DNB Working Paper
No. 587 / February 2018

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DeNederlandscheBank
EUROSYSTEEM

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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Time-varying wage Phillips curves in the euro area with a new measure for labor market slack*

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February 2018

Abstract

Recently, the unemployment gap in the euro area has fallen markedly. However, wages increased less than predicted by traditional Phillips curves. Using Bayesian methods, we estimate the wage Phillips curve with time-varying parameters. We consider alternative measures for labor market slack, namely the unemployment gap and the European Commission's labor shortage indicator. Using the latter indicator, we find a steepening of the wage Phillips curve in Italy and France, and a stable Phillips curve in the Netherlands after the crisis. In Germany (Spain), both measures suggest a recent flattening (steepening) of the wage Phillips curve.

Keywords: Wage Phillips curve, Labor shortage indicator, Time-varying parameters.
JEL classifications: E24, E31, E58.

* We thank Anneli Perridon and Mohamed Harrachi for valuable research assistance, Martin Admiraal and Peter Keus for providing the relevant data series and Peter van Els, Job Swank and Johan Verbruggen for useful comments. All remaining errors are our own. E-mail: d.a.r.bonam@dnb.nl, j.de.haan@dnb.nl and d.van.limbergen@dnb.nl.

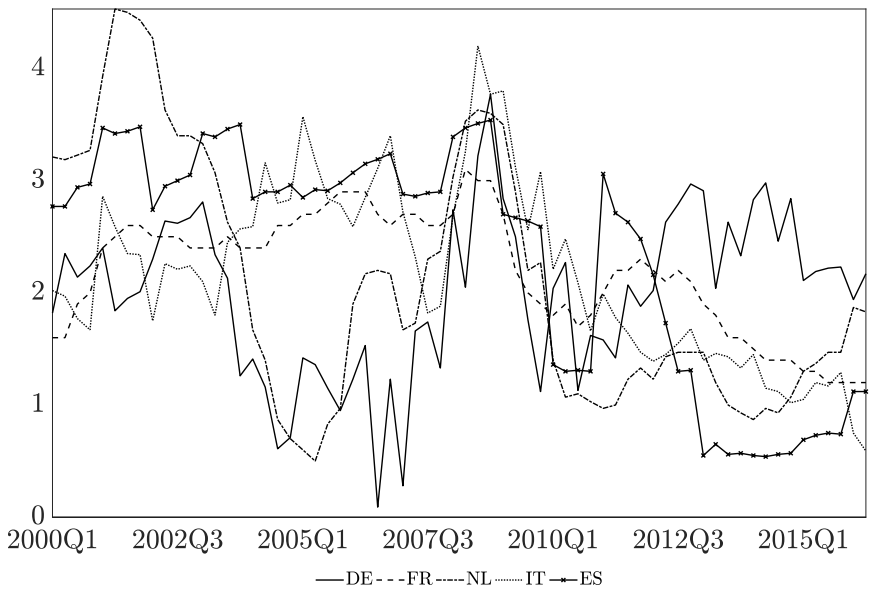
1 Introduction

The wage Phillips curve, which relates nominal wage growth to labor market slack and which is often used to forecast (wage) inflation, has regained attention in recent years, especially within the policy domain. This was triggered by the apparent disconnect in some advanced economies between labor market conditions, which have improved markedly, and wage growth dynamics, which remain subdued despite the sustained rebound in economic activity. In fact, whereas the unemployment rate in the euro area moved from 12% in 2013 to 10.3% in 2016, wage growth actually fell from 1.8% to 1.4% within the same time period. Figure 1 shows that wage growth has been stagnant ever since the 2008 crisis in the five major euro area countries as well. Moreover, a recent study by the European Central Bank (ECB) shows that wage growth projections were too optimistic in recent years (ECB, 2016).[1] In this paper, we aim to shed light on the recent dwindling performance of the wage Phillips curve in the euro area. We consider two possible explanations: (i) a change in the relationship between wage growth and labor market slack, and (ii) a failure of commonly used measures for labor market slack to adequately capture labor market conditions. In addition, we investigate potential heterogeneity in the wage Phillips curve relationship across euro area countries.

The literature suggests several explanations for why the Phillips curve relationship might change over time. Daly and Hobijn (2014), for instance, show that wage pressures arising from labor market slack weaken in times of persistently low inflation due to downward nominal wage rigidity. The relationship between inflation and economic slack might also have waned in recent years due to increased central bank credibility and more firmly anchored inflation expectations (Ball and Mazumder, 2011; Blanchard, 2016), and the increasing role of globalization and external supply shocks (Stock, 2011; Gordon, 2013; Albuquerque and Baumann, 2017). In contrast, Bulligan and Viviano (2017) report a steepening of the wage Phillips curve in Italy, Spain and France where the sensitivity of hourly wage changes to labor

[1] Similarly, inflation has remained quite low in recent years, despite the marked closing of the output gap in the euro area, casting doubt on the stability and reliability of the price Phillips curve (see, among others, Riggi and Venditti, 2015).

Figure 1: Wage growth in the euro area



Notes: The figure shows the year-on-year growth rate of negotiated wages. *Source*: European Central Bank Statistical Data Warehouse.

market slack is found to have increased after the global financial crisis. Similarly, Skarica and Nobile (2016) report a steepening of the Phillips curve in Italy and Spain after the crisis, which according to the authors might reflect the impact of structural reforms. Likewise, Albuquerque and Baumann (2017) show that US inflation has become more responsive to economic slack since 2013. These studies demonstrate the importance of time variation in the Phillips curve relationship.

Alternatively, some authors have questioned the appropriateness of traditional measures for labor market slack in Phillips curve estimations. The unemployment gap, for instance, might not adequately capture changes in labor market conditions due to biased estimates of the natural rate of unemployment. Some studies therefore suggest using alternative slack measures (see e.g. Brandolini et al., 2006). For instance, according to Ball and Mazumder (2015), a significant Phillips curve relationship between inflation and unemployment in the US is obtained if short-term unemployment, i.e. those unemployed for less than 26 weeks, is

used as a proxy for slack. According to the authors, it is the short-term unemployed that put downward pressure on wages rather than the long-term unemployed, since the attachment of the latter to the labor force is relatively weak (see also Krueger et al., 2014). Similarly, Blanchflower and Levin (2015) find that *under*employment, i.e. involuntary part-time employment, and hidden unemployment (discouraged workers) appear crucial to understand the recent sluggish growth in wages in the US.

We re-examine the wage Phillips curve for the five biggest euro area countries, i.e. Germany, France, Italy, Spain and the Netherlands, by explicitly taking into account potential time variation in the Phillips curve relationship and by considering alternative measures for labor market slack. In particular, for each country we estimate the wage Phillips curve, augmented by both backward- and forward-looking explanatory variables, with time-varying parameters using Bayesian methods. In contrast to most other studies on euro area countries which focus on price inflation, we analyze wage inflation. Our benchmark Phillips curve specification features the *unemployment gap* as a proxy for labor market slack. The results from this benchmark specification are compared to an alternative specification in which the *labor shortage indicator* from the European Commission (EC) is used to capture labor market slack. This indicator is based on a survey conducted by the EC in which firms are asked to what extent labor shortage is considered an important factor hampering production. In contrast to the unemployment gap, the labor shortage indicator is not prone to estimation bias and might therefore better capture changes in labor market conditions. We deliberately focus on estimates at the country level rather than at the aggregate euro area level, so as to account for potential heterogeneity across countries in, for instance, labor market institutions and regulations (Skarica and Nobile, 2016; Gross and Semmler, 2017).[2]

We find that the wage Phillips curve flattened in Germany and steepened in Spain in the years after the financial crisis, regardless of which measure for labor market slack is used.

[2] The study by Bulligan and Viviano (2017) comes closest to our work, as it also focuses on wage inflation in several euro area countries and examines changes in the Phillips curve over time, using a different method than the one employed here. The most important difference is that Bulligan and Viviano (2017) use the unemployment rate as slack indicator.

A change in the Phillips curve slope is also detected for France, Italy and the Netherlands, yet the nature of this change differs across the benchmark and alternative Phillips curve specifications. When using the unemployment gap as a proxy for labor market slack, our results suggest that the wage Phillips curve flattened in Italy, the Netherlands and, to a somewhat lesser extent, France. In contrast, when using the labor shortage indicator, the results indicate a *steepening* of the wage Phillips curve in Italy and France, and a *stable* Phillips curve relationship in the Netherlands after the crisis.

By comparing both measures for slack to broader measures of unemployment (i.e. under-employment), we conclude that the recent dwindling performance of the benchmark wage Phillips curve is due to a significant degree of 'hidden slack' that is not captured by the unemployment gap and which continues to weigh on wage growth dynamics. As a policy implication, our results thereby suggest that policymakers ought to consider broader measures of labor market slack, such as the labor shortage indicator, when assessing wage growth dynamics, especially following severe economic crises.

The remainder of the paper is organized as follows. The following section describes the labor shortage indicator in more detail. Section 3 discusses the empirical model and data used, while Section 4 presents the main estimation results and robustness checks. Finally, Section 5 concludes.

2 An alternative measure for labor market slack

The traditional wage Phillips curve relates nominal wage growth, w_t, to a measure for labor market slack, s_t, i.e.

$$w_t = \omega + \gamma s_t + e_t, \tag{1}$$

with ω a constant that can be interpreted as the long-run wage growth or labor productivity, and e_t the error term. The parameter γ measures the slope of the wage Phillips curve. The sign of γ depends on the measure used to capture labor market slack. The simple

representation of the wage Phillips curve in (1) predicts that additional labor market slack, i.e. an increase in s_t, puts downward pressure on wages as more workers compete for the same number of jobs.

A commonly used measure for s_t is the *unemployment gap*, i.e. the difference between the unemployment rate, that is, the incidence of active job-seekers who are out of work and available to start working within two weeks, and the natural rate of unemployment. An increase in the unemployment gap indicates greater labor market slack which, by the wage Phillips curve, leads to a decline in wages. There are, however, several reasons to suspect that the unemployment gap does not adequately capture labor market slack, which would thereby leave the econometrician with an incorrect representation of the Phillips curve relationship. First of all, the unemployment rate does not take into account measures of *under*employment, causing the unemployment gap to potentially underestimate labor market slack. Second, the natural rate of unemployment, which is unobserved and must therefore be inferred from the data, might suffer from an estimation bias, causing the unemployment gap and estimates of the Phillips curve slope to be biased as well.

In response to the first issue, Blanchflower and Levin (2015) propose to consider wider definitions of unemployment when assessing the overall degree of labor market slack. Particularly, some people may not currently seek work, despite being available, i.e. discouraged workers, while others may be actively seeking work, yet are not immediately available to start working. Moreover, some workers may be employed on a part-time basis, but wish to work more hours. Part-time employment has been rising across most euro area economies for over a decade, mainly owing to structural factors such as the growth in the services industry and the rise in female participation in the labor force. However, a recent study by the ECB (2017) shows that a non-negligible share of part-time workers would like to work more hours. The representation of labor market slack by the unemployment rate might be especially biased in times when the economy suffers a large adverse shock, such as the global financial crisis, during which more workers may become discouraged in their job search or

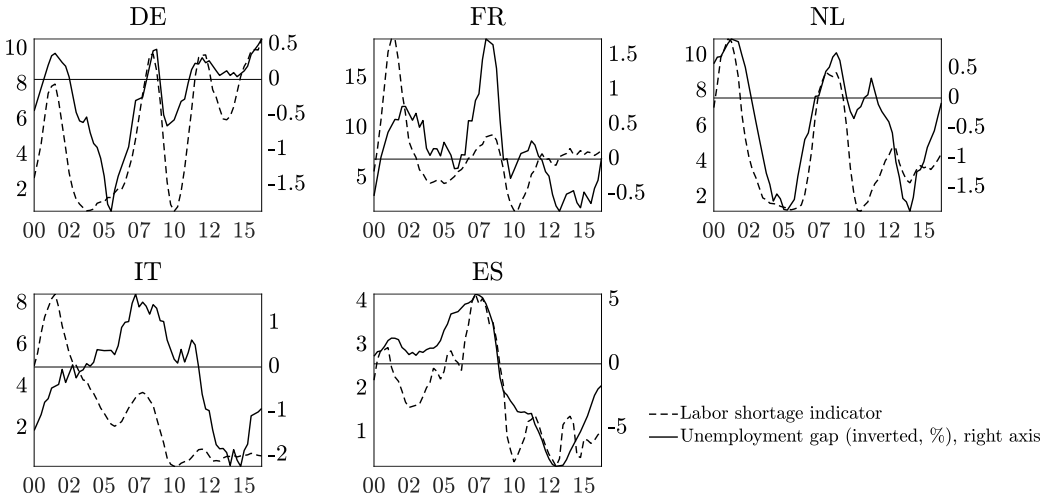
start working fewer hours than desired.

While it is difficult to properly measure the unemployment rate, it may be even more challenging to obtain reliable estimates of the natural rate of unemployment (see, for instance, Staiger et al., 1997). At the root of the problem lies the uncertainty with regards the model specification used to estimate the natural rate of unemployment. A study by the European Commission (EC) argues that, in times of large labor market swings, models that are based on static or adaptive expectations produce more pro-cyclical estimates of the natural rate of unemployment than models based on rational expectations (EC, 2014). One reason is that static/adaptive expectations models do not take full account of price rigidities that have been shown to play an important role in the adjustment process of the labor market. When based on static expectations, EC estimates for the natural rate of unemployment for Spain after the crisis are much higher (26.4% in 2015) than those based on rational expectations models (22%), thereby suggesting a much tighter labor market.

In our analysis of the wage Phillips curve, we employ two measures for labor market slack. As a benchmark, and in line with traditional specifications of the wage Phillips curve, we use the unemployment gap taken from the EC. In view of the above mentioned concerns, we also employ an alternative slack measure. In particular, we use the aggregated response to a question regarding *labor shortage* in an EC survey among firms.[3] The EC survey asks firms on "factors limiting production" and contains a question whether the "shortage of labor force" is a factor that hampers production, to be answered by either "yes" or "no". The responses are compiled into an index that measures the difference between the number of "yes" and "no" answers as a percentage of total answers. A rise (fall) of the index points towards greater (less) difficulties in attracting labor and thereby indicates less (more) labor market slack. When zero, the index indicates neutrality. The survey is conducted on a quarterly basis in different sectors, e.g. industry and services, in all euro area countries, and is available as early as 1985Q1 for some countries. In what follows, we focus on the industry

[3] In what follows, we refer to this measure as the "labor shortage indicator".

Figure 2: Labor market slack in the euro area

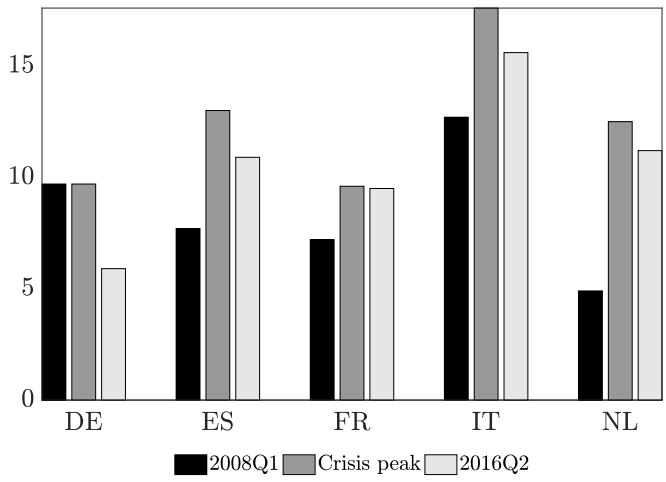


Notes: The labor shortage indicator (left axis) is the balance of answers to the question "Is labor a factor limiting production?" in the European Commission Industry Survey. The unemployment gap (right axis) is multiplied by minus one, such that higher (lower) values of both measures indicate less (more) labor market slack. *Source*: European Commission.

sector which covers 23,940 companies for the euro area as a whole. As the data is quite volatile, we use four-quarter averages of the labor shortage indicator.

Figure 2 compares the evolution of the labor shortage indicator (left axis) with the unemployment gap (right axis) between 1999Q1 and 2016Q2 in Germany, France, Italy, Spain and the Netherlands. To ease comparison, we multiplied the unemployment gap by minus one, such that higher (lower) values of both measures indicate less (more) labor market slack. According to the figure, the two measures behaved quite differently during this period, especially in Italy where the labor shortage indicator showed signs of increased labor market slack already in 2001, whereas the inverted unemployment gap became negative only after the peak of the crisis. What is also apparent is that in most countries, the unemployment gap indicates a decline in slack in the most recent years, pointing towards an improvement in labor market conditions. In contrast, the labor shortage indicator shows no such improvement during this period, yet instead a strong persistence in labor market slack inherited from the crisis. For instance, the Spanish unemployment gap appears to be closing relatively rapidly since 2013 (partly due to a sharp increase in most estimates of the natural rate of unemployment after the crisis), whereas the labor shortage indicator shows a much

Figure 3: Underemployment (% of active population)



Notes: The level of underemployment is calculated as the sum of underemployed part-time workers, persons seeking work, but not immediately available, and persons available to work, but not seeking. The crisis peak refers to 2008Q2 for Germany, 2015Q3 for France, 2013Q3 for the Netherlands, 2015Q1 for Italy and 2013Q2 for Spain. *Source*: European Commission.

more muted recovery of the labor market. The same is observed in France, Italy and the Netherlands.

It thus seems that, at least in recent years, the unemployment gap and labor shortage indicator tell different stories regarding the labor market, with the former suggesting a stronger improvement in labor market conditions than the latter. In order to gauge which of these stories is most plausible, we look at data on underemployment, which the EC also provides. This data, which is referred to as "supplementary indicators to unemployment", quantifies the amount of (i) underemployed part-time workers, (ii) persons seeking work, but not immediately, and (iii) persons available to work, but not seeking. These indicators thereby provide a broader measure of labor market slack. Unfortunately, data on these indicators are available only from 2008 onward and therefore not suited for our main empirical analysis.

Figure 3 displays the number of underemployed (as a percentage of the active population) for three periods: (i) the pre-crisis, (ii) the peak of the crisis, and (iii) the end of our sample in 2016Q2. We approximate the pre-crisis period by 2008Q1, as no earlier data are available.

The peak of the crisis refers to the period with the highest reported rate of underemployment since 2008Q1. According to the figure, there has been a marked increase in underemployment during the crisis, which persisted well into the post-crisis period. With the exception of Germany, the latest data in our sample shows that labor market slack has not dissipated or reverted to pre-crisis levels. This observation seems at odds with the recent development of the unemployment gap, which shows signs of normalization. On the other hand, the behavior of the underemployment rate *is* consistent with the labor shortage indicator, which also suggests a strong persistence in labor market slack in recent years.

Although the labor shortage indicator seems to be a good measure for labor market slack, as it captures changes in labor market conditions across the business cycle quite well, it also has some limitations. Most importantly, the indicator only covers the industry sector and therefore does not contain information on labor market slack in other sectors. However, for a shorter sample period data are also available for the services sector. It turns out that the survey responses from the industry sector correlate quite strongly with those from the services sector in France (0.5), Germany (0.7), Italy (0.8) and the Netherlands (0.8), with only Spain exhibiting a weak correlation between the two series (-0.05). We therefore conclude that, for the majority of our sample, trends in the industry survey are sufficiently correlated with trends in other sectors.[4]

3 Empirical strategy

3.1 The model

We estimate an augmented version of the traditional wage Phillips curve, given by Equation (1), that is similar to the specification studied in theoretical models (e.g. Galí, 2011) and recent empirical work (e.g. Bulligan and Viviano, 2017). In particular, our main specification

[4]In one of our robustness exercises, we replaced the industry survey with the services survey indicator and found our results to remain intact. However, due to a sever lack of available data for most of the countries that we consider, the estimates are somewhat imprecise. These robustness checks are available upon request.

is a hybrid Phillips curve that includes lagged nominal wage growth, w_{t-1}, and expected inflation, π_t^e:

$$w_t = \omega + \rho w_{t-1} + \gamma s_t + \alpha \pi_t^e + e_t. \tag{2}$$

Whereas the lag in wage growth captures the observed persistence in wage dynamics, inflation expectations are aimed to capture potential forward-looking behavior of wage setters.[5]

In order to take into account potential changes in the relationship between wage growth and labor market slack, we allow the coefficients ω, ρ, γ and α in (2) to vary over time. In particular, we estimate the following state-space model:

$$\begin{aligned} w_t &= \omega_t + \rho_t w_{t-1} + \gamma_t s_t + \alpha_t \pi_t^e + e_t \qquad (3) \\ &= x_t \beta_t' + e_t, \quad e_t \sim \mathcal{N}(0, R), \\ \beta_t &= \beta_{t-1} + v_t, \quad v_t \sim \mathcal{N}(0, Q), \qquad (4) \end{aligned}$$

with $\text{cov}(e_t, v_t) = 0$ and $x_t \equiv [1,\ w_{t-1},\ s_t,\ \pi_t^e]'$, and where $\beta_t \equiv [\omega_t,\ \rho_t,\ \gamma_t,\ \alpha_t]'$ are the time-varying parameters to be estimated. We use Bayesian estimation techniques (i.e. Gibbs sampling) to estimate the model (3)-(4).[6] The first $T_0 = 10$ quarters in our sample are used as a training sample to initialize β_0, R_0 and Q_0.[7] The prior distribution for the variance R is an Inverse Gamma distribution, i.e. $R \sim \mathcal{IG}(T_0/2, D_0/2)$, with the scaling parameter initialized at $D_0 = 0.1$. The prior for Q is an Inverse Wishart distribution, i.e. $Q \sim \mathcal{IW}(Q_0, T_0)$, where $Q_0 = R_0 \left(x_{0,t}' x_{0,t}\right)^{-1} \times T_0 \times \tau$ and where $\tau = 0.35$ is a scaling factor that accounts for the fact that the estimate for the covariance matrix, $R_0 \left(x_{0,t}' x_{0,t}\right)^{-1}$, might be imprecise. A total of 12,000 draws were used for the Gibbs-sampling algorithm, of which the first 10,000 draws were discarded.

[5] We have also tested various alternative specifications in which we replace either lagged wage growth or expected inflation with lagged HICP inflation in Equation (2), or in which we simply add lagged HICP inflation as an additional regressor. Neither of these robustness checks, which are available upon request, yield results that are qualitatively different from our main results.

[6] See Primiceri (2005) and Blake and Mumtaz (2012) for further details on the Bayesian estimation of time-varying parameter models.

[7] Extending the training sample, e.g. by setting $T_0 = 15$ or $T_0 = 20$, does not change our main results.

3.2 Data description

As mentioned earlier, we use two measures for labor market slack, s_t. As a benchmark, we use the unemployment gap taken from the European Commission. Our alternative measure is the labor shortage indicator, which we described in Section 2, obtained from the EC Industry Survey. For nominal wage growth, w_t, we use the year-on-year growth rate of negotiated wages taken from the ECB and shown in Figure 1.[8] Finally, for inflation expectations, π_t^e, we use one-year-ahead inflation expectations from Consensus Forecasts.[9]

Our data runs from 1999Q1 to 2016Q2 and estimations are performed for the five biggest euro area countries, i.e. Germany, France, Italy, Spain and the Netherlands, which together comprise about 80% of euro area GDP. As it is likely that the policies of the ECB ushered in a new monetary regime, we deliberately exclude observations prior to the inception of the euro. According to Benati (2008), a change in the monetary regime might significantly alter the statistical properties of the inflation process. Insofar such a change affects inflation expectations, the Phillips curve relationship could change as well, making it more difficult to interpret the potential time variation in the Phillips curve parameters.

4 Estimation results

4.1 Constant parameter estimates

Before we discuss the results for the time-varying parameter model (3)-(4), we first estimate a Phillips curve with *constant* parameters, i.e. Equation (2), using ordinary least squares. Table 1 shows the results for the benchmark specification in which the unemployment gap is used as labor market slack measure, whereas Table 2 shows the results for the alternative specification that uses the labor shortage indicator as slack measure.

[8] We consider negotiated wages rather than compensation per employees or compensation per hour since the latter are subject to one-offs (e.g. bonuses), changes in social contributions, fiscal policy shocks, wage drift and compositional effects, and other idiosyncrasies not linked to collective bargaining.

[9] Tables 3-7 in the Appendix provide descriptive statistics of the main variables considered.

Table 1: Constant parameter estimates of the wage Phillips curve, slack measure (s_t) = unemployment gap

	DE	FR	IT	NL	ES
Dependent variable: nominal wage growth, w_t					
Constant, ω	1.152***	0.041	0.039	-0.02	0.345
	(0.414)	(0.113)	(0.306)	(0.17)	(0.215)
Lagged wage growth, w_{t-1}	0.511***	0.818***	0.771***	0.808***	0.731***
	(0.098)	(0.044)	(0.088)	(0.044)	(0.069)
Unemployment gap, s_t	-0.421***	-0.1***	-0.06	-0.134**	-0.044**
	(0.118)	(0.033)	(0.067)	(0.06)	(0.018)
Inflation expectations, π_t^e	-0.035	0.227***	0.259**	0.253***	0.146
	(0.179)	(0.08)	(0.126)	(0.073)	(0.107)
Adjusted R^2	0.542	0.945	0.779	0.938	0.898
Number of observations	69	69	69	69	69

Notes: Standard errors in parentheses; ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively. Estimation performed using OLS.

The results show that the Phillips curve slope has, for both specifications and for all countries, the expected sign and suggests a negative relationship between wage growth and the unemployment gap, and a positive relationship between wage growth and the labor shortage indicator. There are, however, notable differences across countries with regards the estimation results. The results for the benchmark specification suggest that the Phillips curve is steepest in Germany, with an estimated slope of around -0.4, and flattest in Spain, with a slope of around -0.04. In contrast, according to the alternative specification, the strongest wage/slack relationship is found in Spain, whereas the results for France point to a relatively weak Phillips curve relationship. For Italy, no significant Phillips curve slope is found, regardless of which measure for slack is used.

The estimated parameters for the remaining explanatory variables do not vary much across the two specifications, and also the performance of the two specifications in terms of explaining the variation in wage growth is comparable, as confirmed by the small differences in the adjusted R^2. Lastly, the alternative specification points (at least for most countries) to a somewhat stronger persistence in wage growth dynamics and a greater contribution of inflation expectations than the benchmark specification.

Table 2: Constant parameter estimates of the wage Phillips curve, slack measure (s_t) = labor shortage indicator

	DE	FR	IT	NL	ES
Dependent variable: nominal wage growth, w_t					
Constant, ω	0.758*	-0.282***	-0.152	-0.224**	-0.055
	(0.384)	(0.089)	(0.196)	(0.108)	(0.123)
Lagged wage growth, w_{t-1}	0.566***	0.856***	0.821***	0.792***	0.749***
	(0.096)	(0.04)	(0.066)	(0.04)	(0.069)
Labor shortage indicator, s_t	0.068***	0.014***	0.018	0.061***	0.115**
	(0.023)	(0.004)	(0.021)	(0.017)	(0.056)
Inflation expectations, π_t^e	-0.151	0.33***	0.27**	0.204***	0.197*
	(0.199)	(0.077)	(0.123)	(0.071)	(0.101)
Adjusted R^2	0.519	0.946	0.779	0.944	0.895
Number of observations	69	69	69	69	69

Notes: Standard errors in parentheses; ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively. Estimation performed using OLS.

4.2 Time-varying estimates of the wage Phillips curve slope

The estimates for the time-varying parameter model are shown in Figure 4, which shows the estimated evolution of the slope parameter, γ_t, between 2001Q4 and 2016Q2 (solid blue lines).[10] For comparison purposes, we also added the estimation results of the Phillips curve with constant parameters from Tables 1 and 2, as indicated by the horizontal dashed lines.

For Germany, both the benchmark specification (left column) and alternative specification (right column) point to an initial steepening of the Phillips curve, followed by a flattening of the Phillips curve that persists during the crisis period. Towards the end of the sample, the wage/slack relationship in Germany becomes insignificant (in Bayesian terms). As discussed in Section 2, and evidenced by data on underemployment shown in Figure 3, Germany exhibited a marked improvement in labor market conditions after the crisis, with broad measures of unemployment dipping below pre-crisis levels. However, wage growth has remained subdued: whereas wages grew, on average, by about 3% in 2008, in 2016 wage growth was only 2%. Therefore, whereas the constant parameter estimates point towards a strong and significant relationship between wages and labor market slack in Germany,

[10] Recall that we remove a training sample of 10 quarters and use 1 lag of the dependent variable.

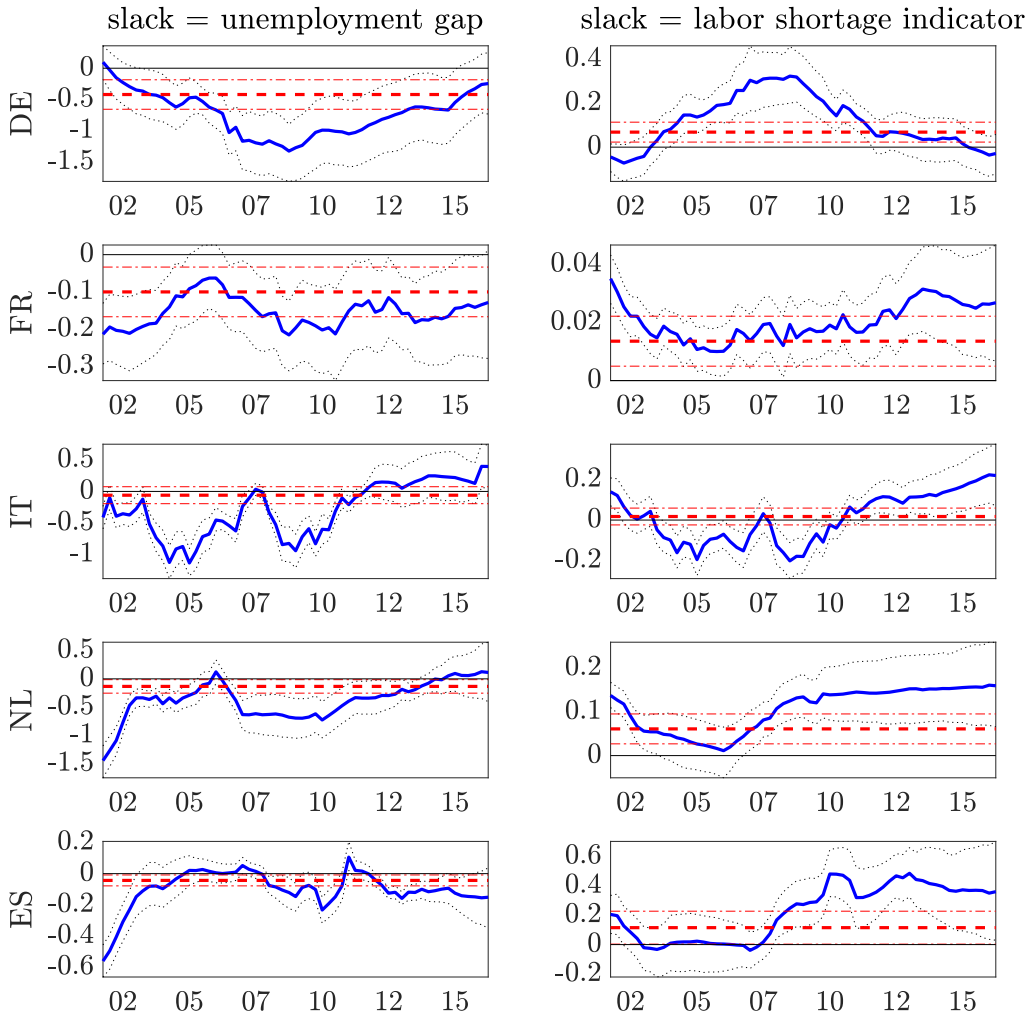
the time-varying parameter estimates suggest that this relationship has weakened in recent years.

For Italy, we find strong time variation in the Phillips curve slope, which seems to underlie the insignificance of the wage/slack relationship inferred from the constant parameter estimates. Moreover, the results for the benchmark specification are strikingly different from those for the alternative specification. When using the unemployment gap to proxy labor market slack, the results suggest that the wage Phillips curve in Italy has flattened in recent years. However, according to the alternative specification, the Phillips curve has *steepened* since 2010. Recall from our discussion in Section 2 that, at least for the most recent years, the labor shortage indicator seems to be a better gauge of labor market conditions than the unemployment rate, as its dynamics have been more consistent with broader measures of unemployment. Therefore, together with the fact that wage growth in Italy has remained stubbornly low (0.7% in 2016 compared to 3.5% in 2008, on average), we consider the results from the alternative specification more convincing and conclude that the Phillips curve in Italy has steepened in the aftermath of the crisis.

Similar results are found for the Netherlands and France: whereas the benchmark specification points to a flattening of the wage Phillips curve, the alternative specification indicates a stable or even stronger wage/slack relationship since 2010. In both countries, the labor shortage indicator shows greater persistence in labor market slack after the crisis than the unemployment gap, which is again more consistent with broader measures of unemployment. Also, wage growth has been weak in these countries compared to the period preceding the crisis. Together, these observations favor the results from the alternative specification that a significant wage Phillips curve emerged following the crisis.

In the case of Spain, both specifications find a strengthening of the wage/slack relationship after 2008. This finding is in line with the observed surge in unemployment during the crisis that was accompanied by suppressed wage dynamics. The steepening of the Spanish wage Phillips curve is most pronounced for the alternative specification. This could be due

Figure 4: Estimates of the wage Phillips curve slope, γ_t



Note: The figure shows estimates for γ_t in Equation (3). The blue solid (dotted) lines reflect the 50th (16th and 84th) percentiles from the posterior distribution. The red horizontal dashed and dashed-dotted lines are the estimates, and corresponding 95% interval, from a time-invariant version of (3), estimated using OLS.

to the fact that, after the crisis, estimates for the Spanish natural rate of unemployment increased, causing the unemployment gap to shrink, thereby suggesting a tightening of the labor market. In contrast, the labor shortage indicator did not show signs of such tightening, yet rather points towards greater persistence in labor market slack. With Spanish wage growth still low (1.1% in 2016 compared to 3.5% in 2008, on average), a strong relationship between wage growth and the labor shortage indicator ensues.

In sum, for those countries where the crisis led to a relatively strong surge in unemployment (France, Italy, the Netherlands, and Spain), and where the unemployment gap has been unable to fully capture the persistence in labor market slack during the aftermath of the crisis, the wage Phillips curve relationship is alive and well and can explain current subdued wage growth, provided the labor shortage indicator is used as a measure for labor market slack. It follows that a good understanding of past and current wage dynamics, and forecasts of future wage pressures, requires a broad assessment of labor market conditions, especially following severe economic crises. Furthermore, imposing a time-invariant Phillips curve slope may cause one to mistakenly conclude that the wage/slack relationship is significant, even though it is not (as we find for Germany), or the other way around (in the case of Italy). Lastly, our results reveal important heterogeneities within the euro area, with wage growth in some countries responding much stronger to labor market improvements than in other countries.

4.3 Robustness checks

We test the robustness of our main results in two ways. First, we use the unemployment *rate* rather than the unemployment gap as a measure for labor market slack in the benchmark Phillips curve specification. Second, for both specifications, we add labor productivity growth per employee as an explanatory variable to the wage Phillips curve.[11]

[11] We also considered other alternative specifications of the wage Phillips curve, e.g. by including lagged HICP inflation as an explanatory variable, using productivity growth per hour rather than per employee, and using different lag structures. Also, we used different priors and training samples to initialize the Gibbs-

One reason to use the unemployment rate as a measure for labor market slack rather than the unemployment gap, is that the latter is an unobserved variable, which must be estimated and therefore is prone to estimation uncertainty. In our first robustness exercise, we replace the unemployment gap in the benchmark specification with the unemployment rate. Data on the unemployment rate (in percentages of the active population) is seasonally adjusted and taken from Eurostat.

Estimates for the time-varying Phillips curve slope are shown in Figure 5 (left column). For comparison purposes, we also report the results for the alternative specification in which the labor shortage indicator is used as slack measure (right column). The results are in line with our main results shown in the left column of Figure 4. What is notable is that the flattening of the German Phillips curve in recent years seems more pronounced when the unemployment rate is used as slack measure, with the results exhibiting much less uncertainty surrounding the median estimates. Moreover, for France and Italy, a slight steepening of the Phillips curve is now observed at the end of the sample, which is more in line with the alternative Phillips curve specification.

Next, we add to both specifications of the wage Phillips curve *labor productivity growth* as explanatory variable, such that Equation (3) is replaced by

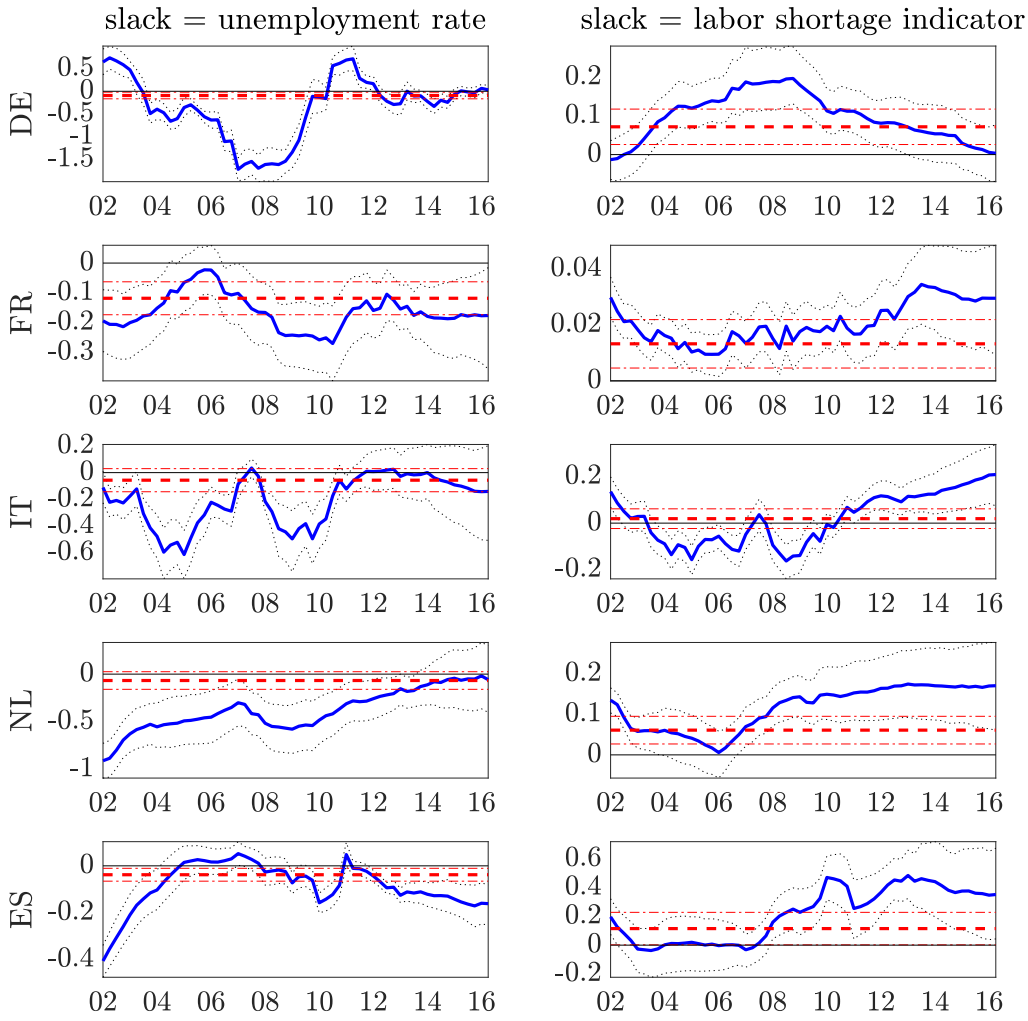
$$w_t = \omega_t + \rho_t w_{t-1} + \gamma_t s_t + \alpha_t \pi_t^e + \mu_t A_t + e_t, \tag{5}$$

with A_t denoting labor productivity growth per employee. According to theory, an increase in labor productivity raises demand for labor, which in turn puts upward pressure on wage growth, above and beyond the effects of labor market tightness. Data on productivity growth are collected from Eurostat.

The time-varying estimates of the Phillips curve slope from this augmented Phillips curve

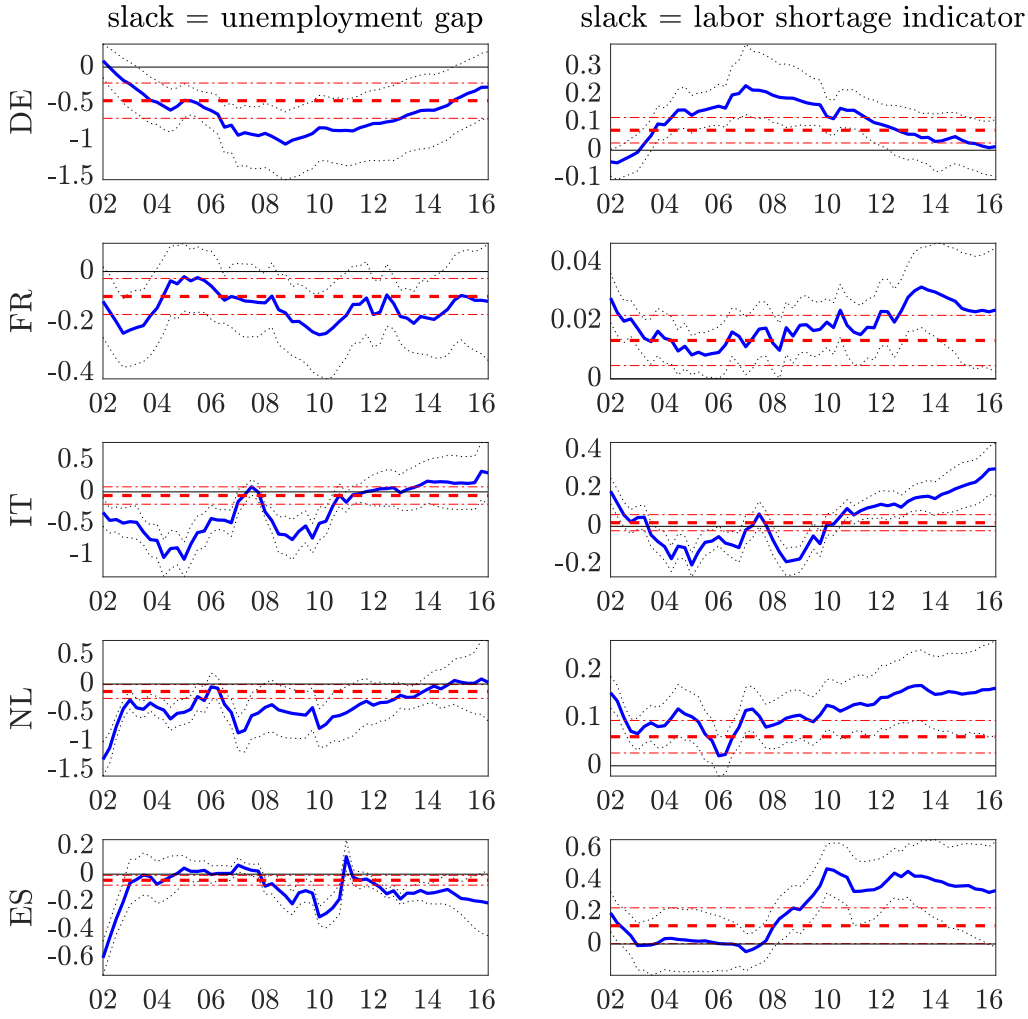
sampling algorithm. The results from these robustness checks, which are available upon request, do not differ much qualitatively from our main results. Moreover, we performed the Bai-Perron test for the Phillips curve with constant parameters and found that the identified breaks coincide with the movements in the time-varying Phillips curve slope.

Figure 5: Estimates of the wage Phillips curve slope, γ_t, when using the unemployment rate as slack measure in the benchmark specification



Note: The figure shows estimates for γ_t in Equation (3). The blue solid (dotted) lines reflect the 50th (16th and 84th) percentiles from the posterior distribution. The red horizontal dashed and dashed-dotted lines are the estimates, and corresponding 95% interval, from a time-invariant version of (3).

Figure 6: Estimates of the wage Phillips curve slope, γ_t, when controlling for labor productivity



Note: The figure shows estimates for γ_t in Equation (5). The blue solid (dotted) lines reflect the 50th (16th and 84th) percentiles from the posterior distribution. The red horizontal dashed and dashed-dotted lines are the estimates, and corresponding 95% interval, from a time-invariant version of (5).

specification are shown in Figure 6. Interestingly, the results are strikingly similar to our main results shown in Figure 4. In fact, the same conclusions can be inferred from these results: the Phillips curve has flattened, in recent years, in Germany, yet steepened in Spain; for France, Italy and the Netherlands, we find a flattening of the Phillips curve after 2010 when using the unemployment gap as slack measure, and a steepening of the Phillips curve when using the labor shortage indicator.

5 Conclusion

Recently, the unemployment gap in the euro area has fallen markedly. However, wages remain low and have increased less than predicted by traditional Phillips curves. We have therefore re-examined the wage Phillips curve for the five biggest euro area countries, i.e. Germany, France, Italy, Spain and the Netherlands, by explicitly taking into account potential time variation in the Phillips curve relationship and by considering an alternative measure for labor market slack. In particular, for each country we estimated the wage Phillips curve, augmented by both backward- and forward-looking explanatory variables, with time-varying parameters using Bayesian methods. As a benchmark, we use the *unemployment gap* as a measure for labor market slack. The results for the benchmark specification are compared to an alternative specification using the survey-based *labor shortage indicator* to capture labor market slack.

When using the unemployment gap as a proxy for labor market slack, our results suggest that the wage Phillips curve flattened in Italy, the Netherlands and, to a somewhat lesser extent, France. In contrast, when using the labor shortage indicator as slack measure, the results suggest a *steepening* of the wage Phillips curve in Italy and France, and a stable Phillips curve relationship in the Netherlands after the crisis. We relate these conflicting results to the observation that, unlike the labor shortage indicator, the unemployment gap has been unable to adequately capture the persistence in *additional* labor market slack (based

on measures of underemployment) in recent years. In fact, the unemployment gap points to a much stronger improvement in labor market conditions in these countries after the crisis than suggested by broader measures of unemployment. Since wage growth has remained stagnant, its relationship with the unemployment gap weakened, implying a flattening of the Phillips curve. In contrast, changes in the labor shortage indicator have been more consistent with broader measures of unemployment, suggesting more labor market slack than the unemployment gap. Consequently, the link between the labor shortage indicator and wage growth remained strong or even strengthened after the crisis, resulting in a steepening of the Phillips curve.

Policymakers should be aware that the Phillips curve relationship can vary both over time and across countries. Moreover, it is imperative to consider broad measures of labor market slack in order to properly assess wage growth dynamics, especially following severe crises when different slack measures point towards different speeds of economic recovery. Our analysis shows that, at least in some countries, the wage Phillips curve relationship has not weakened, implying that wage and price pressures should re-emerge in the euro area once spare capacity is sufficiently absorbed.

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A Descriptive statistics

Table 3: Descriptive statistics: Germany

	Wage growth	Unemployment gap	Labor shortage indicator	Inflation expectations
Mean	2.03	0.28	5.14	1.58
Standard deviation	0.71	0.59	3.12	0.34
Number of obs.	70	70	70	70
Maximum	3.77	1.88	10.58	2.38
Minimum	0.09	-0.58	0.83	0.89

Table 4: Descriptive statistics: France

	Wage growth	Unemployment gap	Labor shortage indicator	Inflation expectations
Mean	2.16	-0.07	7.26	1.47
Standard deviation	0.53	0.66	3.50	0.27
Number of obs.	70	70	70	70
Maximum	3.10	1.53	18.93	2.10
Minimum	1.20	-1.74	1.70	0.62

Table 5: Descriptive statistics: Italy

	Wage growth	Unemployment gap	Labor shortage indicator	Inflation expectations
Mean	2.16	0.27	2.84	1.76
Standard deviation	0.78	1.08	2.33	0.43
Number of obs.	70	70	70	70
Maximum	4.20	2.26	8.45	2.69
Minimum	0.59	-1.66	0.18	0.43

Table 6: Descriptive statistics: Spain

	Wage growth	Unemployment gap	Labor shortage indicator	Inflation expectations
Mean	2.35	0.76	1.88	2.11
Standard deviation	1.00	3.96	1.05	0.72
Number of obs.	70	70	70	70
Maximum	3.54	8.02	4.18	3.20
Minimum	0.54	-5.46	0.23	0.38

Table 7: Descriptive statistics: Netherlands

	Wage growth	Unemployment gap	Labor shortage indicator	Inflation expectations
Mean	2.13	0.36	4.60	1.84
Standard deviation	1.10	0.87	2.80	0.58
Number of obs.	70	70	70	70
Maximum	4.53	1.91	10.95	3.54
Minimum	0.50	-0.99	1.23	0.77

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