in prices are modest while declines in quantities are much larger. Inversely, in sector B, capacity constraints are rapidly reached and increases in prices dwarf increases in quantities. In the aggregate, prices increase and quantities decline: the shock ends up looking like a cost-push shock. Ferrante, Graves and Iacoviello (2023) and Comin, Johnson and Jones (2023) provide quantitative assessments of the importance of this channel and show that it can explain a sizeable fraction of the increase in inflation in the aftermath of the pandemic.

Another possibility is that the high inflation environment itself has led to a steepening of the Phillips curve. This would be the case, for example, if firms chose to change their prices more often in a high inflation environment. Indeed, in the standard New Keynesian model with time-dependent pricing, an increase in the frequency of price adjustment at the micro level mechanically leads to a higher value of κ. Montag and Villar (2023) show preliminary evidence on price setting for the United States during and after the COVID period and find that the frequency of prices changes rose in late 2019 and remained at elevated levels until early 2021 when it started declining. In addition, they find that the size of price adjustments increased sharply over the period from 2020 to mid-2022. While the frequency of price changes is an exogenous parameter in the standard New Keynesian model with time-dependent pricing, it changes with economic conditions in models with menu costs, thus implying that the slope of the Phillips curve becomes state-dependent (see Nakamura et al. (2018), Gagnon (2009), Costain, Nakov and Petit (2022) and Cavallo, Lippi and Miyahara (2023)). In these models, changing prices is costly because it requires acquiring information about costs, price setting by competitors, and many other factors. Therefore, most firms will not change their price in response to a small increase in costs. In contrast, a large share of firms immediately increase their prices in response to a large shock (like the post-COVID inflation surge) in order to avoid a large reduction in profits due to the fact that their price is otherwise too low relative to the optimal price. As a result, firms tend to raise their prices more frequently and the Phillips curve becomes steeper.

A similar mechanism applies also in models with rational inattention (see Maćkowiak, Matějka and Wiederholt 2023 for a detailed survey on this literature). In these models households and firms have a limited amount of attention that they can dedicate to processing information. It is costly and time consuming to constantly adjust behavior in response to shocks. Therefore, agents "rationally ignore" certain data and react sluggishly in response to small shocks. In contrast, households and firms change their behavior (including their prices) much more quickly in response to large shocks. In these models, a closed-form solution for the Phillips curve is available only in special cases (Mackowiak and Wiederholt 2009 and Afrouzi 2024). However, a general insight is that higher capacity of processing information makes the Phillips curve steeper. Weber et al. (2024) present extensive cross-country evidence showing that both consumers and firms are substantially more informed (and thus able to process information) about the state of the economy in periods when inflation is high than in periods when inflation is low. The result is proven using randomized control trials in which some respondents are treated with some information about inflation while other agents do not receive any information. Pfäuti (2023) and Ulvedal and Maih (2024) estimate the inflation attention threshold and show how shocks have larger inflationary effects when they materialize in a context of high inflation.[13]

As we mentioned in the introduction, a possible steepening of the Phillips curve during the post-COVID recovery would change the trade-offs faced by monetary authorities. Indeed, it would imply that contractionary monetary policy has both larger effects on inflation and more limited effects on economic activity, therefore raising the likelihood that central banks may be able to achieve soft landings.

6. Conclusion

In this survey, we have reviewed developments in the estimation and identification of the slope of the Phillips curve. Ten years ago, Mavroeidis, Plagborg-Moller and Stock (2014) concluded that *"New identification approaches and new datasets are needed to reach an empirical consensus."* Researchers have responded to this challenge by proposing new ways of estimating the Phillips curve

[13] Other contributions invoke Phillips curve nonlinearities to explain the recent inflation experience. In Harding, Lindé and Trabandt (2023), the nonlinearity arises from a quasi-kinked demand schedule for goods. Benigno and Eggertsson (2023) and Schmitt-Grohé and Uribe (2023) generate a nonlinear Phillips curve through downward nominal wage rigidities.

based on conditioning on sequences of independently identified structural demand shocks and using disaggregated regional or firm-level data. While these approaches can and should still be refined, they have brought new robust results, notably that traditional approaches to estimating the Phillips curve using lagged macroeconomic variables as instruments tend to underestimate its slope and that unconditional data greatly exaggerate the pre-pandemic flattening of the Phillips curve. At a time when inflation is once again a major policy issue, these methodological advances should form a useful springboard for further research on inflation dynamics.

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