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The Phillips Curve in the Euro Area: New Evidence Using Country-Level Data

Susanne Wellmann*

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Abstract

We study whether the trade-off between inflation and unemployment still exists in the euro area (EA). Using country-level data for member states of the EA, we estimate a refined specification of the Phillips curve in the spirit of Hazell et al. (2022) deploying a non-tradable price index to measure inflation. We find that the slope of the Phillips curve is small and hence the Phillips curve is flat in the EA, similarly to the US. Moreover, reference estimates based on aggregate data overstate the steepness of the Phillips curve considerably. Our findings imply that the insensitivity of inflation with respect to unemployment over the last decade is a result of firmly anchored inflation expectations.

Keywords: Inflation, Phillips curve, Expectations, Euro Area
JEL-Codes: E31, D84, F45,

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1 Introduction

The Phillips curve is the most important and widely-used workhorse model for inflation in economics illustrating the trade-off between inflation and unemployment. It was originally proposed by Phillips (1958) and further discussed by Samuelson and Solow (1960). Over the past decades, the Phillips curve has constantly been subject to criticism and refinements. Nowadays, the New Keynesian Phillips curve featuring inflation expectations has become its state-of-the-art specification. However, in 2022, when we observed rapidly increasing inflation across the globe in response to the Covid-19 pandemic and the war in Ukraine while unemployment remained stable on low levels, the Phillips curve is on trial again. Especially in case of the euro area (EA), where the rise of inflation has not yet come to a halt with a view to the energy crisis, there is an urgent need for further research on the Phillips curve. Against this backdrop, we ask in this paper whether the Phillips curve trade-off between inflation and unemployment still exists in the EA. Moreover, we examine whether country-level data can provide new insights into the Phillips curve and how these new results relate to findings of the recent literature estimating the Phillips curve using aggregate data for the EA.

In order to answer these questions, we build on a new model of a *regional* Phillips curve developed by Hazell et al. (2022) exploiting the variation in inflation and unemployment that we observed in the EA over the last decades. In their spirit, we set up a non-tradable goods' price index to measure inflation and estimate the regional Phillips curve on country-level data for the EA member states covering the period from 2001 to 2021. In addition, we compare our findings based on the regional Phillips curve with results obtained from estimating the aggregate Phillips curve using different measures of inflation expectations. Lastly, we discuss these findings with respect to the recent related literature.

In the aftermath of the financial crisis, when unemployment rose strongly but disinflation did not materialize as expected in most advanced countries, criticism around (the stability of) the Phillips curve increased (Hall 2011, cp.). Since then, a large body of literature has emerged assessing the trade-off in light of the Great Recession, mostly in case of the US (Ball and Mazumder 2011; Blanchard 2016; Coibion and Gorodnichenko 2015, e.g.) but also for the EA (Mazumder 2012, e.g. Riggi and Venditti 2015; Hindrayanto et al. 2019; Ball and Mazumder 2020) and advanced and emerging economies across the globe (Blanchard et al. 2015; Forbes et al. 2021, e.g.). As mentioned above, the Covid-19 pandemic and the subsequent severe supply chain shock leading to rapidly increasing inflation at low levels of unemployment put the Phillips curve yet again to the test. Overall, the literature finds very different results for the Phillips curve slope, that is the parameter that measures how sensitive inflation is to unemployment or any other measure of economic slack, such as the output gap. Most papers estimate the Phillips curve using aggregate data (both in case of the US and the EA) and direct measures of inflation expectations. Early on after the financial crisis, Mavroeidis et al. (2014) have pointed out that there are several caveats to this: first, there is considerable heterogeneity and variation in inflation and unemployment especially in the EA which might not be captured appropriately by aggregate data. Moreover, aggregate (survey) data suffers from a problem of weak instruments. Therefore, they argue, new methodologies and data are necessary to pin down the slope of the Phillips curve more clearly. Additionally, Hazell et al. (2022) argue that simultaneity problems may arise because of the difficulty to disentangle demand and supply shocks in aggregate data. We tackle these issues and estimate a new formulation of the Phillips curve for the EA exploiting country-level panel data. In this way, we exploit variation in inflation and unemployment across the EA and direct measures of inflation expectations become obsolete.

Specifically, we estimate an empirical specification of the *regional* Phillips curve proposed by Hazell et al. (2022) to infer about the sensitivity of inflation to unemployment in the EA. They derive this modified version of the Phillips curve within a standard multi-region New Keynesian model of a monetary union and relate it to the "traditional" aggregate Phillips curve. Importantly, they set out how the problem of accounting for shifts in long-term inflation expectations when estimating the Phillips curve, for example induced through changes in the long-run monetary policy regime, can be overcome by the use of a panel data specification including time-fixed effects. Intuitively, long-run inflation expectations are common across member states of a monetary union and therefore "cancel out" in the estimation using cross-sectional data (Hazell et al. 2022, p. 5). Therefore, it is not necessary to proxy for inflation expectations using for example survey data. Thus, measurement errors and identification problems are substantially reduced. Another essential theoretical feature of the regional Phillips curve is that it only relies on inflation in non-tradable goods. Prices of tradable goods are set at the level of the monetary union and are therefore equal (up to transportation and logistical costs). Hence, they do not contribute to inflation differentials across the member states of the union and are therefore not informative of the slope of the regional Phillips curve. To account for this feature, we construct a non-tradable goods price index using HICP-subcomponents on a 4-digit-level from Eurostat taking advantage of the harmonization of price index construction across EA member states. We also use several different approaches for identification and follow Hazell et al. (2022) in constructing a tradable-demand instrument. This instrument takes advantage of the regional setting and exploits the idea that supply shocks in the tradable goods sector differently affect demand in the non-tradable goods sector depending on the degree of exposition of a country to the supply shock. We also estimate an empirical version of the regional Phillips curve as presented in the recent related literature and compare our results with those reported in Hazell et al. (2022) for the US. Finally, we contrast our results for the slope of the regional Phillips curve with estimates of the aggregate Phillips curve using different measures of inflation expectations, and place our results into the context of existing literature.

We evaluate the regional Phillips curve on quarterly data for EA member states over the period 2001-2021.[1] We find that indeed the slope of the Phillips curve in the EA is small and thus the Phillips curve itself comes across as flat but robust. In our preferred specification, the slope coefficient κ is only 0.0043, though statistically significant, which is substantially smaller compared to estimates

[1]Essentially, the data starts in 1998 but due to the construction of non-tradable goods price inflation we lose 3 years of observations

we obtain from aggregate data ranging between 0.0971 and 0.3812. However, our finding coincides with the estimated slope parameter for the US reported by Hazell et al. (2022) who obtain a value of 0.0062 in the preferred specification. Similar to Hazell et al. (2022), we conclude that the Phillips curve is substantially flatter though stable judging from country-level data compared to aggregate data. This finding is also robust across a number of different specifications regarding methodological aspects of the regional Phillips curve. Our findings clarify why there has been no disinflation in the years after the financial and sovereign debt crises and why inflation has remained below target in the late 2010s when unemployment decreased to record-low levels: the Phillips curve is alive but robustly flat in the EA and inflation has been stabilized by firmly anchored inflation expectations.

The paper proceeds as follows. In the remainder of the introduction, we place the paper in a broader literature context. Section 2 introduces the model of the regional Phillips curve based on Hazell et al. (2022). Afterwards, in Section 3, we describe the data and show some stylized facts on the Phillips curve in the EA. Section 4 introduces the empirical specification of the model illustrated in Section 2 and presents the empirical results of estimating the regional Phillips curve on EA panel data. It also compares findings with estimates of an aggregate Phillips curve and the recent literature. Section 5 concludes.

Related literature. This paper touches upon several strands of the literature on the Phillips curve. After all, the Phillips curve is still an important tool for policymakers at central banks to analyze inflation (Belz et al. 2020; Eser et al. 2020; Hasenzagl et al. 2022).

The literature on using regional or cross-sectional panel data to estimate the Phillips curve is still scarce. To date, there has been no attempt to use EA country-level data to estimate a regional Phillips curve specification, however, there are some papers that use US state- or city-level data (Kiley 2015; Babb and Detmeister 2017).[2] The paper most closely related to ours is Hazell et al. (2022) since we use their newly developed regional Phillips curve model based on regional data to infer about the slope of the Phillips curve in the euro area as described above. In their paper, they develop a regional Phillips curve within a New Keynesian model and estimate this new version of the Phillips curve using a newly-constructed dataset on state-level price indices for non-tradable goods for the US. In their analysis they put special emphasis on the (seeming) difference between the period of the Volcker disinflation and the period since 1990. Based on the new data and the new specification of the Phillips curve, they find that its slope was and is still small which makes the Phillips curve flat. Importantly, they do not use explicit measures of inflation expectations to arrive at this conclusion. In a similar fashion, though with a focus on the optimal inflation target when identifying the Phillips curve, McLeay and Tenreyro (2020) use cross-sectional regional variation in US metropolitan unemployment and price data to infer about the slope of the Phillips curve. They obtain larger estimates of the slope of the Phillips curve compared to estimates based on aggregate data. Similarly, Fitzgerald et al. (2020) estimate the Phillips curve using US state-level data to

[2] To our best knowledge, the only paper using country-level data of EA member states to identify the slope of a structural (aggregate) New Keynesian Phillips curve is Eser et al. (2020). However, they do not estimate a regional Phillips curve in the spirit of Hazell et al. (2022).

identify the structural relationship between unemployment and inflation. They find a relatively stable relation between unemployment and inflation since the 1970s. Hooper et al. (2020) estimate a conventional expectations-augmented Phillips curve using panel data for US states and cities and find a negative slope of the Phillips curve.

Several papers have recently investigated the aggregate Phillips curve for the euro area. They focus on estimating the Phillips curve using aggregate data to explain the puzzling behavior of inflation after the financial crisis (Moretti et al. 2019; Passamani et al. 2021).[3] Ball and Mazumder (2020), for example, estimate the Phillips curve for the EA focusing on core inflation and using professional forecasters' inflation expectations. They find that there was no missing disinflation after the financial crisis. Oinonen and Vilmi (2021) use the New Keynesian Phillips Curve (NKPC) to analyze the inflation outlook in the EA. Including both survey and professional inflation expectations, they find that the Phillips curve explains recent inflation dynamics well. Other literature has studied inflation on the level of EA member states individually, agreeing on a negative but stable slope of the Phillips curve since the financial crisis (see Amberger and Fendel 2016, 2017; Hindrayanto et al. 2019). Still, there is considerable heterogeneity across EA member states (Ribba 2020, e.g.).

2 The regional Phillips curve

In this Section, we shortly summarize the set up of the New Keynesian model in Hazell et al. (2022) in order to set the stage for presenting the regional and aggregate Phillips curve. We will state the assumptions necessary to arrive at the regional Phillips curve and elaborate on the role of cross-sectional data in estimating it. Finally, we present the regional Phillips curve and contrast it to the related strand of the literature.

2.1 Model setup

Hazell et al. (2022) develop the regional Phillips curve in a two-region New Keynesian, open economy model with a tradable and non-tradable goods' sector. Both regions of the model form a monetary and fiscal union. The population of Home (H) and Foreign (F) sum up to one and labor is perfectly mobile within regions but not across regions. Each region features a single labor market. Financial markets are complete across regions. Agents form full-information rational expectations.

Households have preferences according to Greenwood et al. (1988) (abbr. as GHH hereafter) and consume a composite consumption good with consists both of tradable and non-tradable goods. Assuming GHH preferences simplifies the derivation of a regional and aggregate Phillips curve, see Section 2.2. These type of preferences imply that there are no wealth effects on labor supply, which means that marginal costs are independent from consumption.[4] Importantly, non-tradable goods

[3] Equivalently, Coibion and Gorodnichenko (2015), Ball and Mazumder (2011, 2018), Del Negro et al. (2020) do so for explaining US inflation behavior in the aftermath of the financial crisis.

[4] Conversely, assuming separable preferences would imply that the slope of the regional Phillips curve for non-tradable inflation is different from the slope of the aggregate Phillips curve, see appendix of Hazell et al. (2022).

are consumed only within the region they are produced whereas the market for tradable goods is fully integrated across regions. Therefore, the price index for non-tradable goods may differ across regions but the price index for tradable goods does not. Households maximize utility subject to a sequence of period budget constraints. Ponzi-schemes are ruled out such that household debt cannot exceed the present value of future income.

There is a continuum of firms both in the tradable and non-tradable goods sector which are specialized in the production of differentiated goods. Firms only use labor as input in the production of these goods (hence the production is linear in labor with constant returns to labor). Firms' price setting in both sectors follows Calvo (1983). Thus, in each period a fraction of firms $1-\alpha$ can reset their prices while the remaining fraction α cannot adjust their prices. Firms in the non-tradable sector only produce for the region where they are located (i.e. either Home or Foreign), firms in the tradable goods sector face demand from both regions forming the monetary union.

The government conducts a common monetary policy for both regions. Economy-wide inflation and unemployment are both a population weighted average of inflation and unemployment, respectively, of each region. Monetary policy is subject to a time-varying inflation target. Variation in long-run inflation yields variation in long-run unemployment since the long-run Phillips curve is not vertical. Moreover, the monetary authority targets an unemployment rate which is consistent with its long-run inflation target. The interest rate rule follows the Taylor principle ensuring that there exists a unique locally bounded equilibrium. There are no taxes, government spending nor issuance of debt, hence there is no fiscal policy. The government issues a digital currency which is in zero net supply meaning that monetary policy has no fiscal impact. The equilibrium in the two-region economy satisfies household and firm optimization, the government interest rate rule and market clearing.

2.2 The regional and aggregate Phillips curve derived from theory

Hazell et al. (2022) take a log-linear approximation of the model presented verbally in Section 2.1 around a zero-inflation steady state with balanced trade. This yields the following regional Phillips curve for *non-tradable goods* inflation

$$\pi^N_{Ht} = \beta E_t \pi^N_{H,t+1} - \kappa \hat{u}_{Ht} - \lambda \hat{p}^N_{Ht} + \nu^N_{Ht}. \tag{1}$$

and the aggregate Phillips curve for *overall* inflation

$$\pi_t = \beta E_t \pi_{t+1} - \kappa \hat{u}_t + \nu_t \tag{2}$$

where $\kappa = \lambda\varphi^{-1}$ and $\lambda = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$. $\pi^N_{Ht} = p^N_{Ht} - p^N_{H,t-1}$ is non-tradable Home inflation, $\hat{p}^N_{Ht}$ is the percentage deviation of the Home relative price of non-tradables from its steady state value of one, ν^N_{Ht} is a non-tradable Home supply shock and ν_t is an aggregate supply shock. $\hat{u}_{Ht}$ is the percentage deviation of Home unemployment u_{Ht} from its steady state value u_H. Unemployment in Home is defined as $u_{Ht} = 1 - N_{Ht}$ where N_{Ht} is total labor supply in Home. In turn, total labor supply in Home is the sum of labor demanded by firms in the tradable (N_{Ht}^T) and non-tradable (N_{Ht}^N) goods sector. Hence, in the model of the regional Phillips curve, unemployment comprises both sectors while inflation only refers to the non-tradable goods sector.[5]

The slope of the Phillips curve κ in (1) and (2) depends on two parameters: the degree of nominal rigidity λ and the Frisch elasticity of labor supply φ. λ, in turn, depends negatively on the fraction α of firms that keep their prices fixed in a given period. Hence, the larger the degree of price stickiness, the smaller λ. For the slope this means that a larger value of α, which reduces λ, ultimately leads to a smaller slope parameter.

From equation (1) and (2) follows that the slope both of the aggregate Phillips curve for overall inflation and the regional Phillips curve for non-tradable inflation are equal to κ. However, this result does not carry over to the regional Phillips curve including *tradable* inflation.[6] The intuition behind this result is that both regions consume tradable goods produced in Home and Foreign and therefore these goods are priced on the level of the whole economy. Thus, prices of tradable goods do not contribute to differences in inflation between regions. Conversely, the overall regional price index is partly made up of goods which prices are insensitive to changes in regional unemployment. Building on these theoretical results, we follow Hazell et al. (2022) and use non-tradable goods price inflation when estimating the regional Phillips curve in the cross-section of euro area member states.

The essential difference between (1) and (2) is the relative price of non-tradables, that is $\lambda\hat{p}_{Ht}^N$, in the regional Phillips curve. It implies that inflation in the non-tradables sector will be lower the higher is the relative price of non-tradables. Thus, the term pushes relative prices for tradables and non-tradables to parity in the long run. Also, local booms will not result in unbounded inflation of home non-tradables because the demand for these goods is also affected by the relative price of non-tradables to tradable goods in the whole economy. From a model point of view, the reason why this term is appearing in the equation is twofold: On one hand, non-tradable inflation is driven by variation in the real wage deflated by prices of non-tradable goods. On the other hand, labor supply is a function of the real wage deflated by the home consumer price index. Therefore, the real marginal cost variable in the non-tradable Phillips curve gives rise both to an unemployment and a relative price term (Hazell et al. 2022). Ultimately, the parameter λ measures the degree of nominal price rigidity in the economy.

To see the benefit from using cross-sectional data in estimating the regional Phillips curve, Hazell et al. (2022) solve equation (1) forward assuming that the law of iterated expectations holds.[7]. They obtain

$$\pi_{Ht}^N = -E_t \sum_{j=0}^{\infty} \beta^j (\kappa \tilde{u}_{H,t+j} + \lambda \hat{p}_{H,t+j}^N) + \beta E_t \pi_{H,t+\infty}^N + \tilde{\omega}_{Ht}^N \tag{3}$$

[5]These model specifications hold analogously for Foreign (F).

[6]In their appendix, Hazell et al. (2022) show that the slope of the regional Phillips curve for *overall* inflation is smaller than the aggregate Phillips curve by the factor of the expenditure share on non-tradable goods.

[7]Hazell et al. (2022) elaborate on this assumption in their appendix A.10 relying on Adam and Padula (2011) and Coibion et al. (2018).

where $\tilde{u}_{H,t} = u_{Ht} - E_t u_{H,t+\infty}$ and $\tilde{\omega}^N_{Ht} = E_t \sum_{j=0}^{\infty} \beta^j \nu^N_{H,t+j}$.[8] Importantly, the term $\beta E_t \pi^N_{H,t+\infty}$, that is long run inflation expectations, is constant across regions. This implies that variations in these long run inflation expectations will be absorbed by region- and time-fixed effects. The intuition is that long run inflation expectations are independent of the current business cycle and are solely determined by beliefs about the long run monetary policy regime (essentially the inflation target). These beliefs, in turn, are common across all regions (or countries, respectively) forming a monetary union, because monetary policy is set by the common central bank, which is the ECB in case of the euro area. Thus, beliefs formed by the private sector vary uniformly across regions, or countries, respectively in the monetary union. Mechanically, when estimating the regional Phillips curve, these expectations are then "differenced out" in a panel regression including time-fixed effects (Hazell et al. 2022, cp). From the perspective of the theoretical model, Hazell et al. (2022) obtain this result because productivity growth and other drivers of real costs, have a common trend across regions in the long run. There may still be differences across regions (regarding for example TFP) but if these differences are constant over time, they will be absorbed by region- or country-fixed effects, respectively. Any other remaining variation in long run inflation expectations across regions will be absorbed by the error term $\tilde{\omega}^N_{Ht}$. The main conclusion from this result is that long-run inflation expectations can be substituted by time- and region-fixed effects in the estimation. This yields the following regional Phillips curve specification

$$\pi^N_{it} = -E_t \sum_{j=0}^{\infty} \beta^j (\kappa u_{i,t+j} + \lambda \hat{p}^N_{i,t+j}) + \alpha_i + \gamma_t + \tilde{\omega}^N_{it} \quad (4)$$

where the subscript i denotes a region, or country, respectively, in the panel. α_i denotes region-fixed effects which absorb constant differences in expected non-tradable goods inflation across regions. γ_t denotes time-fixed effects which absorb time-variation in $E_t \pi^N_{t+\infty}$ that is common across all regions in the monetary union. Note also that time-fixed effects do not only absorb common long-run trends in inflation expectations but also time variation in long-run expected unemployment $E_t u_{t+\infty}$. Therefore, Hazell et al. (2022) suggest to replace $\tilde{u}_{i,t+j}$ by $u_{i,t+j}$.

The recent regional Phillips curve literature (Hooper et al. 2020; McLeay and Tenreyro 2020, cp) has established an empirical specification of equation (3) which is empirically more tractable, however, it also relies on the assumption that both u_{Ht} and $\hat{p}^N_{H,t+j}$ follow AR(1) processes, where $\psi = \kappa/(1 - \beta\rho_u)$ and $\delta = \lambda/(1 - \beta\rho_{pN})$:

$$\pi^N_{it} = -\psi u_{it} - \delta \hat{p}^N_{it} + \alpha_i + \gamma_t + \tilde{\omega}^N_{it} \quad (5)$$

Obviously, the slope coefficients in equation (4) and (5) are not the same. While κ represents the structural slope coefficient in the regional Phillips curve for non-tradable goods inflation, ψ is a reduced form slope coefficient as estimated in other recent literature. Hazell et al. (2022) argue that since unemployment is quite persistent, ψ will be substantially larger than κ in empirical estimations. Therefore, the literature estimating regional Phillips curves by means of equation (5)

[8] Again, these equations hold analogously for Foreign.

obtain significantly larger slope estimates compared to traditional estimates based on aggregate data , since they estimate the slope coefficient in equation (5) instead of (4). The persistence of unemployment then ultimately results in larger slope estimates in this Phillips curve framework using regional data, since ψ does not only reflect the impact of current unemployment on current inflation but also expected infinite future unemployment.

The regional and aggregate Phillips curves derived above are arguably based on strong assumptions which may not necessarily hold. Hazell et al. (2022) acknowledge this and include a discussion on this in their paper.

3 Data and descriptive statistics

In this section, we present the country-level panel data we use to estimate the slope of the Phillips curve in the EA. First, we discuss how we construct the non-tradable goods' price index and inflation, respectively, and compare it to other measures of inflation. Next, we summarize the data on employment and unemployment that we use to measure labor market slack and to construct the tradable demand instrument. We discuss data on inflation expectations that we use in the final part of the paper to estimate the aggregate Phillips curve in order to compare it with the estimates for the slope of the regional Phillips curve. Lastly, we present some descriptive evidence on the Phillips curve in the EA to set the stage for the formal estimation.[9]

3.1 Construction of a non-tradable goods price index

In order to estimate the regional Phillips curve using non-tradable inflation as suggested by Hazell et al. (2022), we set up a non-tradable price index on country-level for all members of the EA. In selecting the HICP sub-components to construct the non-tradable goods price index, we follow the classification of Hazell et al. (2022), see appendix A for details. We rely on Eurostat data for individual HICP sub-components on the 4-digit-level of the so-called *European classification of individual consumption according to purpose* (ECOICOP).[10] This classification on the 4-digit-level comprises 48 industries.[11] The advantage of using Eurostat's HICP and its sub-components is that its definition is harmonized across European countries and thus comparability across countries is ensured. This also makes aggregation of non-tradable sub-components easily possible. For the US, an analogous publicly available constructed index featuring sub-components on non-tradable goods on state-level does not exist. Hence, Hazell et al. (2022) build an index on their own based on

[9] An overview of all variables and data sources can be found in the appendix in Table A.1.

[10] Unfortunately, these data on sub-components are not seasonally adjusted. However, for estimation we compute year-on-year inflation rates which eliminates seasonality (Hazell et al. 2022). Moreover, we compared headline and core inflation for the euro area both using adjusted and unadjusted data and find that differences are negligible.

[11] Hazell et al. (2022) include 71 industries. However, in the Eurostat ECOICOP classification some individual industries listed in Hazell et al. (2022) are summarized together in one category. For example, "painting entire automobile", "vehicle inspection" and "automotive brake work" are summarized as "Maintenance and repair of personal transport equipment" in Eurostat's ECOICOP classification. An entire list of categories is listed in Section A of the appendix.

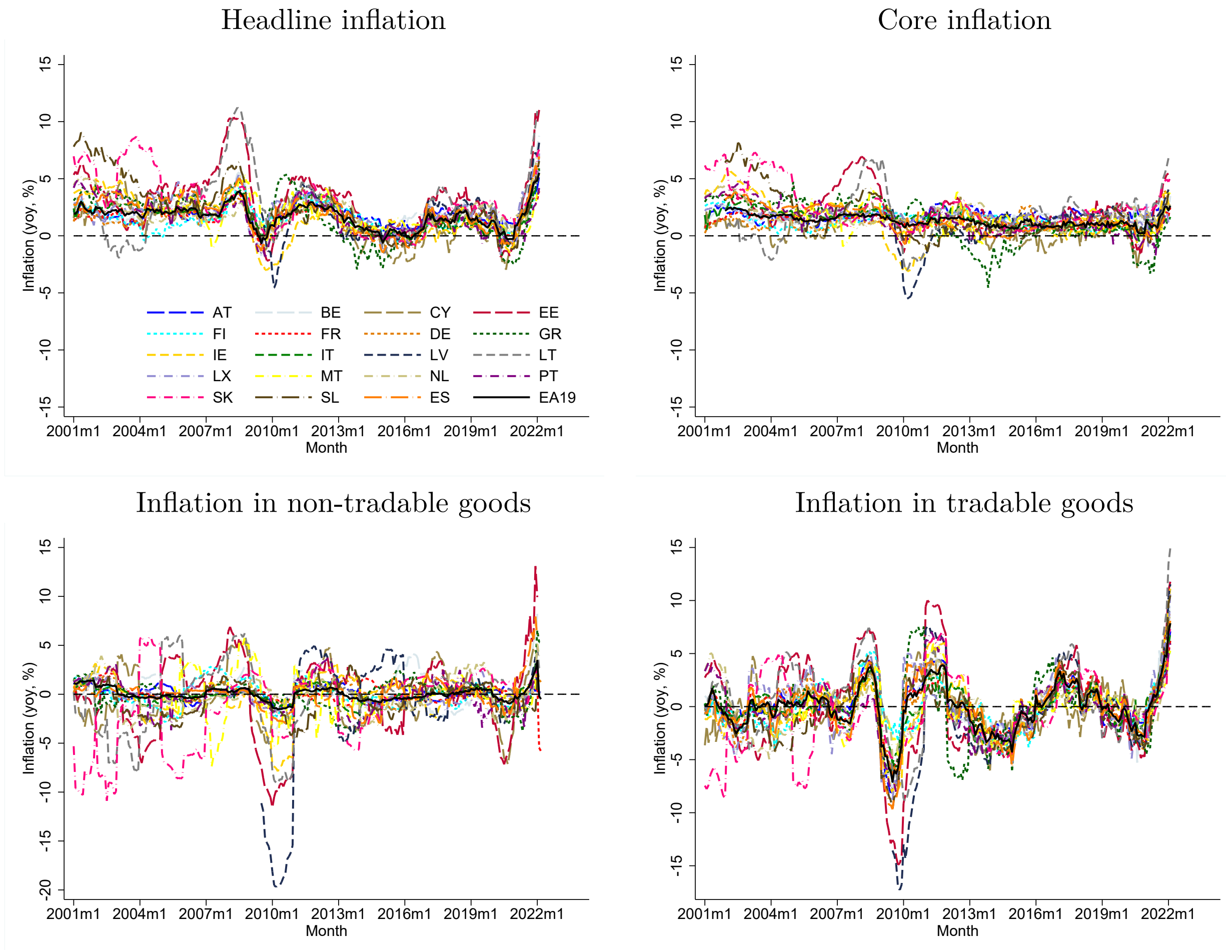
microdata on the state-level from the BLS which potentially involves measurement errors and reduces reproducibility. Finally, to compute the index, we also draw on the weights of sub-components available from Eurostat (used to set up the overall HICP).

The construction of the non-tradable price index makes use of the aggregation methodology of Eurostat deployed to set up the overall HICP on the level of individual countries. We use this aggregation method for consistency to establish the price index for non-tradables. This aggregation method comprises several steps. First, the price indexes of the sub-components on 4-digit-level have to be unchained dividing the value of each month by the value of the previous December multiplying by 100. In the next step, we aggregate the components by computing the weighted arithmetical average. Thereby, we multiply the unchained value of component i with its weight and take the sum over all categories. Then, we divide this sum by the sum of weights of all components labelled non-tradables. Finally, we again chain-link this newly computed price index to its value of the past December times 100. Data for individual HICP non-tradable components on 4-digit-level is available from 1998 onwards. However, due to the construction of the non-tradable goods price index by means of aggregation and chain-linking, the time series for non-tradable inflation starts only in 2001. For comparison and exposition in the descriptive statistics below, we also compute analogously a tradable goods price index based on HICP sub-components of Eurostat. This price index also draws on the 4-digit-level ECOICOP categories and includes the remaining components which were not classified as non-tradable goods before. The computation of the tradable goods price index is analougous to the non-tradable goods price index.

Figure 1 shows 12-month headline, core, non-tradeable and tradeable inflation rates. Several observations are in order. First, we observe that there is considerable heterogeneity among euro area members regarding all four measures of inflation. Second, we observe that there is even more heterogeneity in both non-tradable and tradable goods inflation across EA members compared to overall headline and core inflation. While tradable inflation is more volatile across time also on euro-area average (black solid line lower right panel), non-tradable inflation varies more strongly across countries. This observation is in line with the notion that prices of tradable goods have converged in the monetary union. In some instances, these goods are even priced on the level of the currency union and hence there is less price divergence which implies smaller inflation differentials across the EA (Estrada et al. 2013). Non-tradable goods, on the other hand, respond much more to country-specific marginal costs.[12] The evidence confirming the heterogeneity in non-tradable inflation across the EA strengthens our intention to estimate a regional Phillips curve using country-level data because regional variation is essential for identifying the slope parameter in this model. Moreover, this type of variation helps to overcome caveats of estimating an aggregate Phillips curve for a currency union.

[12] Consistently, Hazell et al. (2022) show that there is much more variation across US states in non-tradable inflation compared to tradable inflation by means of a principal component analysis.

Figure 1: Different measures of inflation for EA member states



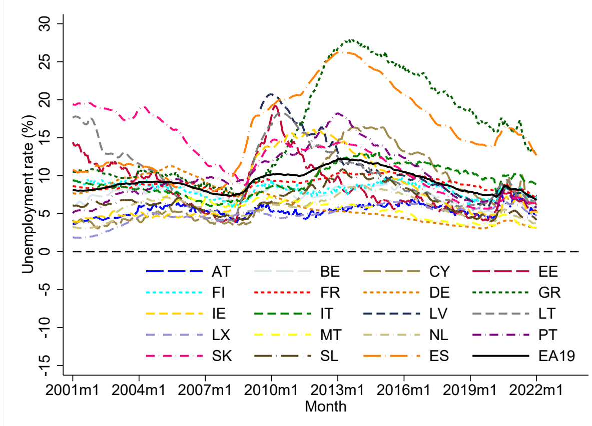
Notes: Different measures of inflation (year-on-year) measured in percent. Top row: headline (left panel) and core inflation (right panel) based on the HICP. Bottom row: non-tradable (left panel) and tradable (right panel) goods inflation. Data sources: Eurostat and own calculations

3.2 Employment data

For estimating the regional Phillips curve for the euro area following the approach of Hazell et al. (2022), we make use both of country-level unemployment and employment data. Specifically, we use the unemployment rate as as measure of economic slack. Time-series data on unemployment rates for EA members (seasonally but not working-day adjusted) on monthly frequency are available from the ECB. For estimation, we collapse monthly unemployment rates to quarterly frequency by computing the quarterly average. In the final part of the paper when estimating the Phillips curve using aggregate data we use the aggregate unemployment rate for the EA obtained from the ECB.

Cross-country variation in unemployment among EA member states is essential for identifying the slope of the regional Phillips curve in a panel data set up (Hazell et al. 2022). Figure 2 plots

Figure 2: Unemployment rates in the EA



Notes: Country-level unemployment rates at monthly frequency are measured in percent and seasonally adjusted. Data source: ECB.

unemployment rates for all member states (colored lines) and the aggregate of the EA19 (black solid line) between 2001M1 and 2022M1. Quite strikingly, unemployment rates in the EA vary a great deal over the sample period, both across the members of the currency union and on the level of individual countries. Still, we observe some co-movement over time, especially regarding the hike in response to the financial crisis and the subsequent decline over the past few years. These observations are in line with what Hazell et al. (2022) show for the US, indicating that their approach of estimating the slope of the regional Phillips curve is suitable for the EA, too. In fact, it seems to be even more applicable, as unemployment across the EA varies between roughly 5 percent in core countries (cp. Luxembourg, Austria and Germany) and up to 30 percent for countries of the periphery (cp. Greece and Spain). On the contrary, according to Hazell et al. (2022), unemployment rates in the US vary only between 5 and roughly 12 percent. Hence, exploitable variation is much larger in the EA compared to the US.

For estimating the regional Phillips curve, Hazell et al. (2022) construct a tradable demand instrument based on tradable employment shares in the spirit of Bartik (1991), see Section 4.1 below. We follow this practice and use country-specific sectoral employment data for all EA member states extracted from Eurostat to construct the instrument. In the choice of sectors included, we rely again on Hazell et al. (2022), following Mian and Sufi (2014). Specifically, Hazell et al. (2022) include the following sectors to compute the tradable employment shares: "Agriculture, forestry, fishing and hunting", "Mining, quarrying and oil and gas extraction", and manufacturing.[13] For the EA, sectoral employment data (not seasonally adjusted) is available on quarterly frequency on the level of A10 sectors according to the European Classification of Economic Activities (NACE rev.2). Based on this sectoral classification and aggregation level, we include the sectors "Agriculture, forestry,

[13] According to the Standard Industrial Classification (SIC) and the North America Industry Classification System (NAICS) for the US, these are SIC sectors A, B, and D, and NAICS sectors 11, 21, and 31 to 33.

fishing" and "Industry (w/o construction)" when computing the tradable employment shares.[14] Since the sectoral employment data is not seasonally adjusted, the tradable demand instrument based on employment shares needs to be seasonally adjusted. Again, we follow Hazell et al. (2022) and exponentially smooth the time series based on a moving-average process. For details on the construction of the instrument, see Section 4.1 below.

3.3 Inflation expectations data

In the last part of the paper, we compare estimates of the slope of the regional Phillips curve for the EA with slope estimates based on aggregate data and different measures of inflation expectations. Aggregate data on year-on-year headline and core inflation based on the HICP for the EA come from the ECB. These time series are seasonally adjusted and on quarterly frequency.

Data on professional inflation expectations come from the Survey of Professional Forecasters (SPF) conducted by the ECB on quarterly frequency.[15] In this survey, professional economists are asked, among other things, about their forecasts of inflation over various horizons. For example, they are asked to provide a point estimate of the year-on-year change in inflation in the future based on the HICP published by Eurostat. The survey question itself covers six different time horizons: current calendar year, next calendar year, calendar year after next, 12-months ahead, 24-months ahead and 60-months ahead. The survey is conducted quarterly in January, April, June and October. Questionnaires are distributed just after the Eurostat press release of the final estimate of last month's inflation rate. Hence, experts know the inflation rate with a lag of one month but have no information on the estimated current inflation rate. Questionnaires completed have to be returned to the ECB within one week. On average, sixty professionals participate each quarter in the survey. However, the panel is unbalanced as forecasters drop out and are replaced by others each round the survey is conducted (López-Pérez 2017). In the estimation below, we draw on two distinct measures of professional inflation expectations: short-term and longer-term forecasts. For the short term we use the 12-month ahead forecasts and for the longer-term expectations we use the 60-month ahead forecasts of the SPF.

Data on quantitative household (or consumer) inflation expectations come from the Business and Consumer Survey (BCS) conducted by the Directorate-General for Economic and Financial Affairs (DGECFIN) of the European Commission (EC). For an overview and evaluation of the data on the country level, see Arioli et al. (2017). Since 1985, the survey is conducted nationally by partner institutions such as ministries or research institutes in each member country of the European Union

[14]Based on the definition of NACE rev.2, these are sectors A and B-E. B-E, that are the sectors summarized as "Industry w/o (construction)", also include "Electricity etc. supply" (D) and "Water supply and sewage" (E) next to "Mining" (B) and "Manufacturing" (C). These sectors are not included by Hazell et al. (2022) in their employment data. However, the sectors B and C are not separately available from Eurostat, hence we use the composite. We checked employment shares for D and E based on NACE rev.2 A64 classification and find that for sector D it was 0.45 percent and for sector E it was 0.72 percent in 2020 of total employment in the EA. We conclude that these sectors are only of minor importance and will not bias results substantially.

[15]Information on the survey and the questionnaire can be retrieved from the website of the ECB SPF

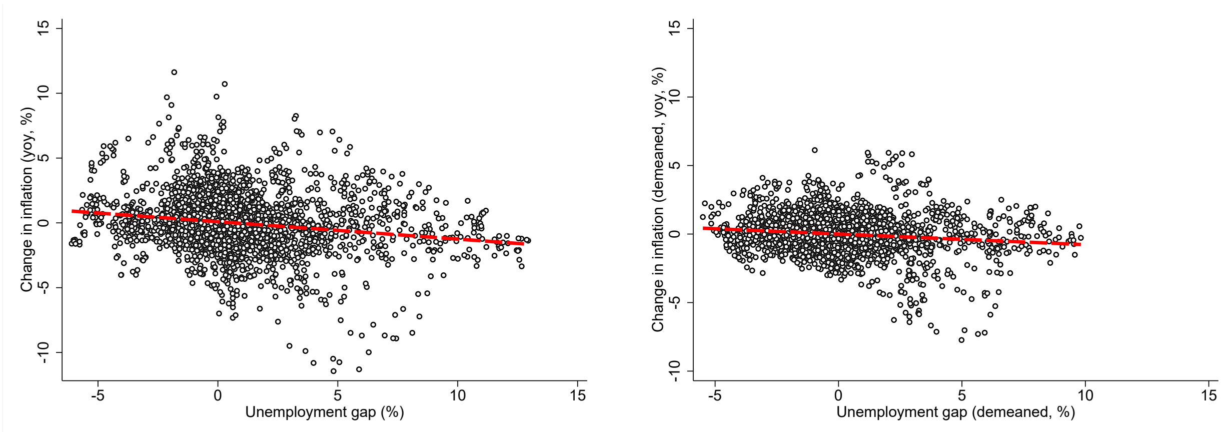
or respectively the EA. Each partner institution is responsible for the sampling frame and sampling methods. The questionnaires, however, are harmonized across countries. For the EA as a whole, the sample includes around 21,000 households. For each country, the individual sample size differs according to its population size. The survey is conducted on a monthly base and interviews take place in the second or third week of each month. By then, people surveyed know at most the last month's inflation rate. The survey question asks for a quantitative estimate of how consumer prices will develop over the next twelve months. Eventually, the EA aggregate is computed as a weighted average of country-aggregate responses. The time series of monthly quantitative consumer inflation expectations is collapsed to quarterly frequency for estimation purposes.

Lastly, we also incorporate a measure of market-based inflation expectations in the analysis below. Therefore, we use data on inflation-linked swaps from Refinitiv accessed through Datastream. Daily data is aggregated to quarterly frequency by taking the end-of-quarter value to take all relevant information of market participants in a given quarter into account. Inflation-linked swaps are financial derivatives by which one contracting party (inflation receiver) is entitled to receive a payment equal to the realized inflation rate times a nominal value in exchange for paying a fixed rate (times a nominal value) to the other contracting party (inflation payer) over an agreed period of time settled in the contract (Grothe and Meyler 2017). This fixed rate, also called fixed leg, indicates the expected inflation rate over the duration of the contract. At maturity of the swap, the difference in the fixed leg and the realized inflation rate are exchanged. Therefore, inflation-linked swaps with different maturities reflect different horizons of inflation expectations. In the analysis below, we use one-year (five-year) spot rates to measure one-year (five-year) ahead market-based inflation expectations and one-year forward rates to measure inflation expectations two-years ahead. Inflation-linked swaps are indexed to Eurostat's HICP excluding tobacco (HICPxT). However, both time series of inflation based on the HICP and HICPxT move very closely, see Grothe and Meyler (2017), so we do not expect major distortions because of this indexation. Another caveat is the timing of the inflation-linked swap contract, called the indexation lag. Swaps are written on HICPxT inflation realized three months before the contract starts. This means that the fixed rate agreed upon actually only reflects 9-months of *expected* inflation in addition to past 3-month *realized* inflation. Thus, the forecast horizon differs slightly with respect to the other surveys described above. For larger horizons, when drawing on forward inflation swap rates, this distortion diminishes (Miccoli and Neri 2018). Another type of distortion in the fixed rate may also arise due to inflation risk which drives risk premia up. Nevertheless, because of their nature as traded instruments, inflation-linked swaps include expectations of a variety of market participants on a high-frequency level and thus include much more information on an aggregated level compared to alternative measures.

3.4 Stylized facts on the Phillips curve in the EA

Before diving into the formal analysis of the Phillips curve in the EA, we want to present some stylized facts about the trade-off. Figure 3 plots the accelerationist Phillips curve which results

Figure 3: Phillips correlation - inflation gap vs unemployment gap

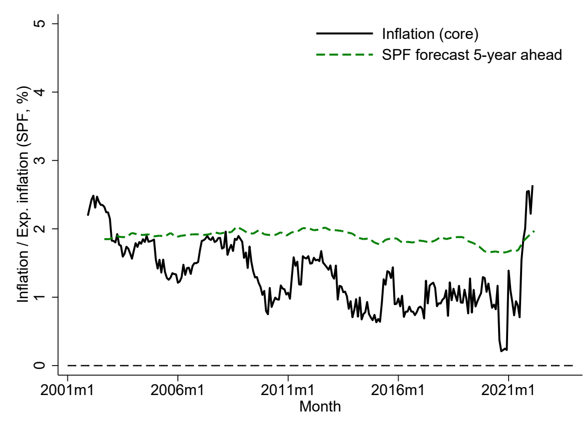


Note: Inflation gap is the year-on-year change in the 12-month inflation rate in percent and the unemployment gap is the difference between the unemployment rate and the NAIRU in percent. Right panel: observations have been demeaned by country and over time. The sample ranges from 2001M1 to 2022M2. The red dashed lines indicate the linear fit of the change in inflation on the unemployment gap. Data sources: ECB, Eurostat, OECD

when assuming backward-looking or adaptive inflation expectations. Stock and Watson (2020) refer to this as the "Phillips correlation". We plot the year-on-year change in the 12-month inflation rate against the unemployment gap defined as the difference between the unemployment rate and the NAIRU published by the OECD. Both variables are measured at monthly frequency on country-level. Additionally, observations in the right panel have been demeaned by country and over time to illustrate the impact of controlling for country- and time-fixed effects similarly to the estimation of the regional Phillips curve below. The red dashed lines indicate the linear fit of a regression of the change in inflation on the unemployment gap. A first glance at the scatter plots suggests that inflation across the euro area is relatively insensitive to changes in unemployment. The systematic relationship between inflation and unemployment seems to be only small in the EA similar to the US as Hazell et al. (2022) point out. By means of pure eyeballing, we observe that the fitted line is almost flat in both panels, even more so in the right one. The estimated slope coefficients which are -0.1341 (p-value: 0.0000) in the left panel and even only -0.0775 (p-value: 0.0000) in the right panel support this observation. Hence, this descriptive evidence suggests that the slope substantially reduces when one accounts for common trends across countries and over time, which are nothing more than long-run inflation expectations in the model of the regional Phillips curve according to Hazell et al. (2022).

Figure 4 illustrates the 12-month core inflation rate based on the core HICP excluding food and energy and the 5-year ahead expected inflation rate measured by the SPF. We clearly observe that, since the introduction of the euro, longer-term inflation expectations of professional forecasters have been stable at close to but below 2 percent, the inflation target of the ECB until mid-2021. Combining the evidence of very stable long run inflation expectations and the forward-solved

Figure 4: Core inflation and long run inflation expectations

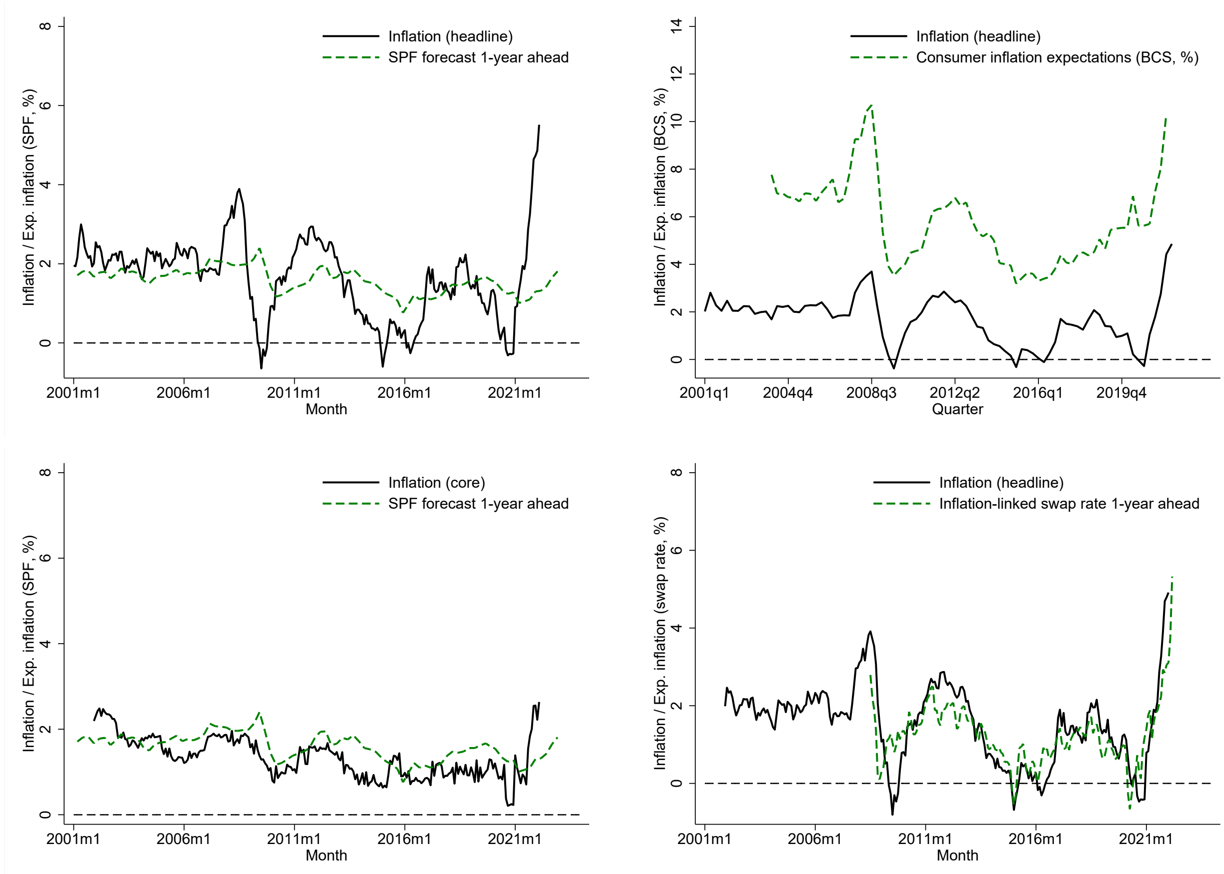


Note: Inflation is the year-on-year change in the core HICP (excluding food, energy, tobacco and alcohol) at monthly frequency for the euro area aggregate expressed in percent. Expected inflation is the 5-year ahead mean forecast of the SPF conducted by the ECB measured in percent.

formulation of the Phillips curve (as in Hazell et al. (2022)) suggests that there is only little room for a steeper Phillips curve in the EA since long run inflation expectations feed strongly into current inflation. Again, this is a similar observation compared to the US.

Figure 5 plots various measures of inflation and inflation expectations. The top left panel of Figure 5 plots headline inflation and professional inflation expectations and the top right panel plots headline inflation and consumer inflation expectations. The bottom left panel plots core inflation and professional inflation expectations while the bottom right panel plots headline inflation (excl. tobacco) and market-based inflation expectations based on the inflation-linked swap rate one-year ahead. A number of observations stand out. Evidently, the size of the inflation gap, that is the difference between inflation and expected inflation, depends on the measure of inflation expectations. While the gap is relatively small for professional and market-based inflation expectations, it is quite large when using household inflation expectations. This is in line with recent findings by D'Acunto et al. (2022) who show that household inflation expectations are generally upward biased. The gap only became larger also for professional inflation expectations in late 2021 when the supply chain shock induced by the Covid-19 pandemic finally resulted in price increases. Still, professional forecasters' expectations were sluggish to adjust. This observation suggests that estimates of the slope of the aggregate Phillips curve may strongly depend on the measure of expectations used, ultimately leading to wrong conclusions also pointed out by Hazell et al. (2022) for the US. We also observe that professional forecasters track core inflation more closely than headline inflation while consumers rather focus on headline inflation including food and energy prices, that is consumption goods of daily life. Moreover, households overstate inflation strongly. This may again blur conclusions derived from the estimation of the aggregate Phillips curve. Finally, a key take

Figure 5: Inflation and different measures of expected inflation



Note: Headline (core) inflation is the year-on-year change in overall HICP (excluding food and energy) at monthly frequency expressed in percent. Top: Left panel shows expected inflation measured by one-year ahead mean forecast of the SPF in percent. Right panel shows expected consumer inflation over the next year in percent. Bottom: Left panel shows core inflation and one-year ahead professional inflation expectations. Right panel shows 12-month headline inflation (excl. tobacco) and inflation-linked swap rate one-year ahead. All time series refer to the EA aggregate. Data source: ECB, Eurostat, EC, Refinitiv via Datastream.

away from Figure 5 is that the inflation gap between realized and expected inflation is rather small throughout the sample (except for consumer inflation expectations) although unemployment rates in the euro area were high at times across some member states (cp. Figure 2). Again, this suggests that the Phillips curve is rather flat.

4 The slope of the regional Phillips curve in the EA

We start out this section by presenting the empirical specifications that we estimate to determine the slope of the regional Phillips curve. Next, we present our results and discuss robustness checks with respect to the methodology on the fly. Finally, we estimate a specification of the aggregate

Phillips curve using several direct measures of inflation expectations and compare our results.

4.1 The empirical specification of the regional Phillips curve

In Section 2 we have summarized the derivation of the regional and aggregate Phillips curve within a basic New Keynesian model. Of course, equation (4) is not suitable for direct estimation using country-level data. Hence, Hazell et al. (2022) propose to replace the expected infinite sums of future employment and the relative price of non-tradeable goods with realized values truncated at $j = T$. This results in the following equation:

$$\pi_{it}^N = -\sum_{j=0}^{T} \beta^j \kappa u_{i,t+j} - \lambda \sum_{j=0}^{T} \beta^j \hat{p}_{i,t+j}^N + \alpha_i + \gamma_t + \tilde{\omega}_{i,t}^N + \eta_{i,t}^N \tag{6}$$

Again, α_i and γ_t denote country- and time-fixed effects, $\tilde{\omega}_{i,t}^N$ denotes a sequence of discounted supply shocks and $\eta_{i,t}^N$ denotes an expectation and truncation error term. This empirical specification of the model-derived regional Phillips curve can be estimated in principal using GMM methods by instrumenting for the expected future sums. Hazell et al. (2022) assume β to be 0.99 in the baseline specification. Furthermore, regarding the identification of supply shocks $\tilde{\omega}_{i,t}^N$, Hazell et al. (2022) argue that supply shocks in the tradable goods sector in one region are not systematically correlated with supply shocks to the non-tradable sector in another region.[16] Also, as indicated above, supply shocks common to the monetary union are absorbed by time-fixed effects. Only region-specific supply shocks to the non-tradeable sector are potential confounders.

Hazell et al. (2022) propose two identification strategies to estimate equation (6). First, they suggest to instrument for each of the forward sums in equation (6) with the four-quarter lagged values of unemployment $u_{i,t}$ and the relative price $\hat{p}_{i,t+j}^N$, itself. They argue that because of the assumption of rational expectations, lagged variables are uncorrelated with the expectations error. Regarding the practical implementation, this means that in the first stage we will truncate the infinite sums at a value of $T = 20$ quarters (following Hazell et al. (2022)) and then regress each one of them on the four-quarter lagged value of unemployment and the relative price including time- and country-fixed effects.[17]. Importantly, due to the truncation of the forward sums at $T = 20$ months, one looses 5 years of observations at the end of the sample.[18] This means the first stage is only estimated on a reduced sample.[19] Standard errors are clustered at the country level and corrected using the correction method of Chodorow-Reich and Wieland (2020) (because of the two-sample 2SLS estimation). In the second stage, we regress four-quarter country-level

[16]Consider, for example, an energy supply shock in Germany relative to Spain, which is not systematically correlated with changes in hairdresser technology in Spain relative to Germany.

[17]For the matter of illustrating the impact and robustness of their theoretical results regarding the inclusion of fixed effects, they include time- and region-fixed effects consecutively. We will follow this practice here.

[18]Hazell et al. (2022) verify their choice of the truncation length by estimating equation (6) on simulated data. In addition to that, they do robustness tests using different values for T. We follow this practice, see below.

[19]Conversely, for the second stage we follow Hazell et al. (2022) and use the whole sample to obtain estimates of κ and λ.

non-tradable inflation over the previous year on the predicted values for the two forward sums from the first stage regression and country- and time-fixed effects. In this way, measurement errors and seasonality are eliminated. Hazell et al. (2022) argue that using year-on-year inflation compared to quarterly inflation, as defined in the theoretical derivation, implies that estimates of κ have to be divided by four in order to account for time aggregation.[20] We follow this practice here.

The second approach of Hazell et al. (2022) to identify the slope of the regional Phillips curve is to construct an instrumental variable that captures differentiated labor demand in the tradable and non-tradable goods sector across the monetary union.[21] This "tradable-demand spillovers" instrument $Z_{i,t}$ is defined as

$$Z_{i,t} = \sum_x [\bar{S}_{x,i} \times \Delta_{3Y} \log S_{-i,x,t}] \tag{7}$$

where $\bar{S}_x, i$ is the average employment share of industry x in country i over time and $\Delta_{3Y} \log S_{-i,x,t}$ is the three-year growth rate in union-wide employment of industry x at time t excluding country i. The identifying assumption is that there are no supply factors that are both correlated with the shifts in $\Delta_{3Y} \log S_{-i,x,t}$ and the average employment share $\bar{S}_{x,i}$ in the cross-section.[22] Practically, we will proceed similar to the first approach outlined above: In the first stage regression, we instrument the truncated forward sums with the four-quarter lagged tradable-demand instrument and the four-quarter lagged relative price of non-tradables. Again, this can only be estimated on a reduced sample because of the truncation of the forward sums at $T = 20$ quarters. Then, in the second stage, we regress year-on-year country-level non-tradable inflation on the predicted values from the first stage including country- and time-fixed effects based on the whole sample.[23]. Standard errors are again clustered at the country-level and corrected for sample-size adjustments as in Chodorow-Reich and Wieland (2020).

In addition, Hazell et al. (2022) also provide an empirical specification of the recently developed and more tractable definition of the regional Phillips curve, that is equation (5):

$$\pi^N_{it} = \alpha_i + \gamma_t - \psi u_{i,t-4} - \delta p^N_{i,t-4} + \varepsilon_i t \tag{8}$$

In estimating equation (8) we follow Hazell et al. (2022) and use OLS to regress year-on-year non-tradable inflation on four-quarter lagged unemployment and the four-quarter lagged relative price of non-tradable goods. Secondly, again, we use the tradeable demand instrument described in equation (7) and instrument for lagged unemployment.

[20]Compare their appendix A.11.

[21]In setting up the instrument, Hazell et al. (2022) follow Bartik (1991).

[22]To give an example, when costs increase as a result of an increase in energy prices (which is the case across the whole Euro area as a result of the war in the Ukraine) but these increases are on average the same in Spain compared to Germany, then these cost increases will be uncorrelated with the instrument.

[23]This procedure follows again the two-sample 2SLS estimation put forward by Chodorow-Reich and Wieland (2020) and implemented by Hazell et al. (2022).

Table 1: The slope of the regional Phillips curve in the EA

	Lagged Unemployment			Tradable Demand IV
	(1)	(2)	(3)	(4)
Estimates of κ from equation (6)				
κ	0.0024^{**} (0.0009)	0.0072^{**} (0.0031)	0.0031 (0.0019)	0.0043^{**} (0.0018)
N	1346	1346	1346	842
Estimates of ψ from equation (8)				
ψ	0.0782^{**} (0.0334)	0.1208^{*} (0.0450)	0.0927^{**} (0.0397)	-0.9939 (1.3264)
N	1526	1526	1526	1022
Country FE	no	yes	yes	yes
Time FE	no	no	yes	yes

Note: Table shows estimates of equation (6) and (8). The dependent variable is year-on-year non-tradable inflation measured in percentage points. In column (1) to (3) of the top panel the regressors are the discounted future sum of unemployment in percentage points and the relative price of nontradables in 100 × log points. In column (4) we instrument the discounted sum of future unemployment by the tradable demand instrument according to equation (7). In column (1) to (3) of the bottom panel the regressors are the fourth lag of unemployment and the relative price of non-tradables. Country- and time-fixed effects are included according to the bottom two rows. Standard errors are reported in parentheses and clustered at the country level. * p<0.10, ** p<0.05, *** p<0.01.

4.2 Baseline results

We estimate the empirical specifications (6) and (8) of the regional Phillips curve by two-sample 2SLS and apply the correction method of Chodorow-Reich and Wieland (2020) to the standard errors clustered at the country-level to adjust for varying sample size. We include country- and time-fixed effects consecutively in the estimation. The data is in quarterly frequency and the sample runs from 2001Q to 2021Q4. We include all EA19 countries and follow the classification of Ilzetzki et al. (2019) and Corsetti et al. (2021) when including observations for countries having joined the EA after its initial formation.[24]

Table 1 summarizes the baseline results from estimating the regional Phillips curve specifications (6) and (8). We start by summarizing the results obtained for the structural slope coefficient κ shown in the top panel. First, consistently across specifications, we observe that the slope coefficient has the correct sign: when unemployment increases, inflation goes down.[25] Moreover, we consistently

[24]Corsetti et al. (2021) provide an exchange rate classification based on the coding of Ilzetzki et al. (2019) for all EA19 members. When setting up this classification, they argue that in fact new members already had a peg to the euro before joining the currency union officially, see Table 1 in their paper and the online appendix. Consequently, these countries' monetary policy was not independent but rather guided by the ECB. We build on this argument and include new members before their actual accession given the national currency was pegged to the euro.

[25]Recall that the sign of the structural parameter κ in equation (4) is negative. For ease of interpretation of the

observe that the slope of the regional Phillips curve is indeed very small but mostly significant. However, we also notice that the size of the coefficient varies strongly across specifications regarding the inclusion of fixed effects and the choice of the instrument. We start by considering the first three columns. While the coefficient is significant when not including fixed effects and including only country-fixed effects it is not significant when including both types of fixed effects. Moreover, it halves in size and is closer to the estimated coefficient excluding fixed effects completely. This result casts some doubts whether one of the main features of this new approach to estimate the Phillips curve, namely the elimination of long-run inflation expectations by means of time-fixed effects applies to the EA. Comparing only columns (2) and (3), it does not seem to be the case. However, it might also be that using the truncated discounted future sum of unemployment as instrument is not a good choice, as column (4) illustrates. When including the tradable demand instrument, the estimated coefficient is significant and lies in the middle of the estimated coefficients excluding time-fixed effects. Hence, while excluding fixed effects understates the slope of the Phillips curve, only including country-fixed effects overstates it. Only when including both types of fixed effects and relying on the tradable demand instrument we obtain a more accurate estimate of the size of the slope. Overall, the small values for the estimated slope coefficients are consistent with the notion that the response of inflation to movements was rather insensitive over the last two decades although unemployment varied a lot for some member states, see Figure 2. Still, our results show that the Phillips curve itself is flat but stable contrary to what many critics have argued.

To illustrate that our estimates do not suffer from weak instruments, we present results of the first stage regressions for the discounted future sum of unemyployment and the relative price of non-tradables in Table A.1. As we observe in the top panel, lagged unemployment and tradable demand strongly predict the present value of unemployment while the lagged relative price does not. For the present value of the relative price of non-tradables roughly the opposite holds true, as expected. The lagged relative price has a strong predictive power while lagged unemployment only weakly predicts the discounted future sum of the relative price of non-tradables. Moreover, the tradable demand instrument does not significantly predict the relative price. From these observations we conclude that all three variables are appropriate choices of instruments.

Table A.2 shows the estimates for λ, that is the coefficient on the relative price of non-tradable goods in equation (6). Here, we consistently observe that the coefficients are close to zero or even zero depending on the choice of fixed effects. These result indicate that prices in the euro area are very rigid, which has been documented before (Dhyne et al. 2006, e.g.) and is comparable to the findings for the US, see Hazell et al. (2022). It also squares with the empirical finding that the slope of the regional Phillips curve is very flat in the EA. Consistent with the theoretical model, a small value of λ indicates a high degree of price stickiness and thus leads to a small slope parameter κ.

Regarding the methodology proposed in Section 2, there are two robustness checks in order. First, we want to point to the choice of the value of the discount factor β which impacts the slope of

empirical result, we multiplied inflation by (-1) when estimating equation (6). In this way, we followed the practice of Hazell et al. (2022).

the Phillips curve through the instrumented forward sums of unemployment and the relative price of non-tradables. Intuitively, the smaller the value for β the more emphasis firms put on the present compared to the future when setting their price. We show results both for using the truncated sum of future unemployment as well as tradable demand as instrument in Table A.3 in the appendix. We find that the value of κ increases as the value of β decreases. It even triples in size when we move from $\beta = 0.99$ to $\beta = 0.90$. This effect is even larger compared to findings for the US were the slope coefficient only doubles. This indicates that prices adjust even more sluggish in the EA compared to the US (Dhyne et al. 2006, cp.). Still, in absolute terms the estimated slope coefficients are still small and thus the Phillips curve appears flat.

In addition, we vary the choice of the truncation length T from 20 to 30 when computing the discounted forward sums of unemployment and the relative price of non-tradables.[26] Again, we show results for both choices of instruments in Table A.4 in the appendix. We find that in case of using the tradable demand instrument the results are stable across the choice of the truncation length. This is in line with results for the US. For lagged unemployment, the results are a bit mixed but still not significant.

Let us now turn to estimates of ψ based on equation (8), see bottom panel of Table 1. A robust finding across the specifications in column (1) to (3) is that the slope parameter of the Phillips curve is significantly negative and substantially larger in absolute terms compared to the estimates for κ. This result is reasonable, as Hazell et al. (2022) argue, because unemployment is quite persistent over time and since the variation in the future sum of unemployment is greater than in unemployment itself, also the estimate of ψ should be larger than the estimate of κ. Another consistent finding is that the specification without fixed effects again underestimates the slope while the specification including only country-fixed effects again overestimates the slope. The estimate including both types of fixed effects reconciles the results. Overall, based on these estimates of ψ one would conclude that the Phillips curve is steeper than it actually is, as predicted by Hazell et al. (2022). In contrast to the top panel, we observe that using the tradable demand instrument for identifying the slope in this specification does not show consistent results. The coefficient has the opposite sign contrary to what we expect and is not statistically significant. Hence, when estimating the reduced-form specification of the Phillips curve, the tradable demand instrument seems not to be a good choice for identification.

As we are heavily drawing on the methodology proposed originally by Hazell et al. (2022), we want to compare their results to ours for the EA. Regarding the estimates of κ, we find that overall the results are in a very similar ballpark. Both in the US and the EA the slope coefficients of the Phillips curve are significantly negative and rather small. Comparing their preferred specification using the tradable demand instrument, they find a value for κ of 0.0062 based on the whole sample while we find a value of 0.0043. When they estimate the model on the post-1990 period only, which makes the sample more comparable to ours, they find an even lower value, namely 0.0055. Hence, in

[26] In contrast to Hazell et al. (2022) we did not extend T to 40 because the sample for the EA is considerably shorter compared to the US sample.

Table 2: The slope of the aggregate Phillips curve using different measures of inflation expectations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
κ	0.1925*** (0.0575)	−0.0668 (0.0571)	0.2096*** (0.0650)	0.3812*** (0.0550)	0.0971 (0.0650)	0.1822*** (0.0681)	0.2213*** (0.0586)
N	88	72	89	78	54	54	33

Note: Table presents estimates of equation (9). Model (1) uses a moving average of past 4-quarter inflation to proxy adaptive expectations. Model (2) uses one-year ahead consumer inflation expectations from the BCS. Models (3) and (4) use 12-months and 60-months ahead professional inflation expectations from the SPF. Model (5) - (7) use 12-months ahead, 60-months ahead and 1-year-1-year-forward market-based inflation expectations derived from inflation-linked swaps. Standard errors are reported in parentheses and clustered at the country level. * p<0.10, ** p<0.05, *** p<0.01.

both currency unions the Phillips curve is flat but robustly stable over the last two to three decades. Still, we want to mention that their results are invariant to the choice of the instrument (truncated forward sum of unemployment versus tradable demand) while our results are more convincing based on the tradable demand instrument. Regarding the estimates of the reduced-form coefficient ψ, they also obtain consistently larger estimates compared to κ, even much larger compared to ours. However, they do not find discrepancies across the choice of the instrument. Overall, it seems fair to say that the results we obtain are in line with those of Hazell et al. (2022) for the US and the relation between inflation and unemployment does not differ greatly across the monetary unions.

4.3 Comparison with aggregate Phillips curve estimates

As we mentioned in the introduction, the current literature on estimating the Phillips curve for the EA relies on aggregate data and uses direct measures of inflation expectations to identify the slope of the Phillips curve. Frequently applied measures of expected inflation are based on household or professional forecaster surveys or even market-based using inflation-linked swaps. In the final part of the paper we now want to compare our results for estimating the regional Phillips curve with "traditional" estimates based on aggregate time series. Therefore, we present our own estimates for a specification of the aggregate Phillips curve or rather the NKPC and compare them to our results summarized in Section 4 as well as recent findings in the literature. Following Coibion and Gorodnichenko (2015), we estimate the following equation:

$$\pi_t = \beta E_t^i(\pi_{t+h}) + \kappa u_t + \varepsilon_t. \tag{9}$$

Here, π_t measures year-on-year *headline* inflation at time t, u_t is the unemployment rate at time t and ε_t is the error term. $E_t^i(\pi_{t+h})$ is expected inflation over the horizon h and i denotes the type of direct measure of inflation expectations applied. Specifically, we rely on 4 different types of measures. First, we use adaptive expectations which implies that the best proxy for next quarter's inflation rate is a measure of past inflation. Formally, we use a moving average of past 4-quarter inflation. Next, we use consumer inflation expectations of the BCS and professional forecasters' inflation expectations as described in Section 3.3. More precisely, household expectations only extend over the next 12 months, that is $h = 1$ year, while we have a short-term ($h = 1$) and a longer-term ($h = 5$) measure available from the SPF. Lastly, we consider three different measures of inflation expectations based on inflation-linked swaps. We include inflation expectations 1- and 5-years ahead based on spot swap rates and 2-years ahead based on a forward inflation-linked swap. For details on the derivation, we refer to Section 3.3.

We present results for κ in Table 2.[27] Consistently across specifications, except for (2) where we use consumer inflation expectations, the estimated slope coefficient has the expected sign and is statistically significant. However, we observe that the absolute values of the estimated coefficients are substantially larger compared to the results for κ in Table 1. The estimated slope coefficients vary between 0.0971 and 0.3812 depending on the choice of inflation expectations. These values square with the descriptive evidence presented in the left panel of Figure 3 where the slope coefficient of the fitted line is 0.1341 in absolute terms. Hence, when using aggregate data, one can get the impression that the slope of the Phillips curve is much steeper compared to estimates using cross-sectional data. We also note that the further ahead inflation expectations reach into the future the larger the estimated coefficient. It roughly doubles in size between one- and five-years ahead into the future. Moreover, the slope is consistently larger across horizons for professional forecasters' expectations compared to market-based expectations. This fits evidence shown in Figure 5: market-based expectations follow actual headline inflation most closely, even closer than professional forecaster' expectations, which leads to smaller inflation gaps. Finally, we observe that estimates of κ presented in Table 2 exceed estimates of ψ shown in Table 1 at least by a factor of two or even three. Altogether, these findings building on aggregate euro area data coincide with several concerns raised in the literature. First, taking an isolated look at Table 2, aggregate estimates are quite sensible to the choice of specification, especially with respect to the measure of inflation expectations, a fact already pointed out by Mavroeidis et al. (2014). Depending on the choice of inflation expectations, estimates may be up to three times larger. Hence, direct (survey) measures of inflation expectations may not be as informative as one might assume when estimating the Phillips curve. Hazell et al. (2022) raise a second concern referring to the use of longer-term aggregate expectation measures. They argue that using longer-term expectations instead of one-year ahead expectations (as is the case in our specifications (4), (6) and (7)) one may end up estimating ψ instead of κ and therefore obtain larger estimates. This concern squares with our empirical findings presented in Table 2. When we proxy for longer-term expectations, say two- or five-years ahead, estimates become substantially larger. They even exceed estimated values of ψ. Only when one translates estimates from ψ to κ, for example using $\psi = \frac{\kappa}{1-\beta\rho_u}$ aggregate and regional estimates of κ are comparable (Hazell et al. 2022).

[27] To make results comparable with Table 1, again we multiplied the inflation rate by (-1) when we estimated equation (9).

Lastly, we compare our results shown in Table 1 and 2 with the most recent literature estimating Phillips curves using mostly aggregate data for the euro area.[28] Table 3 shows the estimated coefficients in recently published studies. At first glance, we observe that the variation in the reported coefficients is quite sizable, ranging from 0.07 to 0.63 which exceeds by far the results we obtain when we estimate an aggregate Phillips curve using different measures of inflation expectations. This finding is not surprising: after all, the slope of the estimated slope parameter depends strongly on the model specification and thus large differences in estimates are likely (Mavroeidis et al. 2014, c.p).

The slope coefficient estimated by Eser et al. (2020) is most close to our estimate of the regional Phillips curve. Interestingly, they estimate an aggregate Phillips curve using a measure of adaptive expectations and pooled country-level data for 18 euro area member states for identification. This coherence shows that building on cross-sectional data to estimate a Phillips curve in a monetary union can significantly change results and contributes to a better understanding of the relationship between inflation and unemployment during a decade of low inflation. Seemingly, the Phillips curve is not dead as people have argued (Hall 2013) but has rather become quite flat but stable over the last years.

Bobeica and Sokol (2019) and Moretti et al. (2019) both find somewhat smaller estimates for the aggregate Phillips curve. However, they both employ a thick-modelling estimation strategy by which they estimate a large number of different specifications and then report the median value for the slope coefficient. Thereby, they alleviate concerns of misspecification for example regarding the choice of inflation expectations. In this way, estimates become closer to the regional Phillips curve which does not rely on explicit measures of expected inflation.[29] Kulikov and Reigl (2020) estimate amongst other things also an aggregate Phillips curve including SPF inflation expectations one-year ahead. Their coefficient of 0.1359 is comparable to our coefficient shown in column (3) of Table 2. Lastly, Amberger and Fendel (2017) estimate a hybrid NKPC using professional inflation expectations from Consensus Economics and find a slope coefficient of 0.1010. This value is again smaller than ours, however, they only include the core EA members which leads to different conclusions. Overall, the recent literature finds much larger estimates of the slope of the aggregate Phillips curve, like us, and exceeds by far results based on the regional Phillips curve that we find for the EA using country-level data.

[28] We focus our comparison here on the literature that also uses the unemployment rate or gap respectively as measure of economic slack. However, there exists yet another related strand of the literature that use (estimates of) the output gap in the empirical analysis of the Phillips curve (Ball and Mazumder 2020; Oinonen and Vilmi 2021; Passamani et al. 2021, c.p.).

[29] Kulikov and Reigl (2020) come up with similar estimation results for their thick modelling approach which are not reported here.

Table 3: Estimates of the aggregate Phillips curve - a comparison w/ the literature

Source	**Estimated Coefficient**
Amberger and Fendel (2017)	0.1010 (0.0445)
Bobeica and Sokol (2019)	0.075 (-)
Eser et al. (2020)	0.0100 (0.0000)
Hindrayanto et al. (2019)	0.6300 (0.2986)
Kulikov and Reigl (2020)	0.1359 (0.0591)
Moretti et al. (2019)	0.07 (-)

Note: absolute values of estimated coefficients are reported to ensure comparability with results reported in Table 2. Standard errors reported in parenthesis (not for Bobeica and Sokol (2019) and Moretti et al. (2019) because they provide the median of estimates of thick modelling approaches).)

5 Conclusion

In this paper we ask whether the Phillips curve trade-off between inflation and unemployment still exists in the euro area. In this context, we analyze whether country-level data of EA member states can provide new insights into the Phillips curve and how our new findings based on a refined methodological approach relate to the recent literature estimating the Phillips curve using aggregate data. To answer these questions, we rely on a new model of a *regional* Phillips curve developed by Hazell et al. (2022). In their spirit, we set up a non-tradable goods price index to measure inflation and estimate the regional Phillips curve on country-level data for the EA member states covering the period from 2001 to 2021. In addition, we compare our findings for the regional Phillips curve with results that we obtain from estimating the aggregate Phillips curve deploying different measures of inflation expectations. Lastly, we discuss these findings with respect to the recent related literature.

We find that the Phillips curve is indeed flat but stable in the EA since the introduction of the common currency. Estimates of the slope of the regional Phillips curve are much smaller compared to estimates we obtain using aggregate data and several measures of inflation expectations. Our results coincide with findings for the US reported by Hazell et al. (2022). Overall, these findings explain the observed insensitivity of inflation to the increase in unemployment after the financial and sovereign debt crisis in the EA and the subsequent missing inflation in the late 2010s when unemployment came down to low levels across the monetary union. Hence, by drawing on country-level data and a new methodological approach to estimate the Phillips curve we can confirm that it still exists but is rather flat in the EA contrary to what aggregate estimates would suggest.

What are the policy implications of a stable but flat Phillips curve? In the face of rapidly increasing inflation in the EA, an urgent question is how the ECB should act to bring down inflation again. If one trusts our findings in this paper, and what Hazell et al. (2022) have found for the US, the Phillips curve in the EA is by no means as steep as people have been thinking based on estimates from aggregate data. Instead, it is flat. Hence, massively and rapidly increasing interest rates will not do the job. On the contrary, its flatness implies that sharp changes in inflation can only arise from changes in expectations or cost-push shocks inducing shifts in the Phillips curve. Hence, the management of long-term inflation expectations by the ECB, which rests strongly on its credibility, is crucial. Only when the ECB signals decisiveness to bring down inflation, long-term inflation expectations stay anchored. In this way, the Phillips curve stabilizes (or shifts back down) with disinflation at no or only small costs of unemployment.[30] However, the ECB has initially been reluctant to undertake actions, not least because there are a number of obstacles the ECB is facing in doing so.[31] It remains to be seen whether it has acted decisive enough just in time to ensure stable inflation expectations bringing inflation back to target.

[30]For a thorough discussion of this intuition in case of the US, see Steinsson (2022).
[31]For a discussion of these obstacles, see a recent commentary by Reis (2022).

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A Data appendix

Here, we list the 4-digit-level ECOICOP subcomponents of the HICP from Eurostat that we include in constructing the non-tradable price index. Thereby, we closely follow Hazell et al. (2022) to make results presented in Section 4.2 comparable to results for the US.[32]. Additionally, Table A.1 lists all variables and data sources used in the empirical analysis.

- Education services
  - Pre-primary and primary education
  - Secondary education
  - Post-secondary non tertiary education
  - Tertiary education
  - Education not definable by level
- Telephone services
  - Postal services
  - Telephone and telefax services
- Food away from home
  - Restaurants, cafés and the like
  - Canteens
- Other personal services
  - Hair dressing salons and personal grooming establishments
  - Cleaning repairing and hire of clothing
  - Repair and hire of footware
  - Repair of jewellery, clocks and watches
  - Other financial services
  - Other services n.e.c.
- Housing services
  - Accommodation services
  - Insurance connected with dwelling
  - Electricity

[32] A detailed mapping of the classification of Hazell et al. (2022) into the classification for the EA and the 4-digit ECOICOP codes are available upon request.

  - Water supply
  - Refuse collection
  - Sewage collection
  - Other services relating to the dwelling
  - Repair of household appliances
  - Repair of furnitures, furnishing and floor coverings
  - Services for the maintenance and repair of the dwelling

- Medical services
  - Medical services
  - Dental services
  - Paramedical services
  - Hospital services
  - Social protection

- Recreational services
  - Cultural services
  - Recording media
  - Repair of audiovisual, photographic and information processing equipment
  - Veterinary and other services for pets
  - Recreational and sporting services
  - Maintenance and repair of other major durables for recreation and culture

- Transportation services
  - Passenger transport by road
  - Passenger transport by railway
  - Passenger transport by sea and inland waterway
  - Other purchased transport service
  - Insurance connected with transport
  - Maintenance and repair of personal transport service
  - Other services in respect of personal transport equipment

Table A.1: Variables and data sources

Variable	Description	Source
p_t^N	Non-tradable goods price index, own calculations. For details, see Section 3.1	Eurostat
p_t^T	Tradable goods price index, own calculations. For details, see Section 3.1	Eurostat
p_t	Headline harmonized index of consumer prices (HICP)	Eurostat
π_t^N	Inflation in non-tradable goods, own calculations	
π_t	Headline inflation, own calculations	
u_t	Unemployment rate, for details see Section 3.2	ECB
S_t	Employment shares in NACE rev.2 sectors A and B-E, own calculations see Section 3.2	Eurostat
NAIRU	Non-accelerating inflation rate of unemployment	OECD
$E\pi_t^{SPF}$	Professional inflation expectations from SPF one-, two-, and five years ahead, for details see Section 3.3	ECB SPF
$E\pi_t^{BCS}$	Consumer inflation expectations from BCS one year ahead, for details see Section 3.3	European Commission BCS
$E\pi_t^{M}$	Market-based inflation expectations based on inflation-linked swap rates, for details see Section 3.3	Refinitiv Eikon Datastream

B Additional tables

Table A.1: First stage regression results for estimates of κ in equation (6)

	(1)	(2)	(3)	(4)
Future sum of unemployment				
Lagged unemployment	11.9588*** (1.8388)	5.1568** (1.3361)	5.9934*** (1.9190)	
Lagged relative price	0.0531 (0.0455)	−0.0278 (0.0644)	−0.0947 (0.1695)	0.0048 (0.1059)
Lagged tradeable demand				0.0237** (0.0087)
N	1123	1123	1123	619
Future sum of relative price of non-tradeables				
Lagged unemployment	25.2500 (25.3892)	110.5610** (39.0243)	40.5619** (18.8976)	
Lagged relative price	18.1915*** (1.5160)	20.5452*** (1.9777)	3.2838** (1.4140)	−1.7811*** (0.5814)
Lagged tradeable demand				−0.0323 (0.1207)
N	822	822	822	335
Country FE	no	yes	yes	yes
Time FE	no	no	yes	yes

Note: Table presents estimates of the first stage regression in equation (6). For details, see notes of Table 1. Country- and time-fixed effects are included according to the bottom two rows. Standard errors are reported in parentheses and clustered at the country level. * p<0.10, ** p<0.05, *** p<0.01.

Table A.2: Estimates of λ from equation (6)

	Lagged Unemployment			Tradable Demand IV
	(1)	(2)	(3)	(4)
λ	0.0000* (0.0000)	0.0000** (0.0000)	0.0006*** (0.0002)	−0.0004** (0.0002)
N	1346	1346	1346	842
Country FE	no	yes	yes	yes
Time FE	no	no	yes	yes

Note: Table presents estimates of λ from regression (6). For details, see notes of Table 1. Country- and time-fixed effects are included according to the bottom two rows. Standard errors are reported in parentheses and clustered at the country level. * p<0.10, ** p<0.05, *** p<0.01.

Table A.3: Estimates of κ as β varies

	Lagged Unemployment			Tradable Demand IV		
	$\beta = 0.99$	$\beta = 0.95$	$\beta = 0.90$	$\beta = 0.99$	$\beta = 0.95$	$\beta = 0.90$
κ	0.0031	0.0061**	0.0097**	0.0043**	0.0025	0.0148**
	(0.0019)	(0.0027)	(0.0036)	(0.0018)	(0.0034)	(0.0066)
N	1346	1346	1346	842	842	842

Note: Table presents estimates of regression specifications (6) for varying values of β. For details, see notes of Table 1. Country- and time-fixed effects are included in all regressions. Standard errors are reported in parentheses and clustered at the country level. * p<0.10, ** p<0.05, *** p<0.01.

Table A.4: Estimates of κ as the truncation length T varies

	Lagged Unemployment			Tradable Demand IV		
	$T = 20$	$T = 25$	$T = 30$	$T = 20$	$T = 25$	$T = 30$
κ	0.0031	0.0014	-0.0017	0.0043**	0.0061**	0.0053***
	(0.0019)	(0.0015)	(0.0013)	(0.0018)	(0.0022)	(0.0016)
N	1346	1346	1346	842	842	842

Note: Table presents estimates of regression specifications (6) for varying truncation lengths T. For details, see notes of Table 1. Country- and time-fixed effects are included in all regressions. Standard errors are reported in parentheses and clustered at the country level. * p<0.10, ** p<0.05, *** p<0.01.