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The New Keynesian Phillips Curve in multiple quantiles and the asymmetry of monetary policy☆

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ABSTRACT

This paper empirically explores the New Keynesian Phillips Curve (NKPC) in multiple quantiles and examines the uncertainty structure of the inflation process focusing on its relation to the asymmetry of monetary policy. We propose a multi-quantile version of the Generalized Method of Moments using the Laplace-type estimator. The empirical findings support the canonical NKPC with larger coefficients for marginal cost and expected inflation in the upper quantiles of the inflation distribution, while the hybrid NKPC fits better with the mid and lower quantiles. Accordingly, the risk of high inflation, measured by the right side tail of the conditional density, is more responsive to a change in expected inflation compared with the center and the left side. These results imply that monetary policy affects the future path of inflation in an asymmetric way, such that a tightening of monetary policy reduces high-inflation risks more than what we expect based on the point path, whereas the effect of expansionary policy on downside risk is minor. We also perform structural break tests and find that the model is unstable through 1983. There is a moderate change in the post-break data such that the downside risk of inflation becomes less responsive to expected inflation, which may reduce the cost of contractionary monetary policy.

1. Introduction

The New Keynesian Phillips Curve (NKPC) has played an important role in recent theoretical work on inflation as well as in monetary policy analysis. It explains inflation dynamics through the relation between expected inflation and marginal cost, and its hybrid version includes lagged inflation as an additional component that shifts the curve. This paper empirically examines the US hybrid NKPC focusing on the roles of forward-looking and backward-looking components, and studies the monetary policy implications. However, rather than using the traditional mean relations, we explore the relations in multiple quantiles. Analyzing multiple quantiles is helpful for investigating various aspects of the relations between inflation and the components in the NKPC other than the conditional mean. In general, those components may influence not only the conditional mean but also many other characteristics of the conditional distribution, such as by expanding its dispersion, stretching one tail of the distribution, and even inducing multimodality. Thus, it is possible that the roles of backward-looking and forward-looking components in the NKPC vary across quantiles if they have asymmetric relations to the uncertainty structure of inflation, and thus relying only on the mean would not be sufficient to capture the relations. Explicit investigation of these relations via multiple quantile estimation can provide a more informative empirical analysis.

The primary purpose of using a multiple-quantile model in this paper is to make useful inferences about the asymmetric monetary policy. The asymmetry can manifest in two ways. First, the monetary authority may respond asymmetrically to different economic circumstances. If the Fed expects inflationary pressure in the near future, it has to focus more on the probability that future inflation will exceed a certain level, such as the target range in the inflation targeting system; thus, the equations for upper quantiles are more interesting. Second, effect of policy on the risk of inflation is asymmetric. If the quantile coefficients are asymmetric in the upper and lower quantiles, then the increase and decrease in the components change the distribution of inflation in an asymmetric way, indicating that the changes in the inflation risk structure in expansionary and tight monetary policy environments would be different. In addition, if the Fed's loss function for inflation forecasting is asymmetric such as Granger (1969)'s *LinLin* with weight $(1-\alpha, \alpha)$, the Fed's optimal

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point forecast is not the conditional mean but the αth conditional quantile.

The NKPC model used in this paper is the hybrid version. The canonical NKPC based on Calvo (1983) does not contain the lagged inflation term, and as Gali et al. (2005) point out, the microfoundation of the lagged term is not clear. Mazumder (2011) uses the canonical model to show that the NKPC produces a counter-intuitive negative and significant coefficient on procyclical marginal cost when surveys of inflation forecasts are used. However, Fuhrer and Moore (1995) find that the canonical NKPC is not successful in explaining the stylized fact that monetary policy has a delayed effect on inflation. Thus, many works augment the NKPC with lagged inflation to capture the persistency of inflation, calling it a hybrid NKPC, and thereby improve the analysis of the lagged effect (Adam and Padula, 2011; Fuhrer and Moore, 1995; Henzel and Wollmershauser, 2008; Gali and Gertler, 1999; Malikane, 2014). On the other hand, Hall et al. (2009) and Kim and Kim (2008) claim that a seemingly significant lagged inflation coefficient is primarily due to the misspecification of the NKPC such as the existence of a structural break and nonlinearity. Examining the backward looking component provides an important monetary policy implication. Without lagged inflation, the monetary policy effect is generally described by the direct change in expected inflation due to the policy change. The presence of the backward looking component indicates the indirect effect of monetary policy on the real economy, implying that the policy effects are more complicated.

To estimate the model, we propose a multi-quantile version of the Generalized Method of Moments (GMM) using the Chernozhukov and Hong (2003)'s Laplace-type estimator(LTE). Chortareas et al. (2012) estimate a similar model for Euro data using Kim and Muller (2004)'s two-stage quantile regression which is the quantile version of univariate 2SLS. Our method is superior to theirs in several respects. First, GMM is generally more efficient than 2SLS in structural models such as the NKPC. Second, our multi-quantile model is a special case of a multiple equation model in which the error terms of different equations are correlated. Thus, as implied by Jun and Pinkse (2009), joint estimation of multiple quantiles is more efficient than separate estimation of each single quantile. Moreover, our method is also advantageous in that the variance–covariance estimator is heteroscedasticity and autocorrelation robust (HAC), while Chortareas et al. (2012) use the covariance estimator designed for *iid* cases, which is generally inconsistent in a structural model. Xu et al. (2015) estimate a quantile version of the Phillips curve with nonlinear GDP. However, they assume that expected inflation is adaptive, and, similar to Chortareas et al. (2012), do not consider join-estimation.

The estimation results substantially differ across quantile levels, and thereby show that monetary policy changes the shape of the conditional distribution of inflation as well as its point path. In the upper quantiles, the estimated coefficients are close to those of canonical NKPC in that the expected inflation coefficients are higher and the lagged inflation one is statistically insignificant. However, the results support the hybrid version in the mid and lower quantile levels, in which the coefficients for lagged inflation are statistically significant with a lower expected-inflation coefficient. The coefficient for marginal cost is also higher and mostly statistically significant in the upper quantiles. Accordingly, it is expected that contractionary monetary policy would be more efficient in terms of reducing high-inflation risks than what we expect based on the point path. The results also imply that if the Fed's inflation forecasts apply much more weight to inflationary pressure than disinflationary pressure, it may be desirable that the Fed adopts canonical NKPC even though the conventional mean equation is close to the hybrid one.

Considering the abundant evidence of structural breaks in inflation models in the early 1980s, we also perform structural break tests using a modified version of Qu (2008), and find that the parameters remain unstable through 1983 in all quantile levels. The empirical results using the post-break data show that the overall patterns across quantiles are similar, except that the expected-inflation coefficient decreased in both tails of the distribution, which is possibly due to the relatively stable inflation in this period. In addition, the results support the view that inflation becomes riskier in the sense of *dispersive order* (Shaked and Shanthikumar, 2006) when increasing expected inflation while decreasing expected inflation makes it less risky, which also support the asymmetry of monetary policy.

The remainder of this paper is organized as follows. Section 2 introduces multiple quantile models in the benchmark NKPC. Section 3 shows the results of the empirical analysis and Section 4 concludes.

2. The New Keynesian Phillips Curve and the conditional quantile model

The canonical NKPC model, originating in Calvo (1983)'s staggered price setting and forward-looking economic agents, expresses current inflation as a function of expected inflation and marginal costs. This model has faced criticism due to its insufficient explanation of the persistence of US inflation dynamics. The hybrid version was introduced to tackle this problem by including a backward-looking component (Gali and Gertler, 1999), which can be expressed as

$$\pi_t = \gamma_0 + \gamma_f \pi^e_{t+1} + \gamma_b \pi_{t-1} + \lambda mc_t \qquad (2.1)$$

where π_t is the rate of inflation, π^e_{t+1} is expected inflation for $t+1$ at time t, and mc_t is marginal cost of production. If $\gamma_b = 0$, Eq.(2.1) is reduced to the canonical NKPC. The choice between the canonical model and the hybrid version has been an important issue not only in the theoretic explanation of inflation dynamics, but also in policy analysis. The presence of lagged inflation in the NKPC indicates the lagged effect of monetary policy via changing the real economy, while the forward-looking term explains the direct effect by changing economic agents' expectations. Consequently, an important policy implication of the hybrid version is that, if the backward-looking component is not significant, the Fed can control current inflation by managing expected inflation with little distortion of the real economy. Gali and Gertler (1999), Gali et al. (2001), and Sbordone (2002,2005) show that expected inflation is an important driving force of current inflation, while Fuhrer and Moore (1995), Fuhrer (1997), and Roberts (1997) insist that lagged inflation is a more important component than expected inflation in explaining actual inflation.

The main purpose of this paper is to examine the hybrid NKPC at multiple quantile levels. To this end, we introduce the conditional quantile equation to the NKPC. Let $x_t = (1, \pi^e_{t+1}, \pi_{t-1}, mc_t)$ and z_t be the vector of instrumental variables for x_t. In addition, let π_t have the conditional distribution function $F_t(\pi) = Pr(\pi_t \leq \pi | \Omega_t)$, where $\Omega_t = \{\mathfrak{F}_{t-1}, z_t\}$ and $\mathfrak{F}_{t-1}$ is the information set at $t-1$. The αth quantile of π_t conditional on Ω_t, denoted as q^α_t, is defined as

$$q^\alpha_t \equiv \inf_{v \in R} \{v : F_t(v) > \alpha\}$$
$$\text{or if } F_t(\pi) \text{ is continuous,} \quad q^\alpha_t \equiv F^{-1}_t(\alpha). \qquad (2.2)$$

That is, conditional quantile q^α_t is that the probability of π_t being less than q^α_t is α. In this paper we assume that there exists a parameter vector $\beta^\alpha = (\gamma^\alpha_0, \gamma^\alpha_f, \gamma^\alpha_b, \lambda^\alpha)\prime$ for all $0 < \alpha < 1$ such that the NKPC in Eq. (2.1) applies to the quantile function q^α_t, i.e. $q^\alpha_t =$