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## The time-varying correlation between output and prices in the United States over the period 1800–2014

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### ABSTRACT

In this study, we examine the time-varying correlations between output and prices, while controlling for the impact of the monetary policy stance and output and inflation uncertainties over the period 1800–2014. The results of the empirical analysis reveal that the dynamic correlations of output and prices were typically negative, suggesting a countercyclical behaviour of prices, apart from the early 1840s and from the beginning until the middle of the 20th century, when the correlation was positive, indicating a procyclicality of prices. A historical decomposition analysis based on a sign-restricted structural vector autoregressive model is able to relate the procyclical and countercyclical behaviour to the predominance of aggregate supply and aggregate demand and/or monetary policy shocks, respectively. Moreover, inflation uncertainty (monetary policy stance) was found to have a positive (negative) effect on inflation over the last 215 years.

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## 1. Introduction

An important question in the business cycle literature is whether prices are procyclical (i.e., output and prices move in the same direction) or countercyclical (i.e., output and prices move in the opposite direction). However, this issue has remained unanswered for the US economy, given that evidence in this regard has been mixed (see Lee, 2006; Konstantakopoulou et al., 2009; Haslag and Hsu, 2012; Brock and Haslag, 2014; Keating and Valcarcel, 2015; and references cited therein for a detailed literature review).

While Friedman and Schwartz (1982) provided evidence that prices are procyclical, this view was challenged by Kydland and Prescott (1990). Cooley and Ohanian (1991), Backus and Kehoe (1992) and Smith (1992) suggested that the contradictory evidence is contingent on the sample period and hence the nature of the underlying macroeconomic shocks driving the business cycle.

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Depending on whether aggregate demand (AD) and/or monetary policy (MP) shocks (aggregate supply (AS) shocks) drive the business cycle, prices would be procyclical (countercyclical). Thus, we need to analyse the correlation between prices and output using a time-varying approach, and then determine which shocks were important over time based on a structural framework.

Against this backdrop, the objective of our study is to analyse the evolution of the correlation between output and prices for the US economy using Engle’s (2002) dynamic conditional correlation (DCC)-GARCH model over the period of 1800–2014. Besides accounting for time-varying volatility behaviour of the data, a major advantage of the DCC-GARCH approach is its ability to detect changes in the conditional correlation over time. Moreover, it is able to distinguish negative correlations due to episodes in single years, synchronous behaviour during stable years and asynchronous behaviour in turbulent years. Unlike rolling windows, an alternative way to capture time variability, the proposed measure does not suffer from the so called “ghost features”, as the effects of a shock are not reflected in  $m$  consecutive periods, with  $m$  being the window span. In addition, under the proposed measure, there is neither a need to set a window span nor a loss of observations, and no subsample estimation is required. As discussed above, depending on the predominance of the type of shock(s), time-variation in the comovement between output and prices may depend on the state of the economy.

Our paper is related to the work of Lee (2006), who also used the DCC-GARCH model to analyse the dynamic correlation between prices and output for the US economy over the quarterly period of 1900:1–2002:4. However, unlike Lee (2006), we not only consider a longer time span, but also analyse the robustness of the conditional correlation between output and prices by incorporating short-term interest rates, output and inflation volatilities in the framework in order to capture the role of monetary policy, output and inflation uncertainties, respectively, in this relationship. More importantly, unlike Lee (2006), using a historical decomposition analysis of the shocks (AS, AD and MP) derived from a sign-restricted Bayesian structural vector autoregression (SVAR), we show that the time-varying correlation can be tied with the dominance of a specific shock(s). To the best of our knowledge, our paper is the first attempt to provide an in-depth time-varying analysis of the correlation between output and prices of the US economy using over two centuries of data.

The remainder of the paper is organized as follows. Section 2 describes the empirical methodology and Section 3 the data used. Section 4 presents the empirical results, with Section 5 summarising the results and offering some concluding remarks.

## 2. Methodology

In order to examine the evolution of co-movements between output and prices, we obtain a time-varying measure of correlation based on the dynamic conditional correlation (DCC) model of Engle (2002).

Let  $y_t = [y_{1t}, y_{2t}]'$  be a  $2 \times 1$  vector comprising the data series. The conditional mean equations are then represented by:

$$A(L)y_t = B(L)x_t + \varepsilon_t, \text{ where } \varepsilon_t | \Omega_{t-1} \sim N(0, H_t), \text{ and } t = 1, \dots, T \quad (1)$$

where  $A$  and  $B$  are matrices of endogenous and exogenous variables, respectively,  $L$  is the lag operator and  $\varepsilon_t$  is the vector of innovations based on the information set,  $\Omega$ , available at time  $t - 1$ . The  $\varepsilon_t$  vector has the following conditional variance-covariance matrix:

$$H_t = D_t R_t D_t, \quad (2)$$

where  $D_t = \text{diag} \sqrt{h_{it}}$  is a  $2 \times 2$  matrix containing the time-varying standard deviations obtained from the univariate GARCH (p,q) models as:

$$h_{it} = \gamma_i + \sum_{p=1}^{P_i} \alpha_{ip} \varepsilon_{it-p}^2 + \sum_{q=1}^{Q_i} \beta_{iq} h_{iq-q}, \forall i = 1, 2. \quad (3)$$

The DCC(M,N) model of Engle (2002) comprises the following structure:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}, \quad (4)$$

where:

$$Q_t = \left( 1 - \sum_{m=1}^M a_m - \sum_{n=1}^N b_n \right) \bar{Q} + \sum_{m=1}^M a_m (\varepsilon_{t-m}^2) + \sum_{n=1}^N b_n Q_{t-n}. \quad (5)$$

$\bar{Q}$  is the time-invariant variance-covariance matrix retrieved from estimating Eq. (3), and  $Q_t Q_t^*$  is a  $2 \times 2$  diagonal matrix comprising the square root of the diagonal elements of

Finally,  $R_t = \rho_{ijt} = c q_{ij,t} \sqrt{q_{ii,t} q_{jj,t}}$ , where  $i, j = 1, 2$  is the  $2 \times 2$  matrix comprising the conditional correlations, which are our main focus.

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