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# Nonlinear Phillips curve, sacrifice ratio, and the natural rate of unemployment

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**Abstract**

This paper estimates the unemployment cost of lowering inflation and the natural rate of unemployment for the U.K. and the U.S. on a nonlinear Phillips curve. The nonlinearity is accommodated through a logistic smooth transition autoregression specification, which is flexible to allow various nonlinear shapes. Empirically, the models are shown to capture the nonlinear features present in the data well. The unemployment costs for lowering inflation vary, depending critically on the state of the economy, the size of intended inflation change, and whether policy makers seek to disinflate or prevent inflation from rising. As a further application, the natural rate of unemployment is produced using a nonlinear analog of the historical decomposition. The estimates are well consistent with the economic episodes.


*JEL classification:* C32; E32; E52

*Keywords:* Phillips curve; Nonlinearity; Sacrifice ratio; Natural rate of unemployment

## 1. Introduction

Recently, growing evidence suggests nonlinearities in the Phillips curve. This has important implications for the unemployment cost of lowering inflation, which is typically estimated to be constant under the assumption that the Phillips curve is linear. For example, Turner (1995) and Debelle and Laxton (1997) find in their multi-country analyses that the Phillips curve is convex for the U.K. and the U.S. The convexity implies that the unemployment cost of lowering inflation will fall as the economy strengthens. However, there is no consensus in the literature about the

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precise nonlinear form of the Phillips curve. Eisner (1997) and Stiglitz (1997) present counter-evidence by concluding that the U.S. data are consistent with a concave Phillips curve. Corrado and Holly (2003) find that the U.K. Phillips curve is approximated better with a mixture of concave and convex curves. The concavity implies that the unemployment cost of lowering inflation will rise with the strength of the economy.[1]

The purpose of this paper is to estimate a nonlinear Phillips curve and assess the unemployment cost of lowering inflation for the U.K. and the U.S. The nonlinearity is accommodated through a logistic smooth transition autoregression (LSTAR) specification in which the model alternates between different regimes, with linearity and discrete nonlinear cases as extreme ends. Importantly, the transition is carried out in a smooth manner so that there can be a continuum of states between the regimes. Thus, the LSTAR model is flexible enough to allow various nonlinear Phillips curve shapes. These include shapes that are convex in one region and concave in another region (i.e. a kinked curve). This feature receives support from the suggestion of Dupasquier and Ricketts (1998) and Filardo (1998) that a model nesting more than one type of nonlinearity may be needed to fit the data better. The bottom line is that we have no need to assume one specific form of nonlinearity or another *a priori*, which should be useful given the apparently contradictory extant evidence on the shape of the Phillips curve.

Here, we build a VAR model of the unemployment rate and inflation augmented with an LSTAR specification. Most of the previous studies, including those mentioned above, were performed with a single-equation framework. The well-known problem of endogeneity in estimating the Phillips curve is an outstanding issue for these studies. They are also limited in the sense that the unemployment–inflation relationship is allowed to vary only with the states of the economy. Our model can offer a more comprehensive analysis as the unemployment costs for lowering inflation are allowed to vary with signs and sizes of the shocks in addition to the states of the economy. A notable exception is the study by Filardo (1998) for the U.S., which applies the threshold vector autoregression model. By construction, the output cost of lowering inflation is nonlinear in a similar way to our specification. One key difference is that regime switching is entirely discrete in Filardo's model. The use of a smooth transition in the present application, as opposed to discrete regime switching, is justified particularly by the fact that slow adjustments and inertia in inflation and consumers' expectations are the main reasons for the tradeoff between inflation and the unemployment rate (or output).[2]

This paper also estimates a natural rate of unemployment for the U.K. and the U.S. While there are several methods for this, one common feature is the use of a linear Phillips curve. Debelle and Laxton (1997) and Laxton et al. (1999) demonstrate, however, that the conventional estimates can be seriously biased and not appropriate for use with the nonlinear Phillips curve. They estimate the natural rate of unemployment under the assumption that the Phillips curve has a hyperbolic shape to impose convexity. In a similar spirit, we construct the natural rate of unemployment directly from the LSTAR model that is designed to capture the nonlinear features in the data. The natural rate of unemployment is defined as the unemployment rate that would have been observed if the effects of demand shocks had been dissipated. This measure of the natural rate is compatible

[1] See Dupasquier and Ricketts (1998) for a survey of the microfoundations underlying the nonlinear Phillips curve.

[2] Inflation tends to move slowly over time, generating a great deal of persistence and inertia. Consumers' expectations may also adjust slowly over time, perhaps being based on some sort of adaptive mechanism. Because decisions about wages and prices depend on expectations of future changes, slow adaptation is self- fulfilling, creating inertia. Further to this, consumers may exert different degrees of inertia and so will adjust with different time lags. When considering aggregate behavior, the time path of regime changes is likely to be better captured by a model which permits gradual rather than discrete adjustment.