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Asymmetries in the transmission of monetary policy shocks over the business cycle: a Bayesian Quantile Factor Augmented VAR

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Abstract

This paper introduces a Bayesian Quantile Factor Augmented VAR (BQFAVAR) to examine the asymmetric effects of monetary policy throughout the business cycle. Monte Carlo experiments demonstrate that the model effectively captures non-linearities in impulse responses. Analysis of aggregate responses to a contractionary monetary policy shock reveals that financial variables and industrial production exhibit more pronounced impacts during recessions compared to expansions, aligning with predictions from the 'financial accelerator' propagation mechanism literature. Additionally, inflation displays a higher level of symmetry across economic conditions, consistent with households' loss aversion in the context of reference-dependent preferences and central banks' commitment to maintaining price stability. The examination of price rigidities at a granular level, employing sectoral prices and quantities, demonstrates that during recessions, the contractionary policy shock results in a more pronounced negative impact on quantities compared to expansions. This finding provides support for the notion of stronger downward than upward price rigidity, as suggested by 'menu-costs models'.

Keywords: Bayesian Quantile VAR, FAVAR, Asymmetric effects of monetary policy, Disaggregate prices, Non-linear models

JEL Codes: C11 C32 E32 E37 E52

Non-technical summary

In this study, I analyze the impact of monetary policy changes in the United States on various economic indicators, including output, inflation, the Excess Bond Premium, and a detailed dataset of sectoral prices and quantities spanning from 1976 to 2005. The results indicate that when the interest rate is tightened, financial variables and industrial production exhibit notably stronger responses during economic downturns compared to periods of economic expansion. However, the response of inflation appears to be more symmetric across different economic conditions.

The increased influence of monetary policy tightening on the Excess Bond Premium and industrial production during recessions suggests that interest rate changes affect borrowing costs and investment decisions more strongly in economic downturns. This phenomenon can be attributed to the weakened state of firms' balance sheets during periods of economic downturn, leading to an increase in the premium as borrowers become more reliant on external finance. While the less pronounced differences in how inflation responds to monetary policy shocks across economic conditions may be due to households' tendency to be more sensitive to consumption losses and central banks measures to maintain price stability. In addition, inflation responses are weaker during recessions due to increased inflexibility in the labor market.

Cross-sectoral analysis of prices and quantities reveals that during recessions, price reactions vary more compared to periods of economic growth. However, on average, the results of this analysis suggest that prices don't change significantly in response to monetary policy shifts. While, when the economy is contracting, monetary policy tightening has a larger negative impact on output compared to expansions. This asymmetry can be attributed to stronger downward than upward price rigidity, meaning that the effects of monetary policy changes are primarily reflected in output.

1 Introduction

Is the efficacy of monetary policy contingent on the economic state? Influenced by seminal papers such as those by Graham (1930), Keynes (1937) or Friedman and Schwartz (1963) this question has been explored extensively in the literature, revealing empirical evidence of monetary policy exerting asymmetric effects on output and prices depending on the prevailing economic state. Accounting for such non-linearities carries significant implications for economic policy formulation and implementation.

This study investigates this question using data from the United States (US) within the framework of a Bayesian Quantile Factor Augmented VAR (BQFAVAR). The proposed nonlinear approach extends the factor augmented VAR (FAVAR) introduced by Bernanke et al. (2005) to incorporate prevailing state of the economy at the policymakers' intervention point through the modeling of the conditional quantile distribution. The results representing the 'neutral' economic scenario align with the average impact observed on response variables in the seminal paper.

However, when conditioning on the tails of the real economic activity factor, proxying economic expansions and recessions, the impact of contractionary monetary policy innovations provides further evidence of the asymmetric impact of monetary policy with respect to the economic state. Specifically, financial variables and industrial production demonstrate heightened responsiveness during economic contractions compared to expansions, while the response of inflation displays a higher degree of symmetry. Studies by Weise (1999), Dolado and Dolores (2001) or Lo and Piger (2005), among others, corroborate these findings, highlighting a stronger impact of monetary policy innovations on real activity during recessions alongside a more homogenous impact on the price level across the different business cycle phases. However, it is noteworthy that these results diverge from previous research, such as that of Tenreyro and Thwaites (2016), which suggests a more pronounced impact of monetary policy shocks during economic expansions. This discrepancy may be attributed, among other reasons, to the counteracting (or reinforcing) impact of fiscal policy during recessions (booms).

Furthermore, my findings align with expectations from the literature on the 'financial accelerator' propagation mechanism. This theory suggests that information asymmetry between borrowers and lenders results in an external finance premium, which typically relies on the borrower's net worth. Borrowers with higher net worth can offer more collateral, reducing their cost of external financing. Bernanke and Gertler (1995) explore the 'balance-sheet' channel of the credit channel theory, where changes in short-term interest rates impact capital costs and the external finance premium.[1] This dependence on borrower net worth creates a 'financial accelerator' propagation mechanism. Consequently, policy tightening increases capital costs through the interest rate channel and lowers collateral values and cash flow, positively affecting the external finance premium.

As a result, monetary policy's impact is most significant during periods when firms heavily rely on external financing. During recessions, firms' balance sheets are typically weaker, causing the premium to rise alongside borrowers' reliance on external finance. Therefore, monetary

[1] See also Blinder (1987), Gertler and Hubbard (1988), Bernanke and Gertler (1989) or Kiyotaki and Moore (1997).

policy tends to have stronger effects during recessions than in booms. Consistent with the predictions of the 'financial accelerator' propagation mechanism, my findings, along with those of Peersman and Smets (2005), indicate a stronger impact on output and financial variables during recessions.

The diminished evidence of state-dependent asymmetries in inflation's response to a monetary policy shock can be attributed to multiple factors. One potential explanation is households' aversion to losses within the framework of reference-dependent preferences and downward stickiness of real wages during recessions. Santoro et al. (2014) suggest that the relatively symmetric response of inflation compared to output during recessions could be explained by the aversion of households to losses, as described in the prospect theory by Kahneman and Tversky (1979). According to their modeling strategy, households' utility is influenced by the deviation of their consumption from a habit-based reference level, below which loss aversion is evident. Consistent with prospect theory, losses in consumption utility are more impactful than gains. Concurrently, inflation responses are attenuated by an increased degree of real rigidity in the labor market.

Additionally, the impact of central banks' commitment to maintaining price stability through monetary policy, irrespective of the state of the economy, must be considered when analyzing the response of inflation. The significant influence of central banks on economic activity and inflation is supported by various research, including Cogley and Sargent (2005), **?**, and Agrippino and Ricco (2021). Moreover, Forni et al. (2020) provide evidence that monetary policy shocks have asymmetric effects on prices and output, but the systematic response of central banks helps to maintain inflation stability. This aligns with the Eurosystem monetary transmission network study Angeloni et al. (2003), which discusses the stabilizing effects of monetary policy on inflation across the business cycle.

Furthermore, this study delves into the presence of price rigidities at a granular level by incorporating Boivin et al. (2009)'s extensive dataset of sectoral prices and quantities. The findings are consistent with those of the reference paper, indicating that the volatility in the granular price series does not translate into price flexibility in response to monetary policy shocks. Additionally, in the short run, prices exhibit more heterogeneous responses during a recession compared to an expansion. Specifically, the contractionary policy shock during recessions has a larger negative impact on quantities than during expansions. This asymmetry in response to monetary policy shocks is in line with the mechanisms elucidated by 'menu-costs models', which attribute it to stronger downward than upward price rigidity, implying that negative fluctuations are primarily reflected in output (e.g., Ball and Mankiw (1994) and Senda (2001)).

This paper attempts to advance the existing empirical literature in three ways. Firstly, the proposed methodology employs rank reduction methods to proxy the state of the business cycle beyond output growth and to improve the identification of the monetary policy shock. Consistent with Sims (1992), extending the available information set allows for better identification of the monetary policy transmission. In addition, the inclusion of unobserved factors allows to map the responses to a monetary policy shock from a broad set of variables. My approach characterizes economic conditions through a factor that captures the dynamics of a set of macroeconomic variables, thereby synthesizing information about the business cycle from various sources.

Secondly, this paper explores diversity across the conditional response distribution (see Koenker (2005)). I investigate whether this method offers valuable insights into identifying monetary policy shocks compared to conventional impulse response analysis, which measures the average impact of a shock on the response variable.

Finally, this analysis contributes to the literature that analyzes the heterogeneity of sectoral prices to enhance the transmission of monetary policy shocks to the aggregate economy. In particular, providing state-dependent cross-sectoral responses represents an innovation compared to previous approaches.

The remainder of the paper is laid out as follows: Section 2 introduces the empirical model and the identification strategy. Section 3 contains the results of a small Monte Carlo experiment to assess the performance of the model picking up on asymmetries in the data. Section 4 discusses the aggregate and cross-sectoral results and their implications for the asymmetry in the monetary policy actions. Section 5 concludes.

2 Empirical methodology

This section sets out the specification of the econometric model used in this study and illustrates my approach to statistical inference. In a similar fashion as Koop and Korobilis (2014) and Dolado et al. (2020) I perform a two step analysis. First I extract a set of common factors that I then include into a quantile Bayesian autoregression, QBVAR henceforth, and uncover the response of the main macroeconomic variables to a monetary policy shock in the US. Hereby I try to understand whether studying the quantiles of the distribution adds to the results of the canonical paper Bernanke et al. (2005).

2.1 Monetary policy transmission and proxies for the business cycle

Bernanke et al. (2005) shows that the FAVAR framework allows for a better identification of the monetary policy shock than conventional VAR models: The fact that the set of variables considered by the researcher in a small scale VAR is likely to be less comprehensive than that taken into account by financial market participants and the Federal Reserve, can give rise to an omitted variable problem. Therefore, by applying rank reduction techniques I aim to base my analysis on an information set that resembles the central bank's monitoring of inflation.[2]

My data set for the US has a monthly frequency and runs from February 1976 to June 2005. Building on Bernanke et al. (2005), the data include a balanced panel of 118 monthly macroeconomic time series from which I extract 5 unobserved factors. For comparability to other empirical studies on the state dependency of monetary policy, I extend this dataset by the Excess Bond Premium (EBP) (Gilchrist and Zakrajšek (2012)) and in an additional exercise by cross-sectoral series for prices and quantities (see section 4.2). The series are standardized and transformed so as to induce stationary. Table 3 in Section C of the Appendix lists the macroeconomic and financial series considered in this study as well as its transformations and

[2]For an articulation of this argument refer to Sims (1992) or Boivin et al. (2009).

sources. The inclusion of unobserved factors carries the additional advantage that the responses of all the variables contained in the panel to a monetary policy shock can be mapped.

The business cycle is traditionally defined as a cycle of expansions and contractions in economic activity. Commonly accepted definitions, such as that from the National Bureau of Economic Research (NBER), characterize a recession as two consecutive quarters of negative growth in key indicators such as GDP. An alternative measure is the output gap, which considers periods when the actual output is below potential.

Econometric approaches, such as Markov switching models, smooth transition models, and Dynamic Stochastic General Equilibrium (DSGE) models, provide a nuanced view of business cycles by capturing regime changes and shifts in statistical properties over time. These models link economic theory with empirical data, offering insights into the propagation of policy shocks. They also enhance understanding of the nonlinear and stochastic characteristics of business cycles, surpassing simpler definitions based on consecutive quarters of negative growth. The Markov switching model, introduced by Hamilton (1989), identifies regimes in economic data, thus capturing the dynamic transitions between different phases of the cycle. This model helps identify periods of expansion and contraction by examining shifts in statistical properties over time. Additionally, smooth transition models, such as those developed by Terasvirta and Anderson (1992), enhance this analysis by allowing for gradual rather than abrupt changes between regimes, which better reflect real economic conditions. DSGE models for business cycle estimation (e.g., Smets and Wouters (2007)), incorporate microeconomic foundations and frictions, providing a robust framework for analyzing policy impacts on business cycles.

Moreover, latent variable models, such as Dynamic Factor models, have been instrumental in distinguishing and analyzing business cycle fluctuations by estimating and interpreting common dynamic factors from economic data, as discussed by Stock and Watson (1989), Diebold and Rudebusch (1996), or Kim and Nelson (1998). This study exploits the information content of large datasets not only to better identify and disentangle structural shocks but also to extract a real economic activity factor. The real economic activity factor captures the intricate dynamics of the economy by synthesizing common fluctuations across various sectors and variables. This factor leverages information embedded in real activity data and exhibits a strong correlation with established business cycle indicators, such as the Chicago National Activity Index.[3]

The performance of the real economic activity factor in proxying the business cycle is further evaluated through a recursive forecasting exercise. This exercise tests Hamilton (2018)'s assertion that negative prediction errors are associated with recessions. Using a bivariate QBVAR model for the US, which includes the level of industrial production and either the median (50^{th} quantile) or the lower decile (10^{th} quantile) of the real economic activity factor, I assess the effectiveness of the factor and its quantiles in capturing business cycle dynamics and overall economic conditions. The results of this exercise, detailed in Section A of the Appendix, align with Hamilton's findings for US employment: the median specification results in negative fore-

[3]Similar to Mumtaz (2010), the real economic activity subsample consists of variables related to real output and income, consumption, housing starts, and inventories. Refer to Section C of the Appendix for a more precise description of the series classification. To remove the influence of real activity from the other variables, I regress the remaining series on the real activity factor and store the residuals. These residuals represent the rest of the panel, cleaned of the impact of real economic activity.

cast errors one year ahead of financial crises, while the 10^{th} quantile specification yields positive or near-zero forecast errors. This evidence supports the claim that the median real economic activity factor serves as a reliable proxy for cyclical real economic developments, and that the 10^{th} quantile effectively captures recessions by driving forecast errors to zero and above.

In the following, to gauge the state of the economy, the conditional tails of the real economic activity factor are analyzed to represent expansions (right-hand tail) or recessions (left-hand tail). Carrying out the analysis separately for expansions and recessions I inspect if there are differences across the quantiles of the response variable's distribution.

The large set of N-observable "informational" series X_t, is related to the unobserved common factors according to the observation equation

$$X_t = \Lambda F_t + \epsilon_t \tag{1}$$

$$F_t = \begin{bmatrix} F_t^E \\ F_t^X \end{bmatrix}, \quad C_t = \begin{bmatrix} F_t \\ R_t \end{bmatrix}$$

where Λ is a matrix of factor loadings and ϵ_t contains series specific components that are uncorrelated with F_t.[4] F_t^E represents the real economic activity factor (extracted from subset X^E) and F_t^X is the set of k common factors extracted from X_t after removing influence of F_t^E. C_t is a vector that combines the unobserved factors and the federal funds rate R_t, which measures of the stance of monetary policy.

2.2 A Bayesian quantile FAVAR model

Quantile regressions complement least squares regression. Two differences arise between the two methods: First, the quantile regression minimizes the sum of absolute errors, instead of the sum of squared errors. Second, the quantile regression places different varying weights on the error terms depending on whether these are below or above the quantile (e.g. Adrian et al. (2019)). Moreover, in frequentist settings the location of the random variable is defined through the minimization of the quantile regression criterion function also known as the "check-loss function" (Koenker and Bassett (1978)). Yu and Moyeed (2001) show that the "check-loss function" is related to the likelihood function for the asymmetric Laplace distribution. By forming the likelihood function based on the asymmetric Laplace distribution, they introduced Bayesian inference in the context of quantile regression.

Since the seminal work of Koenker and Bassett (1978) the literature has seen a large number of applications of quantile regression approaches in the field of risk management to calculate risk measures (e.g. Engle and Manganelli (2004), Chen et al. (2012) and White et al. (2015)) and, more recently, in the field of macroeconomics to measure tail risks to output growth (e.g. Adrian et al. (2019), Figueres and Jarociński (2020) and Adrian et al. (2018)).

Two relevant multivariate extensions of regression quantile models are the vector autoregressive (VAR) quantile model proposed in White et al. (2015) and Bayesian quantile VAR suggested in Schüler (2020). My approach consists in an extension of Schüler (2020)'s VAR framework

[4] Only fast moving variables in X_t are allowed to have a contemporaneous relationship with R_t. An extensive explanation is available in section 2.3.

to consider a large amount of information about the economy incorporating common factors extracted from a large cross section of indicators.

For given C_t and for fixed quantile values $\tau = (\tau_1, \tau_2, ..., \tau_d)'$ the transition equation (2) describes the joint dynamics of F_t and R_t as a reduced form QBVAR.

$$C_t = \nu_\tau + \sum_{i=1}^{p} A_{i|\tau} C_{t-i} + v_{i|\tau} \tag{2}$$

$A_{i|\tau}C_{t-i}$ denotes the dxd matrix of lagged coefficients, with $t = 1, ..., T$ and $d = k + 1^{obs} + 1^E$. ν_τ contains the intercepts and $v_{t|\tau} = (v_{1t|\tau 1}, ..., v_{dt|\tau_d})'$ is a vector of error terms which is distributed following a multivariate Laplace distribution.[5]

2.3 Identification

My baseline specification sets the Fed's policy instrument, the federal funds rate (R_t), as the observable variable. The monetary policy shock is identified recursively by ordering R_t last and considering its innovations as policy shocks. The recursive ordering implies that the factors will not react to a shock to monetary policy shock contemporaneously but within a month. Given that this assumption might not be valid for some of the variables in the panel I perform a categorization into two subsets based on the dynamics of their response to monetary policy shocks. Fast-moving variables are allowed to respond contemporaneously to unanticipated changes in the fed funds rate. While slow-moving variables are assumed to respond within a period to the monetary policy shock. The classification of these variables follow Bernanke et al. (2005).[6]

Following Schüler (2020) I perform pseudo-structural analysis. The focus of this approach is to summarize the common fluctuations of the disturbances at their selected quantiles and not at their first moment. Therefore, instead of the covariance matrix I study the co-exceedance measure introduced by Blomqvist (1950) and Koenker and Portnoy (1990), which captures the common fluctuation of the error terms around quantiles. Schüler (2020) proposes to identify the pseudo-structural shocks $\eta_{t|\tau} = (\eta_{1t|\tau}, .., \eta_{dt|\tau})'$ through the Cholesky decomposition $\Gamma_\tau = H_\tau H_\tau'$. The pseudo-structural shocks conditional on a vector of quantiles are defined as

$$\eta_{t|\tau} = H_\tau^{-1} \tilde{\phi_\tau}(v_{t|\tau}) \tag{3}$$

where $\tilde{\phi_\tau}(v_{t|\tau}) = (\frac{\tilde{\phi_{\tau 1}}(v_{1t|\tau 1})}{f_{v1t|\tau 1}(0)}, ..., \frac{\tilde{\phi_{\tau 1}}(v_{dt|\tau d})}{f_{vdt|\tau d}(0)})'$ with mean zero and unit variance, indicator function $\tilde{\phi_{\tau j}}(v_{jt|\tau j}) = \tau_j - \mathbb{1}((v_{jt|\tau j}) < 0)$, $\mathbb{1}$ and $j \in \{1, \dots, d\}$. $f_{vjt|\tau j}(0)$ is the probability density function of $v_{jt|\tau j}$ evaluated at 0.

Combining the previous blocks, the response to the monetary policy shock is retrieved through the pseudo quantile impulse response function.[7] The pseudo quantile impulse function captures marginal impact of marginal shock j on the system. $Q_\tau(C_{t+h}|\digamma_{t-1})$ defines the baseline scenario and $\check{Q}_\tau(C_{t+h}|\eta_{jt|\tau}, \digamma_{t-1})$ the shock scenario.

[5] Refer to Schüler (2020) for the detailed proof.

[6] The sections C and D of the Appendix identify the variables in the dataset that are classified as slow-moving.

[7] The quantile pseudo-impulse response functions conceptually build the generalized impulse response functions presented in Koop et al. (1996).

$$PQIRF_\tau(h, \eta_{jt|\tau}, \mathcal{F}_{t-1}) \equiv \check{Q}_\tau(C_{t+h}, \eta_{jt|\tau}, \mathcal{F}_{t-1}) - Q_\tau(C_{t+h}, \mathcal{F}_{t-1}) \tag{4}$$

2.4 Overview of the empirical approach

The empirical method can be summarized by the following steps:

1. Extract the economic activity factor as outlined in subsection 2.1.
2. Remove the potential implicit dependence of $\tilde{C}(F_t,\ Y_t)$ on R_t :
   (i) Compute the components that are not R_t ($\tilde{C}^*(F_t)$) by performing principal component analysis on the subset of slow-moving variables.
   (ii) Run the multiple regression of the form

   $$\tilde{C}(F_t,\ Y_t) = b_c * \tilde{C}^*(F_t) + b_R R_t + \epsilon_t$$

   (iii) Compute $\tilde{F}_t = \tilde{C}(F_t,\ Y_t) - \tilde{b}_R R_t$
   (iv) $C_t = \begin{bmatrix} \tilde{F}_t \\ R_t \end{bmatrix}$
3. Estimate a Quantile FAVAR in C_t.
4. Identify the Monetary Policy shock applying a recursive identification scheme.

Carry out 3 and 4 separately for different states of the business cycle by conditioning on the 10^{th} quantile of the real economic activity factor for recessions and on the 90^{th} quantile for expansions.

3 Monte Carlo simulations

I employ Monte Carlo simulations to evaluate the effectiveness of the BQVAR model in capturing data asymmetries and accurately discerning underlying non-linear patterns. These patterns are characterized by a regime-dependent Moving Average model, where the impact of monetary policy on real activity is particularly pronounced during periods of subdued industrial production performance.

Following the methodologies outlined in Barnichon and Matthes (2018) and Mumtaz and Piffer (2022), a moving average model with state-dependent responses to shocks is constructed. Initially, a monthly Vector Autoregression (VAR) model is estimated, providing the framework for calibrating my model. This VAR incorporates industrial production, CPI inflation, and the federal funds rate as endogenous variables, covering the period 1966-2007 for the US, and is modelled with 6 lags.[8] The first variable is estimated with the coefficients related to industrial production as it proxies the real economic activity factor introduced in the previous section, acting as a proxy for the business cycle. This choice aims to maximize the resemblance between

[8]For additional information on the data source used for the calibration of the Monte-Carlo study, refer to Table 2.

the underlying data generating process (DGP) of the simulation study and that of empirical interest.

Utilizing a recursive identification scheme, I estimate the linear impulse responses to a real activity shock (IP), an inflation shock (π), and a monetary policy shock (r). These responses, defined as the true impulse responses, are denoted by $\{\beta_{IP,l}\}_{l=0}^{15}$ for the real activity shock, $\{\beta_{\pi,l}\}_{l=0}^{15}$ for the inflation shock, and $\{\beta_{r,l}^{EXP}, \beta_{r,l}^{REC}\}_{l=0}^{15}$ for contractionary monetary shocks during expansions and recessions, respectively.

To introduce asymmetry during recessions, I modify the impulse responses of the monetary policy shock on industrial production. This adjustment is contingent upon instances where the sampled error of the first variable in the system, namely industrial production, displays a negative value. In such scenarios, the impact of monetary policy on industrial production for $\beta_{r,l}^{REC}$ will be tripled compared to the unmodified case at horizons $l = 1, 2, 3, 4$, while the unmodified version will be retained otherwise. This DGP will be denoted as the 'Non-linear DGP'.

The 'Linear DGP' mirrors the aforementioned description but does not incorporate the state-dependent impact of monetary policy on real activity. I include this case to conduct a thorough assessment and to rule out the possibility of the method artificially imposing asymmetric responses on the system. Instead, my aim is to discern whether the method accurately captures such asymmetries when they are inherent in the DGP.

Then, for each DGP, 100 artificial datasets with sample size $T = 500$ are simulated from a regime-dependent moving average model of order 15, driven by the aforementioned three structural shocks. The choice of a sample size of 500 aims to emulate a monthly data model spanning approximately 40 years, similar to applications in studies such as those by Bernanke et al. (2005) or Boivin et al. (2009).

$$\begin{aligned} y_t = & \sum_{l=0}^{15} \beta_{IP,l} \cdot \epsilon_{IP,t-l} + \sum_{l=0}^{15} \beta_{\pi,l} \cdot \epsilon_{\pi,t-l} \\ & + \sum_{l=0}^{15} \left[\beta_{r,l}^{EXP} \cdot I(\epsilon_{r,t-l} \geq 0) + \beta_{r,l}^{REC} \cdot I(\epsilon_{r,t-l} < 0)\right] \cdot \epsilon_{r,t-l}, \\ & \epsilon_t \sim N(0, I) \end{aligned} \tag{5}$$

with $y_t = (IP_t, \pi_t, r_t)'$ a vector containing the endogenous variables, and $\epsilon_t = (\epsilon_{IP,t-l}, \epsilon_{\pi,t-l}, \epsilon_{r,t-l})'$ a vector containing the structural shocks.

Following the empirical methodology, the model is separately estimated by conditioning on both the 10^{th} and 90^{th} quantiles of the primary variable. This iterative procedure is replicated for each of the 100 simulated datasets. In Figure 1, the impact of the monetary policy shock on all endogenous variables is presented. The results for the 'Non-linear DGP' are displayed in the first row, while those for the 'Linear DGP' are shown in the second row of the panel. The shaded red and green bands represent the 68% pointwise posterior bands for the results corresponding to the 10^{th} and 90^{th} conditional quantiles, respectively.

Visual inspection of the estimated quasi-impulse responses in Figure 1 points to a more persistent and negative impact of those responses conditioned on the 10^{th} quantile of Indus-

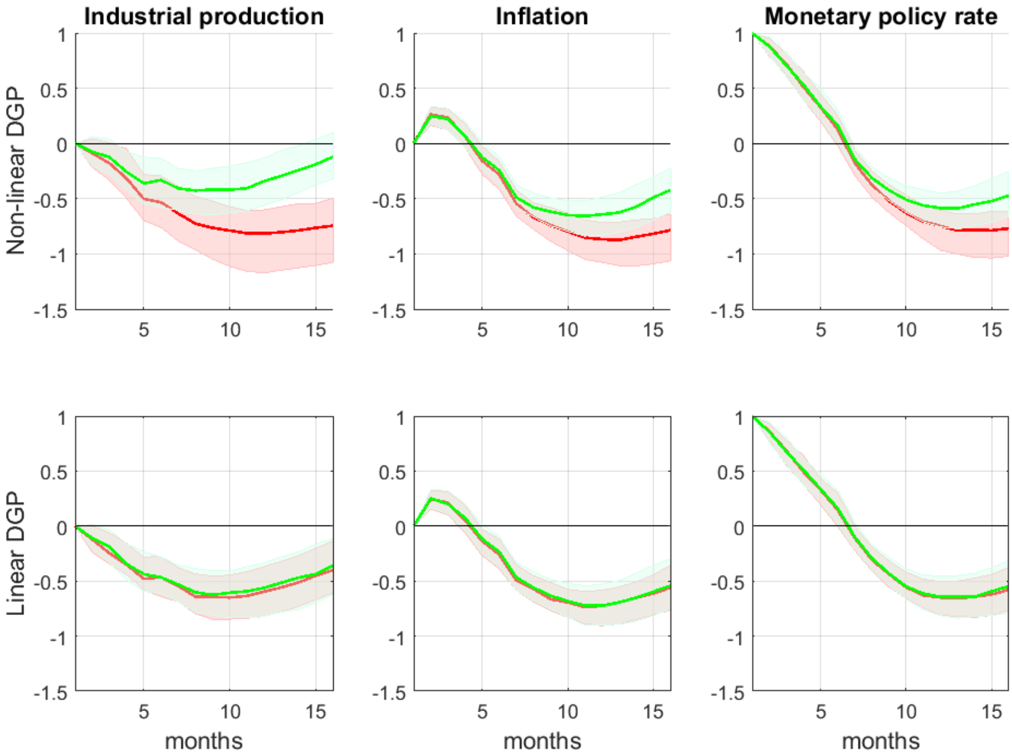

Figure 1: Estimated quasi-impulse responses for the datasets generated within the simulation study. Response to a one-standard deviation shock of a contractionary monetary policy shock for the conditional 10^{th} quantile (red) and 90^{th} quantile (green) of industrial production. The shaded bands delineate the the 68% pointwise posterior bands. The 'Linear DGP' refers to the case in which no asymmetries were incorporated into the moving average model. In the 'Non-linear DGP' the impact of monetary policy on real activity is notably pronounced during recessions.

trial production than those for the 90^{th} conditional quantile. In the 'Non-linear DGP', the model accurately identifies a stronger impact of monetary policy shocks on industrial production one month after the shock. The contemporaneous responses of inflation and the interest rate remain consistent across specifications. However, approximately six months after impact, a slightly stronger impact during recessions compared to expansions becomes evident. This disparity is attributed to the asymmetric reaction of industrial production. The increased impact of industrial production during recessions implicitly affects the interest rate's response, which adheres to a Taylor-type rule within the VAR framework, adjusting in response to macroeconomic developments. In the 'Linear DGP' case, the results for the 10^{th} and 90^{th} quantiles exhibit a consistent pattern, indicating that the model does not artificially impose asymmetric responses on the system.

Overall, this exercise confirms that the proposed methodology appears suitable for capturing the inherent asymmetries within the DGP. Subsequently, this assessment aims to validate the model's appropriateness for analyzing the nonlinear responses to monetary policy shocks in the context of the US economy. The empirical application of the proposed methodology will be illustrated in the next section.

4 Empirical analysis

4.1 Aggregate responses to a contractionary monetary policy shock

4.1.1 Key macroeconomic aggregates

In this section, I discuss the response of my data series to an unexpected increase of 25 basis points in the federal funds rate both, on an aggregate and sectoral level. Prior to studying the asymmetries in the impact of monetary policy across the business cycle, I relate my results for key macroeconomic aggregates to those reported by previous studies in the first column of Panel A: The black lines display the results as in Boivin et al. (2009) and the blue line corresponds to the BQFAVAR model.

The dotted lines show the results from a small-scale VAR under two different specifications and the solid black line displays the FAVAR results.[9] The solid blue line shows the median quantile pseudo impulse responses of my baseline specification to a contractionary monetary policy shock.[10] The baseline specification considers the conditional median of 5 factors and of the federal funds rate. The graphic assessment shows that the BQFAVAR baseline results resemble those of the canonical paper for all three variables. Unlike the small-sized VARs, FAVAR approaches exploit the relevant information contained in the large dataset. Therefore, the FAVAR response of the price level does not display a price puzzle and the response of industrial production is more conventional than that of the VARs.[11]

Figure 2 depicts that after a year an increase of the policy rate by 25 basis points reduces the level of industrial production by 0.14 per cent during an expansion (green) and by twice this magnitude during a recession (red). These results resemble those of Peersman and Smets (2002) and Bruns and Piffer (2021) for real GDP growth.[12] On the contrary, Tenreyro and Thwaites (2016) find stronger effects of monetary policy shocks on GDP during expansions than during recessions. The authors attribute this discrepancy, among other reasons, to the counteracting (or reinforcing) impact of fiscal policy during recessions (booms).

	horizon	
	1 year	4 years
IP	97%	35%
CPI	76%	61%
EBP	97%	33%

Table 1: Table reports the fraction of posterior draws for which the response during a recession was larger than in an expansion on a cumulative basis at different horizons.

The third and fourth columns of Figure 2 show the joint distribution for the cumulated

[9] The first VAR specification includes industrial production, the CPI and the federal funds rate and the second augments specification one with the first principal component of the large dataset. The FAVAR specification is based on 5 factors and the federal funds rate.

[10] The choice of the 50^{th} quantile, representing periods that are neither distinctly expansions nor contractions, enhances comparability with the findings of the canonical paper, where no distinction is made across economic states.

[11] For an articulation of this argument refer to Bernanke et al. (2005).

[12] In Peersman and Smets (2002) a one standard deviation shock is imposed. While in Bruns and Piffer (2021) the size of the shock is equivalent to that imposed in this study (25 basis points), the sign of the shock changes depending on the business cycle phase.

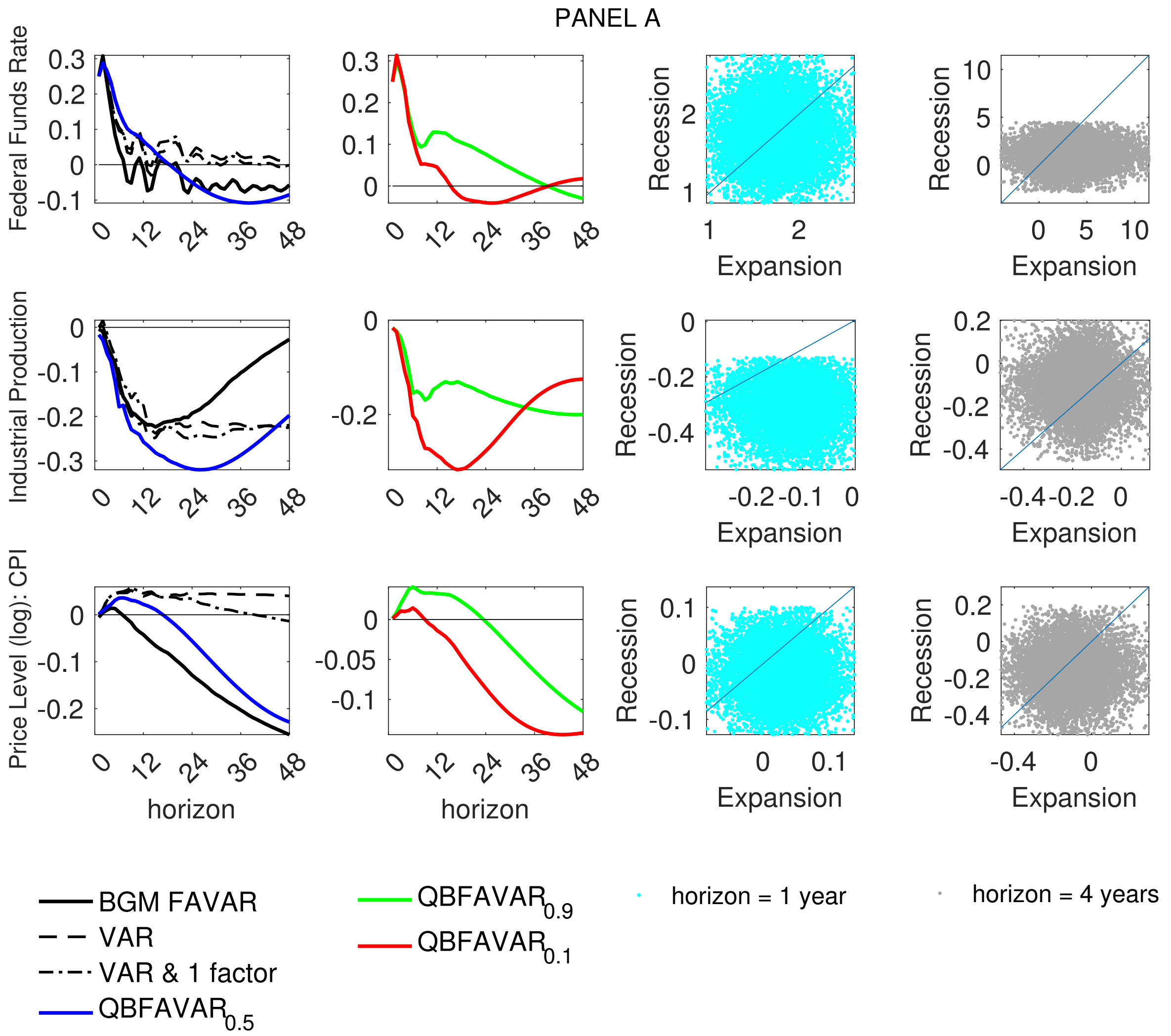

Figure 2: Response to an increase of 25 basis points in the federal funds rate. First two columns display response functions. Black lines display impulse response functions as in Boivin et al. (2009). For QBFAVAR the pseudo-impulse responses are reported. Green lines characterize expansions and red lines recessions. Scatter plots display the relation between expansion periods (x-axis) and recessions (y-Axis) at horizon of 1 year (cyan) and horizon of 4 years (grey).

pseudo impulse response over a year and after 4 years of the expansion and recessions. Values of the expansion periods are plotted on the x-axis, and the associated value of a recession period is shown on the y-axis. Those combinations clustered near the 45°line represent pairs for which there was little or no change between the business cycle phases and the draws that are located above the 45°line represent a higher effect of monetary policy in recessions. At the 1-year horizon the stronger reaction of the observable variables during an expansion is non-negligible with at least 97% of the joint distribution being above the 45°line for industrial production and 76% for inflation (Table 1). The evidence for differences across the business cycle phase is less clear at the longer horizon of 4 years.

Overall, the findings presented in Figure 2 and Table 1 suggest weaker evidence of state-dependent asymmetries in the response of inflation to a monetary policy shock compared to output. This phenomenon may be attributed, as suggested by Santoro et al. (2014), to households' aversion to losses within the framework of reference-dependent preferences, as introduced by Kahneman and Tversky (1979) and commonly known as 'prospect theory'. Consistent with the central principle of prospect theory, losses in consumption utility have a greater impact than gains. Additionally, inflation responses are further dampened due to heightened real rigidity in the labor market

4.1.2 Financial variables

Figure 3 illustrates the state-dependent impact of a contractionary monetary policy shock on the EBP. Increases in the EBP serve as proxies for heightened external finance premiums. In accordance with the 'balance-sheet' strain theory of the credit channel, the EBP exhibits a stronger response during recessions, with 97% of the draws lying above the 45-degree line at the 1-year horizon (see Table 1) .

The 'financial accelerator' propagation mechanism posits that asymmetrical information between borrowers and lenders results in an external finance premium, which is typically contingent upon the borrower's net worth. Borrowers with higher net worth can provide more collateral, thereby reducing their external financing costs.

Bernanke and Gertler (1995) explore the 'balance-sheet' channel of the credit channel theory, where changes in short-term interest rates influence capital costs and the external finance premium. This dependency on borrower net worth gives rise to a 'financial accelerator' propagation mechanism. Consequently, policy tightening raises capital costs through the interest rate channel and reduces collateral values and cash flow, which in turn positively impacts the external finance premium. Thus, monetary policy's effect is most pronounced during periods of heavy reliance on external financing.[13]

According to this theory, such asymmetries stem from deteriorating balance sheet quality, typically observed during economic downturns, leading to increased reliance on external financing and a corresponding rise in the external finance premium. This higher premium amplifies the impact of monetary policy shocks by strengthening the traditional interest rate channel.

My findings for the financial variables align with those reported by other empirical studies on the state dependency of the impact of monetary policy shocks, such as Tenreyro and Thwaites

[13] See for example Blinder (1987), Gertler and Hubbard (1988), or Kiyotaki and Moore (1997).

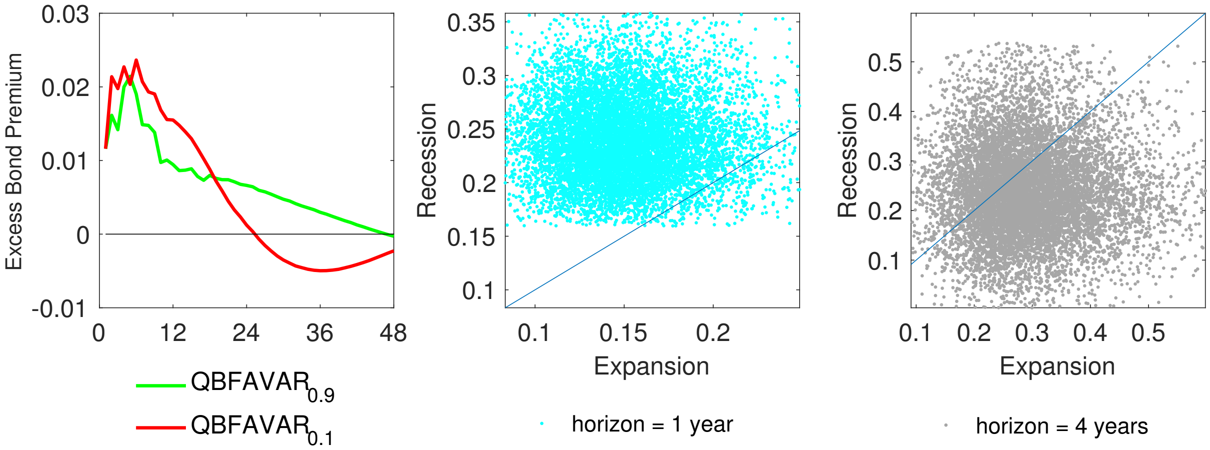

Figure 3: Pseudo-impulse responses to an increase of 25 basis points in the federal funds rate. Green lines characterize expansions and red lines recessions. Scatter plots display the relation between expansion periods (x-axis) and recessions (y-Axis) at the horizon of 1 year (cyan) and the horizon of 4 years (grey).

(2016), who also document a higher response of financial variables during recessions.[14] Other studies, such as Bruns and Piffer (2021), report results of similar magnitude to mine.

4.2 Exploration of price rigidities

This section examines the dynamics of disaggregate quantity and price responses to a contractionary monetary policy shock throughout the business cycle. The analysis of relative prices elucidates the extent to which monetary policy shocks induce real effects. Transitory fluctuations in real economic activity would result from a rapid and uniform adjustment of individual prices (see Baumeister et al. (2013)). Additionally, as emphasized by Aoki (2001) and Balke and Wynne (2007), focusing solely on the responses of aggregate price measures may not always offer a comprehensive understanding of the monetary transmission mechanism.

Overall, my findings align with the predictions of 'Menu-costs models', which elucidate the asymmetric responses to monetary policy shocks characterized by stronger downward than upward price rigidity. This suggests that negative fluctuations are primarily reflected in output.

4.2.1 Sectoral responses

Disaggregated responses offer valuable insights for the formulation of monetary policy. Therefore, I replicate the analysis outlined in Section 4.1 using the extensive dataset from Boivin et al. (2009). This dataset augments that of Bernanke et al. (2005) by including granular consumption and price series. Details on the sources and transformations of the sectoral producer

[14] Tenreyro and Thwaites (2016) find that the external finance premium amplifies the monetary policy shock in a recession and counteracts it during an expansion.

price and personal consumption series are included in Section D of the Appendix.[15]

Figure 4 depicts the median quasi-impulse response functions of the sectoral components of the personal consumption expenditure deflator and its corresponding real quantities following a contractionary policy shock of 25 basis points during two distinct phases of the business cycle. Recessions are displayed in the first column, and expansions are depicted in the second column. The solid lines represent the median responses of the aggregate price deflation and real consumption, while the dashed black lines represent the unweighted average of the granular responses.

The dynamics of the mean of the granular price and quantity responses resemble those of the aggregate indices. In line with Bernanke et al. (2005), Boivin et al. (2009) or Baumeister et al. (2013) I find no evidence of a price puzzle for the aggregate price level measure. However, at the granular level, some sectors exhibit a temporary price puzzle. While there is notable heterogeneity across sectoral responses in terms of magnitude and direction, the asymmetry with respect to the business cycle phase is less pronounced compared to key macroeconomic aggregates and financial variables studied earlier. Nonetheless, granular price responses exhibit discernible asymmetries relative to the state of the economy, with a larger proportion trending towards the negative territory in the medium term during recessions compared to expansions.

4.2.2 Cross-sectoral distribution of prices and quantities

I offer an alternative depiction of the effects of monetary shocks on disaggregated responses by presenting their entire distribution. Figure 5 displays the cross-sectoral smoothed densities of prices at selected horizons in the top row and of quantities in the bottom row.

For both prices and quantities, the distribution widens around 0 at longer horizons. A progression from primarily positive to negative price responses is observable. As posited in Baumeister et al. (2013), the progressive increase in dispersion over time accentuates the differences in speed and size of the adjustments.

During expansions, the response of disaggregate prices in the short term appears to be symmetrically bounded around zero, with a higher density at the origin compared to recessions. Moreover, the distribution of cross-sectoral price responses is slightly left-skewed during recessions. This implies that the shock leads to price increases in a larger share of sectors during downturns, but also that in some areas, the price adjustment involves more extreme reductions in the near term.

The cross-sectoral distribution of quantities shifts to the right of the origin during recessions. These results support the predictions of 'Menu-costs models', which explain this asymmetry in response to monetary policy shocks through stronger downward than upward price rigidity.[16] This implies that negative fluctuations are primarily mirrored in output.

[15] The dataset from Bernanke et al. (2005) spans from 1951:M01 to 2000:M07, but since the granular consumption and price series are available starting in 1976 in Boivin et al. (2009), the sample size is limited to 1976:M01-2000:M07.

[16] See, for instance, Ball and Mankiw (1994) and Senda (2001).

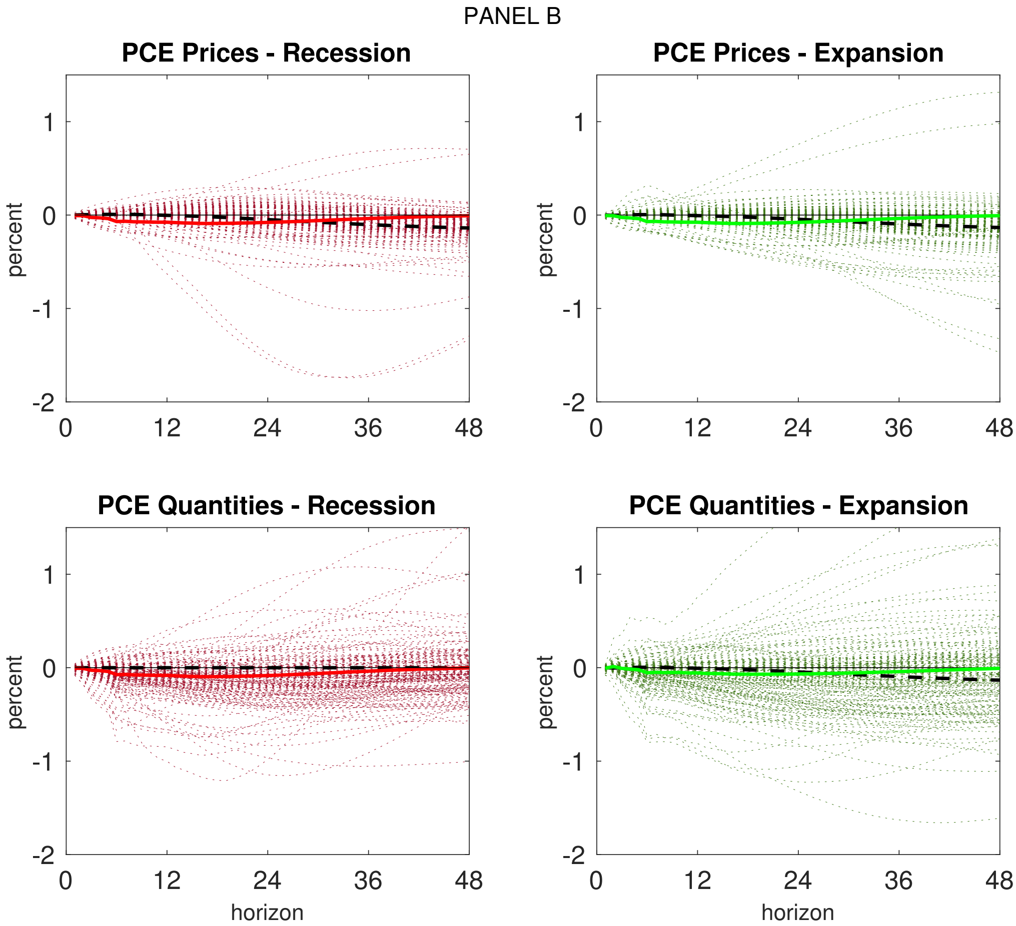

Figure 4: Estimated quasi-impulse responses: Top row displays the response of disaggregate prices during an recession (red) or expansion (green), bottom row that of disaggregate quantities. The monetary shock is a surprise increase of 25 basis points in the federal funds rate. Solid red and green lines represent the aggregate PCE deflator (top row) and real consumption (bottom row). Dashed black lines depicts the unweighted average of individual responses.

5 Conclusion

Extensive empirical evidence highlights the asymmetric responses of output and prices to monetary policy innovations across contractionary and expansionary phases of the business cycle. It is widely acknowledged that monetary policy has more pronounced effects on output and financial variables during contractions than during expansions. In contrast, price responses tend to exhibit little statistical variation across different phases of the business cycle.

This paper investigates the impact of the US monetary policy transmission mechanism over the business cycle, both at the aggregate and disaggregate levels, by extending the FAVAR model introduced by Bernanke et al. (2005). This extension allows the model to consider the conditional tails of the real economic activity factor to represent expansions (right-hand tail) or recessions (left-hand tail). Through Monte Carlo experiments, I demonstrate that the model is capable of capturing impulse response non-linearities driven by state-dependence.

Applying my methodology to the US economy with a broad dataset encompassing roughly

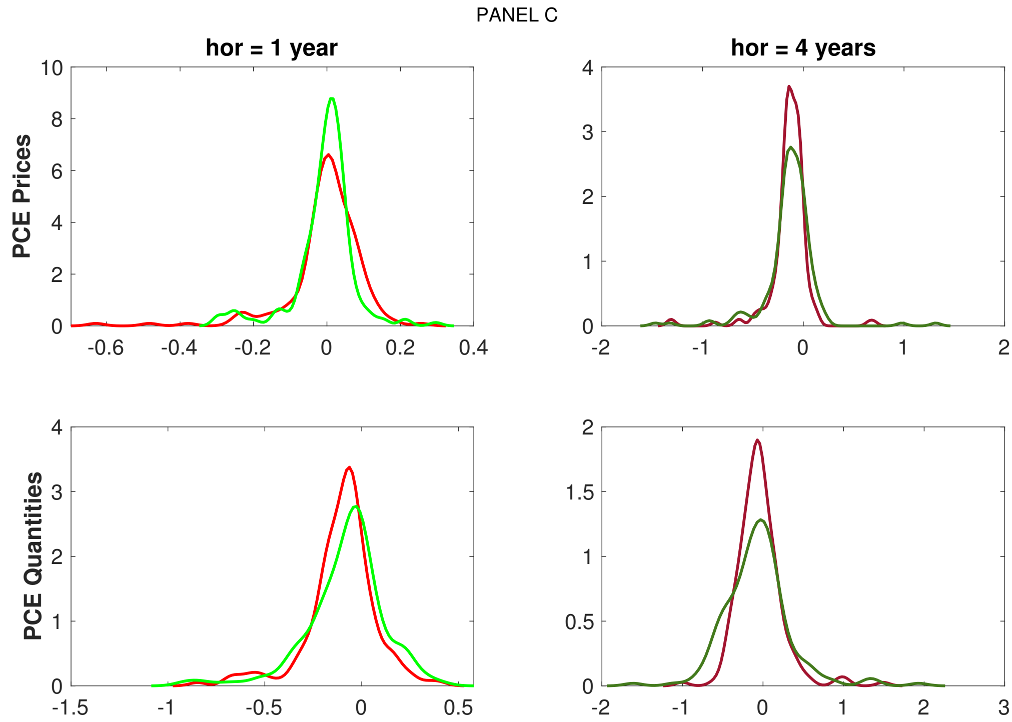

Figure 5: Smoothed densities of disaggregate responses to a 25 basis points increase in the federal funds rate at selected horizons and different states of the business cycle. Red lines represent the responses during a recession and green lines represent the response during an expansion.

600 macroeconomic and financial variables, including sector-specific price and quantity indicators, the outcomes under 'neutral' economic conditions mirror the average impact observed in prior studies such as Bernanke et al. (2005), Boivin et al. (2009), or Baumeister et al. (2013). Consistent with their findings, there is no indication of a price puzzle at the aggregate level, although certain sectors display transient price puzzles at a more detailed level.

In line with numerous studies examining the state dependency of monetary policy, my findings reveal that financial variables and industrial production exhibit increased responsiveness during economic contractions compared to expansions, while inflation responses demonstrate a higher degree of symmetry (e.g. Kakes et al. (1998), Weise (1999), or Lo and Piger (2005)). However, it is worth noting that these results differ from previous research, such as that of Tenreyro and Thwaites (2016), which suggests a more pronounced impact of monetary policy shocks during economic expansions.

My findings support the predictions of the 'financial accelerator' propagation mechanism literature, indicating a stronger impact of monetary policy innovations on output and financial variables during recessions. This is consistent with periods of subdued economic performance, where firms' balance sheets are typically weaker, leading to an increase in the premium alongside borrowers' reliance on external finance (see, for example, Bernanke and Gertler (1995), or Peersman and Smets (2005)).

The lower evidence of state-dependent asymmetries in the response of inflation to a monetary policy shock may be attributed to households' aversion to losses within the framework of reference-dependent preferences, as advocated by Santoro et al. (2014) and introduced by Kahneman and Tversky (1979) in 'prospect theory'. In addition, inflation responses are dampened by the increased real rigidity in the labor market during recessions.

Analyzing the dynamics of granular price responses across different phases of the business cycle reveals a progression from primarily positive to negative price adjustments. Furthermore, during recessions, I observe a larger heterogeneity in price adjustments, with a higher share of sectors responding with price increases, but also extreme price reductions. These findings align with the mechanisms underlying 'menu-costs models', where contractionary policy shocks lead to larger negative impacts on quantities during recessions (e.g. Ball and Mankiw (1994) and Senda (2001)).

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Appendix

A Properties of the real economic factor

Hamilton (2018) asserts that negative prediction errors are associated with recessions, highlighting that cyclical factors are the primary reasons for prediction errors in macro and financial variables. To evaluate the effectiveness of the real economic activity factor in capturing the business cycle and its conditional tails in representing expansions (right tail) or recessions (left tail), I conduct a one-year-ahead forecast of industrial production levels using a bivariate QB-VAR model for the US. This model comprises industrial production and either the median (50^{th} quantile) or the lower decile (10^{th} quantile) of the real economic activity factor.[17] The estimation employs monthly data for the US from January 1976 to June 2005 and considers two lags. Both models are estimated recursively over an expanding data window, starting with the first 10 years of data, providing approximately 220 out-of-sample forecasts from 1986 onward.

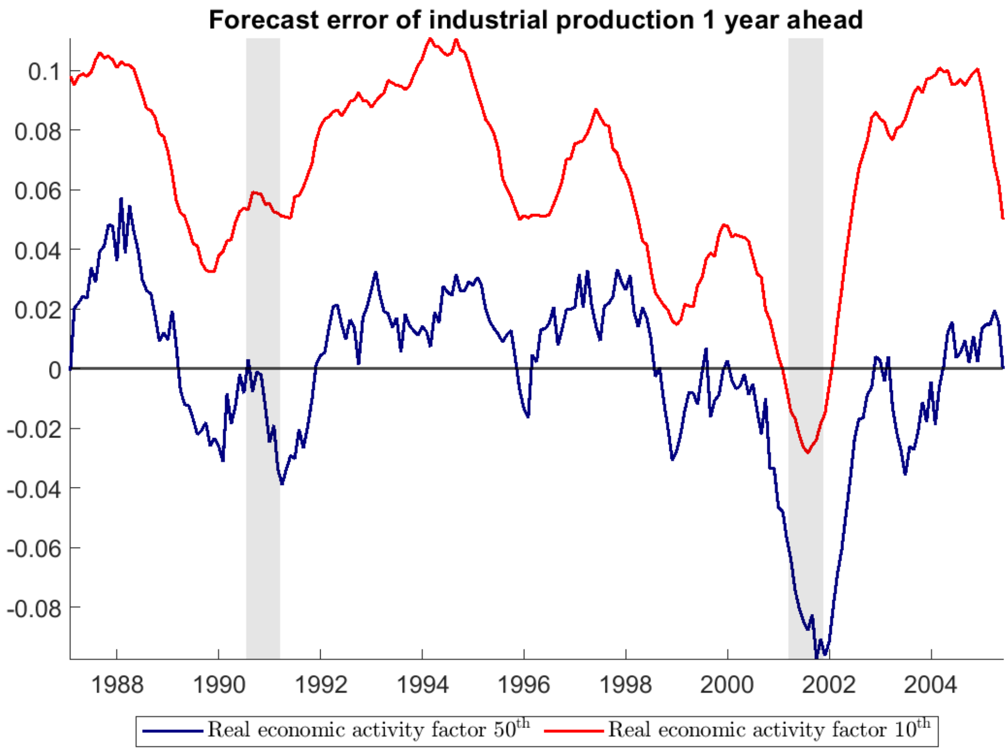

Figure 6: One year ahead forecast error of industrial production. The blue line represents the forecast errors of the specification that considers the median (50^{th} quantile) of the real economic factor, while the red line represents the forecast errors of the specification that considers the left tail (10^{th} quantile) of the real economic factor. Grey vertical areas display the NBER economic recessions.

From these projections, I compute the one-year-ahead forecast errors and present them in Figure 6, alongside the NBER classification of economic recessions (grey shaded areas), facilitating a visual representation of the forecast error dynamics around financial crises. In line

[17]Refer to Section C of the Appendix for details on the data sources. Please note that the levels of industrial production are considered (i.e. transformation code = 1).

with Hamilton (2018)'s findings for US employment, the median specification results in negative forecast errors one year ahead of financial crises, whereas the 10^{th} quantile specification yields positive or near-zero forecast errors. This evidence supports the assertion that the median real economic activity factor serves as a reliable proxy for the business cycle, while the 10^{th} quantile effectively captures recessions by driving forecast errors to zero and beyond.

Data Descriptions

B Data for the Monte-Carlo study

	Monthly *1966:01-2007:12*	
United States		
Industrial Production	Federal Reserve Economic Data	% change
Consumer Price Index *for all Urban Consumers*	Federal Reserve Economic Data	% change
Federal Funds Effective Rate	Federal Reserve Economic Data	%

Table 2: Variables for Monte-Carlo study

C Main Data Set

The main dataset adheres to the format outlined in Stock and Watson (2002) concerning the series number, series mnemonic, data span, and transformation. Transformation codes utilized are as follows: 1 – no transformation; 2 – first difference; 4 – logarithm; 5 – first difference of logarithm. Second differencing of logarithms was not utilized. These series were directly obtained from the DRI/McGraw Hill Basic Economics Database. An asterisk (*) next to the mnemonic indicates a variable presumed to exhibit slow movement in estimation. Variables included in the real economic activity subsample are highlighted in **bold**. All variables cover the sample span of $1976:01-2005:06$.

Table 3: Main Data Set

OUT	————	Real Output and Income	
1	**IPS11***	5	Industrial Production Index - Products, Total
2	**IPS299***	5	Industrial Production Index - Final Products
3	**IPS12***	5	Industrial Production Index - Consumer Goods
4	**IPS13***	5	Industrial Production Index - Durable Consumer Goods
5	**IPS18***	5	Industrial Production Index - Nondurable Consumer Goods
6	**IPS25***	5	Industrial Production Index - Business Equipment
7	**IPS32***	5	Industrial Production Index - Materials
8	**IPS34***	5	Industrial Production Index - Durable Goods Materials
9	**IPS38***	5	Industrial Production Index - Nondurable Goods Materials
10	**IPS43***	5	Industrial Production Index - Manufacturing (SIC)
11	**IPS67e***	5	Industrial Production Index - Mining NAICS = 21
12	**IPS68e***	5	Industrial Production Index - Electric and Gas Utilities
13	**IPS10***	5	Industrial Production Index - Total Index
14	**PMI***	5	Purchasing Managers' Index (SA)
15	**PMP***	5	NAPM Production Index (Percent)
16	**PYQ***	5	Personal Income (Chained) (Bil 2000$, SAAR)
17	**MYXPQ***	5	Personal Income Less Transfer Payments (Chained) (Bil 2000$,SAAR)
18	**IPS307***	5	Industrial Production Index - Residential Utilities
19	**IPS316***	5	Industrial Production Index - Basic Metals
EMP	————	Employment and Hours	
20	LHEL*	5	Index of Help-Wanted Advertising In Newspapers (1967 = 100; SA)
21	LHELX*	4	Employment: Ratio; Help-Wanted Ads: No. Unemployed Clf
22	LHEM*	5	Civilian Labor Force: Employed, Total (Thous., SA)
23	LHNAG*	5	Civilian Labor Force: Employed, Nonagric. Industries (Thous., SA)
24	LHUR*	1	Unemployment Rate: All Workers, 16 Years & Over (%, SA)
25	LHU680*	1	Unemploy. by Duration: Average(Mean) Duration in Weeks (SA)
26	LHU5*	1	Unemploy. by Duration: Persons Unempl.Less Than 5 Wks (Thous., SA)
27	LHU14*	1	Unemploy. by Duration: Persons Unempl. 5 To 14 Wks (Thous., SA)
28	LHU15*	1	Unemploy. by Duration: Persons Unempl. 15 Wks + (Thous., SA)
29	LHU26*	1	Unemploy. by Duration: Persons Unempl. 15 To 26 Wks (Thous., SA)
30	BLS_LPNAG*	5	Total Nonfarm Employment (SA) - CES0000000001
31	BLS _LP*	5	Total Private Employment (SA) - CES0500000001
32	BLS_LPGD*	5	Goods-Producing Employment (SA) - CES0600000001
33	BLS_LPMI*	5	Natural Resources and Mining Employment (SA) - CES1000000001
34	BLS_LPCC*	5	Construction Employment (SA) - CES2000000001

35	BLS_LPEM*	5	Manufacturing Employment (SA) - CES3000000001
36	BLS_LPED*	5	Durable Goods Manufacturing Employment (SA) - CES3100000001
37	BLS_LPEN*	5	Nondurable Goods Manufacturing Employment (SA) - CES3200000001
38	BLS_Ser.-EMP*	5	Service-Providing Employment (SA) - CES0700000001
39	BLS_Tra.EMP*	5	Trade, Transportation, and Utilities Employment (SA) - CES4000000001
40	BLS_Ret.- EMP*	5	Retail Trade Employment (SA) - CES4200000001
41	BLS_Whol. EMP*	5	Wholesale Trade Employment (SA) - CES4142000001
42	BLS_Fin.-EMP*	5	Financial Activities Employment (SA) - CES5500000001
43	BLS_P-Ser.EMP*	5	Private Service-Providing Employment (SA) - CES0800000001
44	BLS_LPGOV*	5	Government Employment (SA) - CES9000000001
45	BLS_LPHRM*	1	Manufacturing A wkly H Prod. Workers(SA) - CES3000000005
46	BLS_LPMOSA*	1	Manufacturing A wkly Overtime Prod. Workers (SA) - CES3000000007
47	PMEMP		NAPM Employment Index (Percent)
HSS ———— Housing Starts and Sales			
48	**HSFR***	4	Housing Starts (Thous. U., SA)
49	**HSNE***	4	Housing Starts: Northeast (Thous. U., SA)
50	**HSMW***	4	Housing Starts: Midwest (Thous. U., SA)
51	**HSSOU***	4	Housing Starts: South (Thous. U., SA)
52	**HSWST***	4	Housing Starts: West (Thous. U., SA)
53	**HSBR***	4	Housing Authorized: Total New Private Housing Units (Thous., SAAR)
54	**HMOB***	4	Mobile Homes: Manufacturers' Shipments (Thous. U., SAAR)
INV ———— Real Inventories and Inventory-Sales Ratios			
55	PMNV	1	NAPM Inventories Index (Percent)
ORD———— Orders and Unfilled Orders			
56	PMNO	1	NAPM New Orders Index (Percent)
57	PMDEL	1	NAPM Vendor Deliveries Index (Percent)
58	MOCMQ	5	New Orders (Net) - Consumer Goods & Materials, 1996 Dollars (BCI)
59	MSONDQ	5	New Orders, Nondefense Capital Goods, In 1996 Dollars (BCI)

SPR ———— Stock Prices			
60	FSPCOM	5	S&P's Common Stock Price Index: Composite (1941-43=10)
61	FSPIN	5	S&P's Common Stock Price Index: Industrials (1941-43=10)
62	FSDXP	1	S&P's Composite Common Stock: Dividend Yield (% Per Annum)
63	FSPXE	1	S&P's Composite Common Stock: Price-Earnings Ratio (%, NSA)
64	FSDJ		Common Stock Prices: Dow Jones Industrial Average
EXR ———— Exchange Rates			
65	EXRSW	5	Foreign Exchange Rate: Switzerland (Swiss Franc Per U.S.$)
66	EXRJAN	5	Foreign Exchange Rate: Japan (Yen Per U.S.$)
67	EXRUK	5	Foreign Exchange Rate: United Kingdom (Cents Per Pound)
68	EXRCAN	5	Foreign Exchange Rate: Canada (Canadian $ Per U.S.$)
INT ———— Interest Rates			
69	FYFF	1	Interest Rate: Federal Funds (Effective) (% Per Annum, NSA)
70	FYGM3	1	Interest Rate: U.S.Treasury Bills,Sec Mkt,3-Mo.(% Per Ann, NSA)
71	FYGM6	1	Interest Rate: U.S.Treasury Bills,Sec Mkt,6-Mo.(% Per Ann, NSA)
72	FYGT1	1	Interest Rate: U.S.Treasury Const Maturities, 1− Yr. (% Per Ann, NSA)
73	FYGT5	1	Interest Rate: U.S.Treasury Const Maturities, 5− Yr. (% Per Ann, NSA)
74	FYGT10	1	Interest Rate: U.S.Treasury Const Maturities, 10− Yr. (% Per Ann, NSA)
75	FYAAAC	1	Bond Yield: Moody's AAA Corporate (% Per Annum)
76	FYBAAC	1	Bond Yield: Moody's BAA Corporate (% Per Annum)
77	SFYGM3	1	Spread FYGM3 - FYFF
78	SFYGM6	1	Spread FYGM6 - FYFF
79	SFYGT1	1	Spread FYGT1 - FYFF
80	SFYGT5	1	Spread FYGT5 - FYFF
81	SFYGT10	1	Spread FYGT10 - FYFF
82	SFYAAAC	1	Spread FYAAAC - FYFF
83	SFYBAAC	1	Spread FYBAAC - FYFF
84	EBP	1	Excess Bond Premium (FRED Database)

MON ———— Money and Credit Quantity Aggregates			
85	FM1	5	Money Stock: M1 (Bil$, SA)
86	FM2	5	Money Stock:M2 (Bil$, SA)
87	FM3	5	Money Stock: M3 (Bil$, SA)
88	FM2DQ	5	Money Supply - M2 In 1996 Dollars (BCI)
89	FMFBA	5	Monetary Base, Adj for Reserve Requirement Changes (Mil$, SA)
90	FMRRA	5	Depository Inst Reserves: Total,Adj For Reserve Req Chgs (Mil$, SA)
91	FMRNBA	5	Depository Inst Reserves: Nonborrowed,Adj Res Req Chgs (Mil$, SA)
92	FCLBMC	1	Wkly Rp Lg Com'l Banks: Net Change Com'l & Indus Loans (Bil$, SAAR)
93	CCINRV	5	Consumer Credit Outstanding - Nonrevolving(G19)
94	IMFCLNQ		Commercial & Industrial Loans Oustanding In 1996 Dollars
PRI ———— Price Indexes			
95	PMCP	1	NAPM Commodity Prices Index (Percent)
96	PWFSA*	5	Producer Price Index: Finished Goods (82=100, S A)
97	PWFCSA*	5	Producer Price Index: Finished Consumer Goods (82=100, SA)
98	PWIMSA*	5	Producer Price Index: Intermed Mat.Supplies & Components (82=100, SA)
99	PWCMSA*	5	Producer Price Index: Crude Materials (82=100, SA)
100	PUNEW*	5	CPI-U: All Items (82-84=100, S A)
101	PU83*	5	CPI-U: Apparel & Upkeep (82-84=100, SA)
102	PU84*	5	CPI-U: Transportation (82-84=100, SA)
103	PU85*	5	CPI-U: Medical Care (82-84=100, SA)
104	PUC*	5	CPI-U: Commodities (82-84=100, SA)
105	PUCD*	5	CPI-U: Durables (82-84=100, SA)
106	PUXF*	5	CPI-U: All Items Less Food (82-84=100, SA)
107	PUXHS*	5	CPI-U: All Items Less Shelter (82-84=100, SA)
108	PUXM*	5	CPI-U: All Items Less Medical Care (82-84=100, SA)
109	PSCCOM	5	Spot Market Price Index: BLS & CRB: All Commodities (1967=100)
AHE ———— Average Hourly Earnings			
110	BLS_LEHCC*	5	Construction Av H Earnings of Production Workers (SA) - CES2000000006
111	BLS_LEHM*	5	Manufacturing Av H Earnings of Production Workers (SA) - CES3000000006
OTH ———— Miscellaneous			
112	HHSNTN	1	U. of Michigan Index of Consumer Expectations (Bcd-83)

D Sectoral Data Set

This section contains the details of the granular dataset of Boivin et al. (2009). The format is equivalent to that for the main data set in terms of series number, series, data span, transformation code, and series description as they appear in the database. The transformation for all data was the first difference of logarithms, coded as 5. This dataset comprises 194 monthly price series on Personal Consumption Expenditures with no missing observations, and 194 monthly real consumption series on Personal Consumption Expenditures. The table5 describes the 194 price series. The corresponding 194 real consumption series were ordered and transformed in a similar fashion and are listed in table 4. All price and quantity series are treated as slow moving variables.

D.1 Personal Consumption Expenditures (price indexes and nominal expenditures)

Series were downloaded from the underlying tables of the Bureau of Economic Analysis.

Table 4: Personal Consumption Expenditure Data Set

1	P1NDCG3*	5	New domestic autos
2	P1NFCG3*	5	New foreign autos
3	P1NETG3*	5	Net transactions in used autos
4	P1MARG3*	5	Net purchases of used autos: Used auto margin
5	P1REEG3*	5	Net purchases of used autos: Employee reimbursement
6	P1TRUG3*	5	Trucks, new and net used
7	P1REVG3*	5	Recreational vehicles
8	P1TATG3*	5	Tires and tubes
9	P1PAAG3*	5	Accessories and parts
10	P1FNRG3*	5	Furniture, including mattresses and bedsprings
11	P1MHAG3*	5	Major household appliances
12	P1SEAG3*	5	Small electric appliances
13	P1CHNG3*	5	China, glassware, tableware, and utensils
14	P1RADG3*	5	Video and audio goods, including musical instruments, and computer goods
15	P1FLRG3*	5	Floor coverings
16	P1CLFG3*	5	Clocks, lamps, and furnishings
17	P1TEXG3*	5	Blinds, rods, and other

18	P1WTRG3*	5	Writing equipment
19	P1HDWG3*	5	Tools, hardware, and supplies
20	P1LWNG3*	5	Outdoor equipment and supplies
21	P1OPTG3*	5	Ophthalmic products and orthopedic appliances
22	P1GUNG3*	5	Guns
23	P1SPTG3*	5	Sporting equipment
24	P1CAMG3*	5	Photographic equipment
25	P1BCYG3*	5	Bicycles
26	P1MCYG3*	5	Motorcycles
27	P1BOAG3*	5	Pleasure boats
28	P1AIRG3*	5	Pleasure aircraft
29	P1JRYG3*	5	Jewelry and watches
30	P1BKSG3*	5	Books and maps
31	P1GRAG3*	5	Cereals
32	P1BAKG3*	5	Bakery products
33	P1BEEG3*	5	Beef and veal
34	P1PORG3*	5	Pork
35	P1MEAG3*	5	Other meats
36	P1POUG3*	5	Poultry
37	P1FISG3*	5	Fish and seafood
38	P1GGSG3*	5	Eggs
39	P1MILG3*	5	Fresh milk and cream
40	P1DAIG3*	5	Processed dairy products
41	P1FRUG3*	5	Fresh fruits
42	P1VEGG3*	5	Fresh vegetables
43	P1PFVG3*	5	Processed fruits and vegetables
44	P1JNBG3*	5	Juices and nonalcoholic drinks
45	P1CTMG3*	5	Coffee, tea and beverage materials
46	P1FATG3*	5	Fats and oils
47	P1SWEG3*	5	Sugar and sweets
48	P1OFDG3*	5	Other foods
49	P1PEFG3*	5	Pet food
50	P1MLTG3*	5	Beer and ale, at home
51	P1WING3*	5	Wine and brandy, at home
52	P1LIQG3*	5	Distilled spirits, at home

53	P1ESLG3*	5	Elementary and secondary school lunch
54	P1HSLG3*	5	Higher education school lunch
55	P1OPMG3*	5	Other purchased meals
56	P1APMG3*	5	Alcohol in purchased meals
57	P1CFDG3*	5	Food supplied to employees: civilians
58	P1MFDG3*	5	Food supplied to employees: military
59	P1FFDG3*	5	Food produced and consumed on farms
60	P1SHUG3*	5	Shoes
61	P1WGCG3*	5	Clothing for females
62	P1WICG3*	5	Clothing for infants
63	P1WSGG3*	5	Sewing goods for females
64	P1WUGG3*	5	Luggage for females
65	P1MBCG3*	5	Clothing for males
66	P1MSGG3*	5	Sewing goods for males
67	P1MUGG3*	5	Luggage for males
68	P1MICG3*	5	Standard clothing issued to military personnel (n.d.)
69	P1GASG3*	5	Gasoline and other motor fuel
70	P1LUBG3*	5	Lubricants
71	P1OILG3*	5	Fuel oil
72	P1LPGG3*	5	Liquefied petroleum gas and other fuel
73	P1TOBG3*	5	Tobacco products
74	P1SOAG3*	5	Soap
75	P1CSMG3*	5	Cosmetics and perfumes
76	P1OPHG3*	5	Other personal hygiene goods
77	P1SDHG3*	5	Semidurable house furnishings
78	P1CLEG3*	5	Cleaning preparations
79	P1LIGG3*	5	Lighting supplies
80	P1PAPG3*	5	Paper products
81	P1RXDG3*	5	Prescription drugs
82	P1NRXG3*	5	Nonprescription drugs
83	P1MDSG3*	5	Medical supplies
84	P1GYNG3*	5	Gynecological goods
85	P1DOLG3*	5	Toys, dolls, and games
86	P1AMMG3*	5	Sport supplies, including ammunition
87	P1FLMG3*	5	Film and photo supplies
88	P1STSG3*	5	Stationery and school supplies
89	P1GREG3*	5	Greeting cards
90	P1ARTG3*	5	Expenditures abroad by U.S. residents: Government expenditures abroad

91	P1ARSG3*	5	Expenditures abroad by U.S. residents: Other private services
92	P1REMG3*	5	Less: Personal remittances in kind to nonresidents
93	P1MGZG3*	5	Magazines and sheet music
94	P1NWPG3*	5	Newspapers
95	P1FLOG3*	5	Flowers, seeds, and potted plants
96	P1OMHG3*	5	Owner occupied mobile homes
97	P1OSTG3*	5	Owner occupied stationary homes
98	P1TMHG3*	5	Tenant occupied mobile homes
99	P1TSPG3*	5	Tenant occupied stationary homes
100	P1TLDG3*	5	Tenant landlord durables
101	P1FARG3*	5	Rental value of farm dwellings
102	P1HOTG3*	5	Hotels and motels
103	P1HFRG3*	5	Clubs and fraternity housing
104	P1HHEG3*	5	Higher education housing
105	P1HESG3*	5	Elem and second education housing
106	P1TGRG3*	5	Tenant group room and board
107	P1TGLG3*	5	Tenant group employee lodging
108	P1ELCG3*	5	Electricity
109	P1NGSG3*	5	Gas
110	P1WSMG3*	5	Water and sewerage maintenance
111	P1REFG3*	5	Refuse collection
112	P1LOCG3*	5	Local and cellular telephone
113	P1INCG3*	5	Intrastate toll calls
114	P1ITCG3*	5	Interstate toll calls
115	P1DMCG3*	5	Domestic service, cash
116	P1DMIG3*	5	Domestic service, in kind
117	P1MSEG3*	5	Moving and storage
118	P1FIPG3*	5	Household insurance premiums
119	P1FIBG3*	5	Less: Household insurance benefits paid
120	P1RCLG3*	5	Rug and furniture cleaning
121	P1EREG3*	5	Electrical repair
122	P1FREG3*	5	Reupholstery and furniture repair
123	P1PSTG3*	5	Postage
124	P1MHOG3*	5	Household operation services, n.e.c.
125	P1ARPG3*	5	Motor vehicle repair
126	P1RLOG3*	5	Motor vehicle rental, leasing, and other
127	P1TOLG3*	5	Bridge, tunnel, ferry, and road tolls

128	P1AING3*	5	Insurance premiums for user-operated transportation
129	P1IMTG3*	5	Local transportation: Mass transit systems
130	P1TAXG3*	5	Taxicab
131	P1IRRG3*	5	Railway
132	P1IBUG3*	5	Bus
133	P1IAIG3*	5	Airline
134	P1TROG3*	5	Other
135	P1PHYG3*	5	Physicians
136	P1DENG3*	5	Dentists
137	P1OPSG3*	5	Other professional services
138	P1NPHG3*	5	Hospitals: Nonprofit

D.2 Producer Price Indices

Series were downloaded from the website of BLS.

Table 5: Producer Price Indices Data Set

1	311119*	5	Other animal food manufacturing
2	311119$p*$	5	Other animal food manufacturing (primary products)
3	311211*	5	Flour Milling
4	311212*	5	Rice milling
5	311213*	5	Malt mfg
6	311223$a*$	5	Other oilseed processing (cottonseed cake and meal and other byproducts)
7	311223$p*$	5	Fats and oils refining and blending (primary products)
8	311311*	5	Sugarcane mills
9	311313*	5	Beet sugar manufacturing
10	311412*	5	Frozen specialty food manufacturing
11	311520*	5	Ice cream and frozen dessert mfg
12	311920*	5	Coffee and tea manufacturing
13	312140*	5	Distilleries
14	32211−*	5	Pulp mills
15	2213*	5	Paperboard mills
16	325620$p*$	5	Toilet preparation mfg (primary products)
17	325920*	5	Explosives manufacturing
18	32731−*	5	Cement mfg
19	327320*	5	Ready mixed concrete mfg and dist
20	327410*	5	Lime
21	327420*	5	Gypsum building products manufacturing
22	327910*	5	Abrasive product manufacturing
23	331210*	5	Iron steel pipe & tube mfg from purch steel
24	333210*	5	Sawmill & woodworking machinery mfg
25	334310*	5	Audio & video equipment mfg
26	335110*	5	Electric lamp bulb & part mfg
27	336370*	5	Motor vehicle metal stamping
28	337910*	5	Mattress mfg
29	311421*	5	Fruit and vegetable canning

30	311423*	5	Dried and dehydrated food manufacturing
31	311513*	5	Cheese manufacturing
32	311611*	5	Animal except poultry slaughtering
33	311612*	5	Meat processed from carcasses
34	311613*	5	Rendering and meat byproduct processing
35	311711*	5	Seafood canning
36	311712*	5	Fresh & frozen seafood processing
37	311813$p*$	5	Frozen cakes pies & other pastries mfg (Primary products)
38	3118233*	5	Dry pasta manufacturing (macaroni spaghetti vermicelli and noodles)
39	312111$p*$	5	Soft drinks manufacturing (primary products)
40	312221*	5	Cigarettes
41	3122291*	5	Other tobacco product mfg (cigars)
42	313111*	5	Yarn spinning mills
43	3133111*	5	Broadwoven fabric finishing mills (finished cotton broadwoven fabrics not finished in weaving mills)
44	315111*	5	Sheer hosiery mills
45	315191*	5	Outerwear knitting mills
46	315223*	5	Men's boy's cut & sew shirt excl work mfg
47	315224*	5	Men's boy's cut & sew trouser slack jean mfg
48	315993*	5	Men's and boys' neckwear mfg
49	316211*	5	Rubber and plastic footwear manufacturing
50	316213*	5	Men's footwear excl athletic mfg
51	316214*	5	Women's footwear excl athletic mfg
52	316992*	5	Women's handbag & purse mfg
53	321212*	5	Softwood veneer or plywood mfg
54	3212191*	5	Reconstituted wood product mfg (particleboard produced at this location)
55	3219181*	5	Other millwork including flooring
56	321991*	5	Manufactured homes mobile homes mfg
57	3221211*	5	Paper except newsprint mills (clay coated printing and converting paper)
58	322214*	5	Fiber can tube drum & other products mfg
59	324121*	5	Asphalt paving mixture & block mfg
60	324122*	5	Asphalt shingle & coating materials mfg
61	324191$p*$	5	Petroleum lubricating oils and greases (primary products)
62	325181*	5	Alkalies and chlorine

63	3251881*	5	All other basic inorganic chemical manufacturing (sulfuric acid gross new and fortified)
64	3251921*	5	Cyclic crude and intermediate manufacturing (cyclic coal tar intermediates)
65	325212*	5	Synthetic rubber manufacturing
66	325222*	5	Manufactured noncellulosic fibers
67	325314*	5	Fertilizer mixing only manufacturing
68	3254111*	5	Medicinal & botanical mfg (synthetic organic medicinal chemicals in bulk)
69	3261131*	5	Unsupported plastics film sheet excluding packaging manufacturin
70	326192*	5	Resilient floor covering manufacturing
71	326211*	5	Tire manufacturing except retreading
72	327111*	5	Vitreous plumbing fixtures access ftg mfg
73	327121*	5	Brick and structural clay tile
74	327122*	5	Ceramic wall and floor tile
75	327124*	5	Clay refractories
76	327125*	5	Nonclay refractory manufacturing
77	327211*	5	Flat glass manufacturing
78	327213*	5	Glass container manufacturing
79	327331*	5	Concrete block and brick manufacturing
80	3279931*	5	Mineral wool manufacturing
81	331111*	5	Iron and steel mills
82	331112*	5	Electrometallurgical ferroalloy product mfg
83	331221*	5	Rolled steel shape manufacturing
84	331312*	5	Primary aluminum production
85	331315*	5	Aluminum sheet plate & foil mfg
86	331316*	5	Aluminum extruded products
87	331421*	5	Copper rolling drawing & extruding
88	3314913*	5	Other nonferrous metal roll draw extruding
89	3314923*	5	Other nonferrous secondary smelt refine alloying (secondary lead)
90	331511*	5	Iron foundries
91	3322121*	5	Hand and edge tools except machine tools and handsaws (mechanics' hand service tools)
92	332213*	5	Saw blade & handsaw mfg
93	3323111*	5	Prefabricated metal building and component manufacturing
94	332321*	5	Metal window and door manufacturing

95	332431*	5	Metal can mfg
96	324393*	5	Other metal container manufacturing
97	332611*	5	Spring heavy gauge mfg
98	3326122*	5	Spring light gauge mfg (precision mechanical springs)
99	3327224*	5	Bolt nut screw rivet & washer mfg (externally threaded metal fasteners except aircraft)
100	332913*	5	Plumbing fixture fitting & trim mfg
101	332991*	5	Ball and roller bearings
102	332992*	5	Small arms ammunition mfg
103	332996*	5	Fabricated pipe & pipe fitting mfg
104	332998*	5	Enameled iron & metal sanitary ware mfg
105	333111*	5	Farm machinery & equipment mfg
106	333131*	5	Mining machinery & equipment mfg
107	333132*	5	Oil and gas field machinery and equipment mfg
108	333292*	5	Textile machinery
109	333293*	5	Printing machinery & equipment mfg
110	3332941*	5	Food products machinery mfg (dairy and milk products plant machinery)
111	333992*	5	All other industrial machinery mfg (chemical manufacturing machinery equip. and parts)
112	333997*	5	Automatic vending machine mfg
113	334411*	5	Machine tool metal cutting types mfg
114	334414*	5	Machine tool metal forming types mfg
115	334415*	5	Cutting tool & machine tool accessory mfg
116	334417*	5	Speed changer industrial high speed drive & gear mfg
117	3339233*	5	Other engine equipment mfg
118	3332981*	5	Pump & pumping equipment mfg (indus. pumps except hydraulic fluid power pumps)
119	3333111*	5	Conveyor & conveying equipment mfg
120	333512*	5	Overhead crane hoist & monorail system mfg
121	333513*	5	Industrial truck tractor trailer stacker machinery mfg
122	3335151*	5	Welding & soldering equipment mfg (welding & soldering equipment mfg)
123	333612*	5	Scale & balance except laboratory mfg
124	333618*	5	Electron tube mfg
125	3339111*	5	Electronic capacitor mfg
126	333922*	5	Electronic resistor mfg
127	3339233*	5	Electronic connector mfg
128	3345153*	5	Electricity measuring testing instrument mfg

129	334517p*	5	Irradiation apparatus manufacturing (primary products)
130	3351211*	5	Residential electric lighting fixture mfg
131	335122*	5	Commercial electric lighting fixture mfg
132	335129*	5	Other lighting equipment mfg
133	335212*	5	Household vacuum cleaner mfg
134	335221*	5	Household cooking appliance mfg
135	335311*	5	Power distribution specialty transformer mfg
136	335312*	5	Motor & generator
137	33531p*	5	Relay & industrial control mfg (primary products)
138	335911*	5	Storage battery mfg
139	3359291*	5	Other communication and energy wire
140	335932*	5	Non-current carrying wiring device mfg
141	335991p*	5	Carbon & graphite product mfg (primary products)
142	336321p*	5	Vehicular lighting equipment mfg (primary products)
143	337121*	5	Upholstered household furniture
144	337122*	5	Wood household furniture except upholstered
145	337124*	5	Metal household furniture
146	337211*	5	Wood office furniture
147	3372141*	5	Nonwood office furniture (office seating including upholstered nonwood)
148	3399111*	5	Jewelry except costume mfg
149	3399123*	5	Silverware & hollowware mfg (Flatware and carving sets made wholly of metal)
150	339931*	5	Doll & stuffed toy mfg
151	339932*	5	Game toy & children's vehicle mfg
152	339944*	5	Carbon paper & inked ribbon
153	3399931*	5	Fastener button needle & pin
154	3399945*	5	Broom brush & mop mfg (other brushes)

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