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# U.S. wage growth and nonlinearities: The roles of inflation and unemployment

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## ABSTRACT

Despite a low unemployment rate, wage growth in the U.S. was negligible during the 2013–2015 period. Conventional linear models of the relationship between wages and unemployment, the so-called wage Phillips curve (WPC), and previous models of the WPC that rely on regime-switching driven only by changes in unemployment, provide a poor fit in the aftermath of the Great Recession. Meanwhile, standard linear theoretical general equilibrium models are based on an assumption that economic agents take into account nominal wages relative to prices when making labor decisions, suggesting that there is a role for inflation in determining the empirical dynamics of the WPC. We employ a nonlinear empirical model to study how the relationship between U.S. wage growth and unemployment changes over the business cycle. In particular, we estimate a threshold vector autoregression with multiple threshold variables and multiple threshold parameters for each threshold variable for the 1965–2015 period. We find that the WPC changes according to the dynamics of both unemployment and inflation. Specifically, it changes as the unemployment rate transitions above or below the two estimated thresholds, defined by 5.03% and 7.77%. Simultaneously, it also evolves depending on whether inflation is above or below 0.38% relative to trend. The results show a strong negative relationship between wage growth and unemployment during periods of expansion when inflation is above its long-run trend. The relationship weakens, although remains negative, during periods of expansions with low inflation and during mild recessions. Our results indicate that the negligible wage growth observed during 2013–2015 was driven not only by labor market slack, as suggested by previous studies, but also by the low inflation environment.

## 1. Introduction

The debate regarding the stance of monetary policy in the aftermath of the Great Recession has led to a renewed interest in the wage Phillips curve (WPC), which describes the relationship between wage growth and unemployment (Galí, 2011; Galí et al., 2012; Blanchflower and Posen, 2014). While recent studies have found persuasive evidence of nonlinearities in this relationship (Fisher and Koenig, 2014; Kumar and Orrenius, 2016; Donayre and Panovska, 2016), the regime-switching in the WPC has been motivated only by changes in the unemployment rate.

In this study, we consider the inflation gap as a second threshold variable. To address the dependence of wage growth on both inflation and unemployment, this paper estimates a threshold vector autoregression (TVAR) of the WPC using two threshold variables. Additionally, we consider multiple threshold parameters for each of the threshold variables. In this context, our contribution to the literature is three-fold.

First, this is the first paper that directly allows the behavior of wage growth to exhibit threshold-type nonlinearities with regime-changing that depends on the dynamics of both inflation and the unemployment rate. Second, we consider nonlinearities in the relationship between wage growth, inflation, and unemployment in a multivariate environment. If wage growth, unemployment and inflation are interdependent, a single-equation approach to model the WPC would not be appropriate. In that case, our multivariate nonlinear threshold TVAR approach better captures the underlying dynamic interrelations among all variables in the system. Third, we also consider multiple threshold parameters for the multiple threshold variables, motivated by the robust evidence of the WPC changing dynamics as the unemployment rate transitions between two different threshold parameters. See, inter alia, Donayre and Panovska (2016) for evidence of nonlinearities in the WPC driven by the unemployment rate.

Because our goal is to test whether there is any evidence of state-dependence in the behavior of wage growth, we employ a TVAR. While

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time-varying parameter VAR models where the parameters follow a random walk are more general in the sense that the VAR coefficients can evolve in an unrestricted way over time, they have been shown to miss threshold-type effects, even when they are relatively strong in the true data generating process (Lubik et al., 2015). Furthermore, unlike a time-varying parameter VAR, the TVAR allows us to directly relate the variable that causes the regime-switching to the unemployment rate and the inflation gap. Meanwhile, it is important to note that the choice of TVAR implicitly assumes that the response of wage growth changes abruptly across regimes. This assumption is consistent with, for example, the evidence that the wage elasticity of labor demand changes over the business cycle.<sup>1</sup> Moreover, previous estimates of the smoothness parameter in models that use a smooth transition threshold equation to model Phillips-type relationships are large, suggesting an abrupt transition between regimes (Lye and McDonald, 2008; Musso et al., 2009).

We find strong evidence that the implied WPC exhibits threshold-type nonlinearities and that the regime-switching is better described by changes in both inflation and unemployment. In particular, the estimated threshold parameters suggest that this relationship changes according to whether the unemployment rate is above, in between or below regimes defined by 5.03% and 7.77%. Simultaneously, the relationship also changes as inflation is above or below 0.38% relative to trend. We study the dynamics of the model by means of impulse-response functions (IRFs) where the shocks are orthogonalized via sign restrictions. The analysis of the IRFs suggests a negative relationship between wage growth and unemployment, consistent with the implications of a WPC derived from the standard New Keynesian model with staggered wage setting in Galí (2011). However, this relationship varies according to the level of unemployment and of the inflation gap. It is particularly strong during periods of expansion with high inflation gaps and weakens, although remains negative, during periods of expansions with low inflation gaps and during mild recessions, when wage growth responds more strongly to unemployment shocks. This suggests that the negligible wage growth observed during 2013–2015 was driven by both the low inflation environment and labor market slack, which is confirmed by a counterfactual exercise where shocks to only inflation or only unemployment are allowed to hit the system. However, the effect of inflation on wages falls when there is substantial labor market slack in the economy. Finally, the results are robust to different specifications of trend inflation and to different measures of inflation and unemployment.

The remainder of the paper is organized as follows. A brief review of the literature is discussed in the next section. The third section presents the data and discusses stylized facts that additionally motivate the use of two threshold variables when modeling the relationship between wages, the unemployment rate, and inflation. The model and the empirical procedure are described in the fourth section. In the fifth section, we discuss the evidence in favor of nonlinearity, the dynamic responses of wages to unemployment and inflation shocks, and briefly discuss nominal rigidities in the context of our model. Section six conducts a series of robustness checks. A counterfactual exercise that decomposes the path of wage growth based on each type of shocks for two histories of interest is carried out in Section 7. The last section provides some concluding remarks.

## 2. Related literature

The relationship between wage growth and the unemployment rate dates back to the seminal work of Phillips (1958), and relates to the subsequent studies by Lucas (1972, 1973), Barro (1977) and Adams (1985). These studies found evidence that wage growth is negatively

<sup>1</sup> Intuitively, firms are more willing to increase wage markups during expansions as revenue increases. Therefore, the wage elasticity of labor demand may increase in expansions and fall in recessions, as argued by Galí et al. (2012).

linked to the unemployment rate. More recently, theoretical models demonstrate that this link still holds in a DSGE-based framework (Galí, 2011; Galí et al., 2012).

Much of the recent focus on the WPC stems from the fact that different models that attempt to explain the behavior of wage growth have different implications for policy. On the one hand, there are arguments that favor a rapid increase in the Federal Funds rate (FFR) given that the unemployment rate has returned to levels consistent with those prevailing before the Great Recession (Bullard, 2015). On the other hand, alternative views favor a slow policy normalization, given the recent low inflationary environment, reflected in low wage growth (Blanchflower and Levin, 2015).

The evidence for state-dependence of the WPC has been modeled in the literature only by changes in unemployment (Kumar and Orrenius, 2016; Donayre and Panovska, 2016). The choice of the unemployment rate as a threshold variable that determines the prevailing regime that drives the link between wages, unemployment and inflation is motivated by the fact that as business conditions improve, the unemployment rate falls while worker's bargaining power increases, putting upward pressure on wages. This evidence complements the well-known fact that both economic agents and firms take prices into account when deciding the optimal wage, as well as recent findings which suggest that changes in prices relative to their long-term trend are systematically related to fluctuations in wages (Knotek and Zaman, 2014; De Schryder et al., 2015). Consequently, it is likely that the relationship between wage growth and unemployment may behave differently as the inflation gap evolves.

It is important to mention that the focus on the inflation gap allows us to capture information embedded in prices that may not be captured by measures of unemployment, and that is relevant for policy decision-making. While the evidence in favor of nonlinearity and the relevance of a second threshold variable will be, ultimately, tested formally, considering the possibility of the inflation gap as a second threshold variable is relevant for various reasons. Measures of the inflation gap embed information about price pressures, price setting behavior and underlying and external demand pressures not captured by the unemployment rate (Ascari and Sbordone, 2014). In addition, the inflation gap is important for policy decision-making, as evidenced by the standard minimization of a loss function in the optimal monetary policy literature, which suggests monetary authorities care about bringing inflation back to trend (Cogley et al., 2010).

## 3. Data and stylized facts

In this section, we illustrate some stylized facts to motivate our empirical model. For this purpose, we describe the data employed for the stylized facts and the empirical model in the first subsection.

### 3.1. Data

The empirical analysis relies on monthly U.S. data drawn from the Federal Reserve Economic Data (FRED) website. Unemployment is measured as one hundred times the ratio of unemployed people relative to the civilian labor force. The natural rate of unemployment used here is the implied Congressional Budget Office (CBO) estimate, which is obtained directly from the FRED database.<sup>2</sup> Inflation is

<sup>2</sup> Since the CBO only provides the natural rate of unemployment at the quarterly frequency, we assume that the quarterly estimate for the natural rate is a good approximation for the natural rate of unemployment at the monthly frequency for all three months in a given quarter. However, assuming that the unemployment trend is unknown or substituting cyclical unemployment with the level of the unemployment rate in the TVAR does not significantly alter the results. In a similar setting, Donayre and Panovska (2016) find that alternative specifications that do not assume prior knowledge of the natural rate of unemployment, as well as other measures of unemployment, do not affect the timing of regimes when estimating a single-equation-based WPC.

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