The Competition Effect in Business Cycles[*]

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Abstract

How do changes in market structure affect the US business cycle? We estimate a monetary DSGE model with endogenous firm/product entry and a translog expenditure function by Bayesian methods. The dynamics of net business formation allow us to identify the 'competition effect', by which desired price markups and inflation decrease when entry rises. We find that a 1 percent increase in the number of competitors lowers desired markups by 0.18 percent. Most of the cyclical variability in inflation is driven by markup fluctuations due to sticky prices or exogenous shocks rather than endogenous changes in desired markups.

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Monetary business cycle models typically feature monopolistic competition; this is to justify price setting power and sticky prices. At the same time, such models tend to depart from Dixit and Stiglitz (1977) by assuming a fixed range of products and firms, an assumption which in the presence of above-zero profits is difficult to uphold. In response to this, a largely *theoretical* literature has emerged that investigates the role of firm and product entry for aggregate fluctuations. In particular, the 'competition effect', by which an increase in the number of competitors reduces desired markups and inflation, acts as an endogenous propagation and amplification mechanism. Floetotto and Jaimovich (2008) present a business cycle model with oligopolistic competition, where firm entry has a negative effect on markups. Colciago and Etro (2010) show that such a model outperforms the standard real business cycle (RBC) model in terms of matching second moments of certain variables in the data. Bilbiie, Ghironi and Melitz (2011) show that an RBC model with translog consumption preferences generates a competition effect and countercyclical markups. Under this preference structure, the price-elasticity of demand is increasing in the number of available products.

This paper provides an *empirical* model validation exercise which is so far missing in the literature. It uses Bayesian techniques to estimate the competition effect in a dynamic stochastic general equilibrium (DSGE) model with endogenous entry. We seek to answer two questions. First, how does the competition effect influence the cyclical behavior of markups? Second, is this effect important in explaining US inflation fluctuations?

Our first question relates to the dynamics of price-cost markups, which are key in business cycle transmission. Consider the standard New Keynesian model. On the one hand, an expansionary demand shock raises marginal costs. If prices do not adjust fully, markups fall. On the other hand, an expansionary supply shock lowers marginal costs. If prices do not adjust fully, markups rise. When entry and exit dynamics are taken into account, markups may additionally depend on the degree of competition, i.e. on the number of firms or products.[1] The response of entry to a shock determines how the competition effect works. If an expansionary shock (i.e. one that raises output) leads to profit opportunities over

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[1] Campbell and Hopenhayn (2005) present empirical evidence that markups are negatively related to the number of competitors in an industry.

and above entry costs, new firms and products enter. Then desired markups and inflation are reduced through the competition effect. In contrast, if an expansionary shock crowds out entry, desired markups and inflation rise through the competition effect. Therefore, the competition effect may amplify or dampen propagation in the New Keynesian model. This paper characterizes the conditional dynamics of entry (or the 'extensive margin') and markups in response to an array of shocks.

In spite of the importance of markup dynamics for model predictions, there is no consensus on the conditional properties of markups in the data, or even on their unconditional cyclicality. This lack of consensus comes from the difficulties in measuring unobserved markups. The influential work by Rotemberg and Woodford (1999) finds evidence of countercyclical markups, while the more recent contribution by Nekarda and Ramey (2010) presents evidence supporting procyclical markups. We circumvent the measurement problem by excluding markups from the estimation and focussing instead on directly observable variables. Using our parameter estimates, we then back out the markup series implied by the model and describe its cyclical behavior. In addition, we quantify the contribution of the competition effect and desired markup shocks to the markup-output correlation.

Our second question concerns the contribution of entry and the competition effect to movements in inflation. The answer to this question has implications for monetary policy. Optimal monetary policy aims at eliminating inefficiencies arising from price setting distortions; i.e. it tries to replicate the equilibrium allocations that would arise under perfect price flexibility. If the competition effect accounts for a large fraction of inflation variability, the central bank runs the risk of reacting to changes in inflation that do not reflect price rigidities but instead endogenous changes in market structure. In order to assess this risk, we wish to quantify the relevance of the competition effect for US inflation.

Firm and product turnover has been neglected in empirical business cycle research, e.g. in the influential studies by Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007). Two exceptions are worth noting, however. Cecioni (2010) estimates a New Keynesian Phillips Curve augmented with firm entry. She finds that the pass-through of real marginal costs to inflation becomes stronger when entry and the competition effect are taken into account. Lewis and Poilly (2012) estimate two variants of the endogenous-entry model

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by minimizing the distance between the model-based impulse responses to a monetary policy shock and their empirical counterparts. The first model variant features translog preferences and a demand-driven competition effect, while the second assumes strategic interactions between oligopolists and a supply-driven competition effect. They find that the first model generates a significant competition effect in the monetary transmission mechanism, while the second model does not. This paper estimates a DSGE model with endogenous entry using Bayesian methods as in Smets and Wouters (2007). The model features sunk-cost driven entry dynamics and a translog expenditure function for intermediate goods, as well as a host of nominal and real frictions. Assuming a range of exogenous shocks and using a Bayesian approach allows us to address the two research questions posed above, which is not possible in the limited information estimation exercise in Lewis and Poilly (2012) or with the single-equation method of Cecioni (2010).

Our contribution is twofold. First, we show that the way the competition effect influences business cycle transmission is shock-dependent. Supply shocks and monetary policy shocks entail a procyclical movement of entry, thereby inducing a countercyclical desired markup response. Demand shocks, in contrast, lead to a countercyclical response of entry and procyclical desired markups.[2] The model-implied markup is countercyclical once the competition effect and shocks to desired markups are taken into account. Second, we carry out a counterfactual analysis of US inflation, showing that the historical inflation path was not strongly altered by the competition effect. Empirically, therefore, the competition effect of entry does not pose a great risk of monetary policy mistakenly reacting to efficient markup fluctuations.

The paper proceeds as follows. In Section 1, we present an outline of the baseline model. Section 2 contains details on the estimation method, the data, our choice of priors, and posterior distribution statistics. In Section 3, we characterize the transmission channels of various shocks through the competition effect and the overall cyclicality of the model-implied markup. We perform a counterfactual decomposition of US inflation in Section 4. Section 5 discusses a number of robustness exercises. Section 6 concludes.

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[2]Our analysis of transmission channels extends Bilbiie, Ghironi and Melitz (2007) and Bilbiie, Ghironi and Melitz (2011), who consider fewer shocks and a smaller set of frictions.

1 Model

Our model combines the entry mechanism and the translog expenditure function proposed by Bilbiie, Ghironi and Melitz (2011) with a set of real and nominal frictions as in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007). In this section, we derive in detail the part of the model related to the translog expenditure function, desired markups and the competition effect. The remaining model equations are presented in linearized form.[3] Hatted variables denote deviations from the deterministic steady state. Variables without a hat or time subscript refer to the steady state level. The equilibrium we consider is symmetric: all households, firms and entrants are identical.

1.1 Translog Expenditure Function, Desired Markups and Competition Effect

We assume that aggregation over intermediate goods varieties takes the translog form, such that the elasticity of demand for an individual good is increasing in the number of competing goods. Consumers choose the cost-minimizing combination of goods to obtain one unit of Y_t^C, the aggregate goods bundle, at price P_t, the aggregate (welfare-based) price index. As in Feenstra (2003), we postulate that the optimal expenditure function is given by:

$$\ln P_t = \frac{1}{2}\frac{\tilde{N} - N_t}{\gamma_t \tilde{N} N_t} + \frac{1}{N_t}\sum_{f=1}^{N_t}\ln p_t^f + \frac{\gamma_t}{2}\sum_{f=1}^{N_t}\sum_{j=1}^{N_t}b_{fj}\ln p_t^f \ln p_t^j, \tag{1}$$

$$\text{where } f, j = 1, \ldots, N_t \text{ and } \begin{cases} b_{fj} = -\frac{N_t - 1}{N_t}, \text{ for } f = j \\ b_{fj} = \frac{1}{N_t}, \quad\quad \text{ for } f \neq j \end{cases}$$

N_t is the (time-varying) number of available goods and $\tilde{N} > N_t$ is the (constant) number of all conceivable goods.[4] The interpretation of γ_t will become clear below. By Shephard's lemma, the demand for a particular good f, for a given price p_t^f, equals the derivative of the expenditure function with respect to the price, $y_t^f = Y_t^C \frac{\partial P_t}{\partial p_t^f}$. Hence the expenditure share on an individual good f, defined as $s_t^f \equiv \frac{p_t^f y_t^f}{P_t Y_t^C}$, can be written as the elasticity of the price

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[3]For a full model derivation, see the appendix available at http://sites.google.com/site/vivienjlewis.

[4]We use the terms 'goods' and 'firms' interchangeably throughout, assuming that each firm produces exactly one differentiated variety. For expositional purposes, we treat N_t as a natural number in this subsection. In the remainder of the model outline, $N_t \in \mathbb{R}^+$.

index to the price of product f, approximated as:

$$s_t^f = \frac{\partial \ln P_t}{\partial \ln p_t^f}.$$

Taking the derivative of the log expenditure function (1) with respect to $\ln p_t^f$, yields

$$s_t^f = \frac{1}{N_t} + \gamma_t(\overline{\ln p_t} - \ln p_t^f), \tag{2}$$

where $\overline{\ln p_t} = \sum_{j=1}^{N_t} \frac{\ln p_t^j}{N_t}$ is the mean log price. Therefore, γ_t measures the (exogenous) price-elasticity of the expenditure share. We approximate the price-elasticity of demand as $\varepsilon_t^f \equiv -\frac{\partial \ln y_t^f}{\partial \ln p_t^f}$. Taking logs of the definition of the expenditure share, and differentiating with respect to $\ln p_t^f$, we find

$$\frac{\partial \ln s_t^f}{\partial \ln p_t^f} = 1 - \varepsilon_t^f.$$

Rearranging, using the approximation $\partial \ln s_t^f = \partial s_t^f / s_t^f$ and differentiating (2) with respect to $\ln p_t^f$, we can derive the price-elasticity of demand as

$$\varepsilon_t^f = 1 - \frac{\partial s_t^f}{\partial \ln p_t^f} \frac{1}{s_t^f} = 1 + \frac{\gamma_t}{s_t^f}. \tag{3}$$

We impose $\gamma_t > 0$ to ensure that the demand elasticity exceeds unity.

Under symmetry $(p_t^f = p_t^j = p_t)$, the price index (1) simplifies to

$$P_t = \exp\left(\frac{1}{2}\frac{\tilde{N} - N_t}{\gamma_t \tilde{N} N_t}\right) p_t.$$

Defining the real product price ρ_t as the ratio of the nominal product price p_t to the aggregate price index P_t, i.e. $\rho_t \equiv p_t/P_t$, we have

$$\rho_t(N_t) = \exp\left(-\frac{1}{2}\frac{\tilde{N} - N_t}{\gamma_t \tilde{N} N_t}\right).$$

The real product price is a positive function of the number of firms and products, N_t. In linearized form, this is[5]

$$\hat{\rho}_t = \nu \hat{N}_t, \text{ where } \nu = \frac{1}{2\gamma N}.$$

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[5] The linearized real product price contains an additional term, $\frac{\tilde{N}-N}{\tilde{N}}\nu\hat{\gamma}_t$. We set this term to zero, assuming a negligible number of conceivable goods that are not produced, $\tilde{N} - N \simeq 0$.

The elasticity of the real product price to the number of firms/products is $\nu \geq 0$. This parameter captures 'love of variety', which measures the degree to which consumers can increase their utility by spreading their consumption expenditure across more differentiated goods. Under the translog expenditure function assumed above, love of variety is inversely related to the steady state number of firms N and to the price-elasticity of the spending share in steady state, γ.[6] Under price symmetry $(\overline{\ln p_t} = \ln p_t^f)$, the expenditure share (2) equals the inverse of the number of goods,

$$s_t(N_t) = \frac{1}{N_t}. \tag{4}$$

The demand for a single variety is then found by rearranging the definition of the expenditure share $s_t = \frac{\rho_t y_t}{Y_t^C}$ and substituting out s_t using (4), $y_t = \frac{Y_t^C}{\rho_t N_t}$. In linearized form, this is:

$$\hat{y}_t = \hat{Y}_t^C - \hat{\rho}_t - \hat{N}_t.$$

Furthermore, using (4) in (3), the demand elasticity simplifies to

$$\varepsilon_t(N_t) = 1 + \gamma_t N_t. \tag{5}$$

Intuitively, more product diversity makes demand more elastic, as products become more substitutable with entry. With a time-varying demand elasticity, the desired markup defined as $\mu_t^d(N_t) \equiv \frac{\varepsilon_t(N_t)}{\varepsilon_t(N_t)-1}$ is also time-varying. In particular,

$$\mu_t^d(N_t) = \frac{1 + \gamma_t N_t}{\gamma_t N_t}.$$

In linearized form, the desired markup is:

$$\hat{\mu}_t^d = -\eta(\hat{\gamma}_t + \hat{N}_t), \text{ where } \eta = \frac{1}{1 + \gamma N}. \tag{6}$$

The desired markup (6) has an endogenous component $(-\eta \hat{N}_t)$ and an exogenous component $(-\eta \hat{\gamma}_t)$. The elasticity of the desired markup to the number of firms captures the 'competition effect'. For $\eta > 0$, desired markups are eroded by the arrival of new entrants. Assuming a translog expenditure function, the competition effect equals the inverse steady state demand elasticity, $\eta = \frac{1}{\varepsilon}$.

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[6]In Dixit and Stiglitz (1977) preferences, love of variety is $\nu = \frac{1}{\varepsilon-1}$, where ε denotes both the substitution elasticity between goods as well as the price-elasticity of demand. Floetotto and Jaimovich (2008) assume zero love of variety ($\nu = 0$), such that no utility gain arises from additional product diversity.

1.2 Firms

We consider a two-sector economy where capital and labor are employed to produce goods and new firms. Let the subscript C denote the goods-producing (manufacturing) sector and let subscript E denote the entry sector. The aggregate production function for goods states that output is produced under a Cobb-Douglas technology with capital services $\hat{K}^s_{C,t}$ and labor $\hat{L}_{C,t}$, weighted by α_C and $1 - \alpha_C$, respectively, where $\alpha_C \in (0,1)$. Total goods output of all firms is the sum of firm output $\hat{y}_t$ and the stock of firms $\hat{N}_t$,

$$\hat{y}_t + \hat{N}_t = \alpha_C \hat{K}^s_{C,t} + (1 - \alpha_C) \hat{L}_{C,t} + \hat{\eta}^Z_t.$$

The variable $\hat{\eta}^Z_t$ denotes exogenous total factor productivity (TFP). New firms $\hat{N}_{E,t}$ are produced with an analogous technology,

$$\hat{N}_{E,t} + \hat{\eta}^E_t = \alpha_E \hat{K}^s_{E,t} + (1 - \alpha_E) \hat{L}_{E,t} + \hat{\eta}^Z_t. \tag{7}$$

The exogenous variable $\hat{\eta}^E_t$ captures entry costs per firm, measured in terms of a composite of labor and capital services. The production structure is symmetric such that the capital share is the same in the two sectors, $\alpha_C = \alpha_E = \alpha$.[7] Marginal costs $\widehat{mc}_t$ for producing goods as well as firms are a weighted average of the rental rate of capital $\hat{r}^k_t$ and the real wage $\hat{w}_t$, less TFP,

$$\widehat{mc}_t = \alpha \hat{r}^k_t + (1 - \alpha) \hat{w}_t - \hat{\eta}^Z_t.$$

Cost minimization by firms implies that the rental bill and the wage bill are proportional to each other,

$$\hat{r}^k_t + \hat{K}^s_{C,t} = \hat{w}_t + \hat{L}_{C,t}.$$

Perfect factor mobility equates the capital-labor ratio across the two sectors,

$$\hat{K}^s_{C,t} - \hat{L}_{C,t} = \hat{K}^s_{E,t} - \hat{L}_{E,t}.$$

Firm-level profits are denoted d_t, while aggregate profits are given by

$$\hat{d}_t + \hat{N}_t = (\varepsilon - 1) \hat{\mu}_t + \hat{Y}^C_t, \tag{8}$$

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[7]In an additional exercise, we set $\alpha_C = \alpha$ and $\alpha_E = 0$. See the sensitivity analysis in Section 5.

where $\varepsilon = 1 + \gamma N$ is the steady state price-elasticity of demand, see (5). Monopolistic firms set prices as a markup $\hat{\mu}_t$ over marginal costs,

$$\hat{\rho}_t = \hat{\mu}_t + \hat{mc}_t.$$

Price setters are subject to a quadratic price adjustment cost of the Rotemberg (1982)-type. Non-adjusted prices are indexed to lagged inflation. The New Keynesian Phillips Curve (NKPC) relates the change in product prices $\hat{\pi}_{p,t}$ to its lagged and expected future value, and to the difference between the desired and the actual markup,

$$\hat{\pi}_{p,t} - \lambda_p \hat{\pi}_{p,t-1} = \frac{\varepsilon - 1}{\kappa_p}(\hat{\mu}_t^d - \hat{\mu}_t) + \beta(1 - \delta_N) E_t\{\hat{\pi}_{p,t+1} - \lambda_p \hat{\pi}_{p,t}\}, \qquad (9)$$

where $\kappa_p > 0$ is the degree of price stickiness, $\lambda_p \in (0,1)$ is the rate of indexation, $\beta \in (0,1)$ is the representative agent's subjective discount factor. We substitute the desired markup (6) in (9) to obtain an alternative formulation of the NKPC,

$$\hat{\pi}_{p,t} - \lambda_p \hat{\pi}_{p,t-1} = \frac{\varepsilon - 1}{\kappa_p}(-\eta \hat{N}_t - \hat{\mu}_t) + \beta(1 - \delta_N) E_t\{\hat{\pi}_{p,t+1} - \lambda_p \hat{\pi}_{p,t}\} + \hat{\eta}_t^P, \qquad (10)$$

where $\hat{\eta}_t^P$, often referred to as a 'cost-push shock', is a transformation of the price-elasticity of the spending share,

$$\hat{\eta}_t^P = -\frac{\varepsilon - 1}{\kappa_p}\eta \hat{\gamma}_t. \qquad (11)$$

and thus represents an exogenous shock to desired price markups, see (6). We multiply the exogenous component of the desired markup in (6) by $\frac{\varepsilon-1}{\kappa_p}$ in order to have the desired markup shock enter the NKPC with a unit coefficient. Through the competition effect ($\eta > 0$), an increase in the number of firms and goods has a direct negative effect on inflation.

1.3 Households

Households derive utility from consuming $\hat{C}_t$ and disutility from working $\hat{L}_t$. The respective marginal utilities are given by

$$\hat{U}_{C,t} = -\frac{\sigma_C}{1 - b}(\hat{C}_t - b\hat{C}_{t-1}) \quad \text{and} \quad \hat{U}_{L,t} = \sigma_L \hat{L}_t,$$

where $\sigma_C > 0$ is the degree of risk aversion, $b \in (0,1)$ captures external habit formation in consumption and $\sigma_L > 0$ is the inverse Frisch elasticity of labor supply with respect to

the real wage. The household has access to a risk-free one-period nominal bond that pays interest $\hat{R}_t$; the optimal choice of bonds leads to the Euler equation

$$\hat{U}_{C,t} = E_t\{(\hat{R}_t - \hat{\pi}^C_{p,t+1}) + \hat{U}_{C,t+1}\} + \hat{\eta}^T_t, \tag{12}$$

where $\hat{\pi}^C_{p,t}$ is the change in the welfare-based price index P_t. The 'time preference' shock $\hat{\eta}^T_t$ is derived from a disturbance to the subjective discount factor β. Capital services are the sum of the capital stock $\hat{K}_t$ and its utilization $\hat{u}_t$,

$$\hat{K}^s_t = \hat{u}_t + \hat{K}_t.$$

The optimal choice of capital utilization results in a utilization rate that is adjusted to the rental rate of capital with elasticity σ_a,

$$\hat{u}_t = \sigma_a \hat{r}^k_t,$$

where $\sigma_a = \frac{1-\tilde{\sigma}_a}{\tilde{\sigma}_a}$ and $\tilde{\sigma}_a \in (0,1)$ measures utilization adjustment costs. Accumulation of physical capital takes the form

$$\hat{K}_{t+1} = (1 - \delta_K)\hat{K}_t + \delta_K \hat{I}_t + \delta_K (1 + \beta)\varphi_K \hat{\eta}^I_t,$$

where $\hat{I}_t$ is intensive margin investment, i.e. investment in physical capital, and $\delta_K \in (0,1)$ is the capital depreciation rate. The optimal choice of physical capital gives rise to a q-equation,

$$\hat{q}_t = E_t\{-(\hat{R}_t - \hat{\pi}^C_{p,t+1}) + [1 - \beta(1 - \delta_K)]\hat{r}^k_{t+1} + \beta(1 - \delta_K)\hat{q}_{t+1}\}, \tag{13}$$

where the real value of capital $\hat{q}_t$ depends positively on its expected future value and on the expected future rental rate, and negatively on the real interest rate. Physical investment is subject to flow adjustment costs of the type introduced in Christiano, Eichenbaum and Evans (2005). As a result, current investment is a function of its lagged and expected future value, as well as the current value of capital,

$$\hat{I}_t = \frac{1}{(1 + \beta)\varphi_K}\hat{q}_t + \frac{\beta}{1 + \beta}E_t\{\hat{I}_{t+1}\} + \frac{1}{1 + \beta}\hat{I}_{t-1} + \hat{\eta}^I_t,$$

where φ_K captures investment adjustment costs at the intensive margin. The term $\hat{\eta}^I_t$ represents an exogenous shock to investment-specific technology. Extensive margin investment is

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determined analogously. The number of firms and goods evolves according to the following law of motion,

$$\hat{N}_{t+1} = (1 - \delta_N)\,\hat{N}_t + \delta_N \hat{N}_{E,t}, \tag{14}$$

where δ_N is the firm exit rate. The value of a firm $\hat{v}_t$ depends positively on its expected future value, on expected future dividends, and negatively on the real interest rate,

$$\hat{v}_t = E_t\{-(\hat{R}_t - \hat{\pi}^C_{p,t+1}) + [1 - \beta(1 - \delta_N)]\,\hat{d}_{t+1} + \beta(1 - \delta_N)\,\hat{v}_{t+1}\}. \tag{15}$$

The number of entrants depends on its lagged and expected future value, and on the difference between firm value and the entry cost $\widehat{mc}_t + \hat{\eta}^E_t$,

$$\hat{N}_{E,t} = \frac{1}{(1 + \beta)\,\varphi_N}[\hat{v}_t - (\widehat{mc}_t + \hat{\eta}^E_t)] + \frac{\beta}{1 + \beta}E_t\{\hat{N}_{E,t+1}\} + \frac{1}{1 + \beta}\hat{N}_{E,t-1}, \tag{16}$$

where φ_N captures investment adjustment costs at the extensive margin.[8] Total investment is the sum of intensive and extensive margin investment,

$$\widehat{TI}_t = \frac{I}{TI}\hat{I}_t + \frac{vN_E}{TI}(\widehat{mc}_t + \hat{N}_{E,t} + \hat{\eta}^E_t).$$

We assume monopolistic wage setters and sticky wages as in Erceg, Henderson and Levin (2000). In addition, we stipulate that non-adjusted wages are indexed to price inflation with coefficient λ_w. Wage inflation $\hat{\pi}_{w,t}$ is thus determined as follows,

$$\hat{\pi}_{w,t} - \lambda_w \hat{\pi}_{p,t-1} = \frac{\theta_w - 1}{\kappa_w}[(\hat{U}_{L,t} - \hat{U}_{C,t}) - \hat{w}_t] + \beta E_t\{\hat{\pi}_{w,t+1} - \lambda_w \hat{\pi}_{p,t}\} + \hat{\eta}^W_t,$$

where $\kappa_w > 0$ is the degree of wage stickiness, $\theta_w > 1$ is the elasticity of substitution between labor types, and $\hat{\eta}^W_t$ denotes an exogenous shock to wage inflation.

1.4   Market Clearing

The aggregate goods bundle $\hat{Y}^C_t$ is a weighted average of private consumption $\hat{C}_t$, physical capital investment $\hat{I}_t$, the costs of adjusting the utilization rate $\hat{u}_t$ and exogenous government consumption $\hat{\eta}^G_t$,

$$\hat{Y}^C_t = \frac{C}{Y^C}\hat{C}_t + \frac{I}{Y^C}\hat{I}_t + \frac{r^k K}{Y^C}\hat{u}_t + \hat{\eta}^G_t.$$

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[8]For a more detailed derivation of the dynamic entry equation (16), see Lewis and Poilly (2012).

Let $\hat{Y}_t$ denote total expenditure, which equals goods output and investment at the extensive margin,

$$\hat{Y}_t = \frac{Y^C}{Y}\hat{Y}_t^C + \frac{\upsilon N_E}{Y}(\hat{mc}_t + \hat{N}_{E,t} + \hat{\eta}_t^E).$$

The market clearing conditions for labor and capital services are, respectively,

$$\hat{L}_t = \frac{L_C}{L}\hat{L}_{C,t} + \frac{L_E}{L}\hat{L}_{E,t}, \quad \text{and} \quad \hat{K}_t^s = \frac{K_C}{K}\hat{K}_{C,t}^s + \frac{K_E}{K}\hat{K}_{E,t}^s.$$

1.5 Monetary Policy

Monetary policy follows a Taylor-type rule with interest rate smoothing. The interest rate is adjusted in response to the level and the growth rate of the output gap, to product price inflation and to the lagged interest rate,

$$\hat{R}_t = \tau_R \hat{R}_{t-1} + (1 - \tau_R)\left(\tau_\pi \hat{\pi}_{p,t} + \tau_Y \hat{Y}_t^{gap}\right) + \tau_{dy}\Delta\hat{Y}_t^{gap} + \hat{\eta}_t^R \tag{17}$$

where Δ is the first difference operator and $\hat{Y}_t^{gap}$ is the output gap defined as actual output $\hat{Y}_t$ less the natural output level that would prevail under perfectly flexible prices and wages, $\hat{Y}_t^n$. The term $\hat{\eta}_t^R$ represents an exogenous monetary policy shock.

1.6 Exogenous Shock Processes

Table 1 summarizes the functional forms assumed for the eight exogenous shocks.

[insert Table 1 here]

Except for the government spending and markup shocks, all disturbances follow $AR(1)$ processes in logarithmic terms. Following Smets and Wouters (2007), government spending is also affected by the innovation in the TFP-process and disturbances to price and wage markups follow $ARMA(1,1)$ processes.

2 Estimation

We apply Bayesian estimation techniques as in Fernandez-Villaverde and Rubio -Ramirez (2004) and Smets and Wouters (2003, 2007). For a detailed description, we refer to the original papers. In a nutshell, using the Bayesian paradigm prior information is combined

with the data to obtain posterior distributions for the parameters.[9] In the following, we describe the data sources and transformations, before turning to our choice of priors and to the posterior distributions of the model parameters.

2.1 Data

In the model, real variables are deflated by the welfare-based price index P_t, which is unobserved. Empirical measures of the price index correspond rather to the product price p_t, given that consumption baskets are not updated frequently enough to fully take into account the welfare effects from product turnover. To link the model with the data, we strip out the variety effect on the price index by multiplying each real variable by P_t and dividing by p_t. For any real variable z_t in the model, the linearized data-consistent counterpart then reads $\hat{z}_t^R = \hat{z}_t - \hat{\rho}_t$.

In our baseline specification, we estimate the model using eight series of US quarterly data from 1957Q1 until 1995Q3. These are output, consumption, investment, hours, net business formation, real wages, inflation and the interest rate. These eight time series are used to identify the eight structural innovations in the theoretical model, see Table 1. Our vector of observables is thus

$$\mathbf{Y}_t = (\hat{Y}_t^R, \hat{C}_t^R, \widehat{TI}_t^R, \hat{N}_{E,t}, \hat{L}_t, \hat{w}_t^R, \hat{\pi}_{p,t}, \hat{R}_t).$$

Data sources and filtering are as follows. Series for GDP, consumption and investment are obtained from the US Department of Commerce: Bureau of Economic Analysis (BEA). As in Smets and Wouters (2007), personal consumption expenditures include durable goods consumption. Investment is measured as gross fixed private domestic investment, which abstracts from changes in inventories. Net business formation (NBF) is published in the BEA's Survey of Current Business and covers the majority of US businesses. The original data source is the Dun and Bradstreet Corporation. This series has been discontinued; data run from January 1948 to September 1995. Data for hours and wages are from the US Department of Labor - Bureau of Labor Statistics (BLS). Following Chang, Gomes

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[9]We use 1,000,000 iterations of the Random Walk Metropolis Hastings algorithm to simulate the posterior distributions and achieve acceptance rates of about 35% in all our specifications. We discard the initial 4% of the drawings to compute the posterior moments in each case. We monitor the convergence of the marginal posterior distributions using CUMSUM statistics as defined by Bauwens, Lubrano and Richard (1999).

and Schorfheide (2002), who point to the limited coverage of the nonfarm business sector compared to GDP, we multiply the index of average hours for the nonfarm business sector (all persons) by civilian employment (16 years and over). The interest rate is the Effective Federal Funds Rate from the Board of Governors of the Federal Reserve System. Inflation is measured as the first difference of the log implicit price deflator of GDP (from the BEA). All raw series are seasonally adjusted using the Census X12 method. All nominal variables are deflated with the GDP deflator. The aggregate real variables are expressed in per capita terms, by dividing by the Civilian Noninstitutional Population over 16 (from the BLS), and linearly detrended in logarithmic terms. The inflation rate and the nominal interest rate are demeaned by subtracting their respective sample averages.

2.2 Priors

An overview of our priors can be found in Table 2. Six parameters are fixed. The subjective discount factor is set to $\beta = 0.99$, implying a steady state annualized real interest rate of 4%. Physical capital depreciates at an annual rate of 10%, i.e. $\delta_K = 0.025$. Similarly, the firm exit rate is set to $\delta_N = 0.025$, so as to fit the annual job destruction rate of 10% observed in US data. The parameter of the Cobb-Douglas production function capital share is calibrated to $\alpha = 0.24$, which implies a mean labor share in GDP of three quarters. The government consumes roughly one fifth of all goods produced, $G/Y^C = 0.21$. Finally, following Smets and Wouters (2007) the elasticity of substitution between different labor types is set at $\theta_w = 3$, implying a net wage markup of 50%.

[insert Table 2 here]

The prior distributions on the shock parameters are quite diffuse, with beta distributions with mean 0.5 and standard deviation 0.15 for the autoregressive and moving average co-efficients and inverse gamma distributions with mean 0.1 and standard deviation 2 for the standard errors of the innovations. For most of the structural parameters we use priors as imposed by Smets and Wouters (2007). The monetary policy parameters, however, are given gamma distributions, instead of normal distributions, to impose a lower bound of zero. The Rotemberg price and wage adjustment cost parameters, κ_p and κ_w, are assumed to be

gamma distributed with mean 50 and a standard deviation of 5. The mean lies between the value of $\kappa_p = 77$, estimated by Ireland (2001), and the prior mean of $\kappa_p = \kappa_w = 20$ imposed by Krause, Lopez-Salido and Lubik (2008). Moreover, a Rotemberg parameter of 50 corresponds to an average contract duration of about 4 quarters in the Calvo model, a value which lies in the ballpark of estimates obtained from the New Keynesian Phillips curve literature. For the demand elasticity ε we impose a diffuse normal distribution with mean 4 and standard deviation 1.5. This suggests an average price markup of 33%, which lies in the middle of the range 20 to 40% that is typically reported for the US average price markup, e.g. Hall (1988), Roeger (1995), Basu and Fernald (1997), Oliveira Martins and Scarpetta (1999) and Christopoulou and Vermeulen (2008).

2.3 Posterior Estimates

In the following, we discuss our posterior estimates and contrast them, where possible, with the existing empirical evidence from the fixed-variety literature. Our baseline estimation results are reported in Table 2, which summarizes the modes, means and the 5th and 95th percentiles of the posterior distributions. We discuss the mean estimates of the standard parameters first, before turning to the entry-related parameters.

While our estimates of the standard parameters are in line with the literature, several observations are worth making. Compared to business cycle models without entry, see e.g. Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007), our estimate of investment adjustment costs and of capital utilization costs are somewhat higher at about $\varphi_K = 8.57$ and $\tilde{\sigma}_a = 0.73$, respectively. Recall that total investment data is matched with the sum of intensive and extensive margin investment in our model, whereas in the fixed-variety model the investment series proxies physical capital investment only. For the Rotemberg price and wage stickiness parameters κ_p and κ_w, we obtain values of 61 and 62, respectively, which corresponds to an average contract duration of about 3 quarters for prices and 2.5 quarters for wages in the Calvo analog.[10] These estimates are at the lower end of those obtained in the macro literature, but are in line with the micro evidence on the frequency

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[10]Strictly speaking, we cannot compute an average price contract duration in our model, as this requires a constant population of price setters.

of price adjustment, e.g. Blinder et al. (1998) and Nakamura and Steinsson (2008). Finally, the estimated degree of price indexation $\lambda_p = 0.51$ is somewhat higher than the value of 0.24 reported in Smets and Wouters (2007). This difference may come from our higher NKPC slope estimate, which implies a higher inflation volatility for a given value of price indexation. Adjustment costs in entry are estimated at 1.96. This is substantially lower than the value above 8 reported in Lewis and Poilly (2012), who estimate a model similar to the one presented above by impulse response matching techniques. These different results can be explained by the different stochastic structures of the two models. In Lewis and Poilly (2012), fluctuations are driven only by monetary policy shocks. Here, however, we consider a range of shocks. To our knowledge, no other empirical evidence on this parameter exists.

Our main parameter of interest is the price-elasticity of demand, which determines the steady state markup, the competition effect, as well as consumers' love of variety. We find a mean estimate of $\varepsilon = 5.64$ in our baseline estimation, which implies that price markups are 22% on average. While this estimate lies in the ballpark of many micro studies of average markups, e.g. Christopoulou and Vermeulen (2010), it is significantly lower than the 60% steady state markup implied by the Smets and Wouters' (2007) model with fixed costs and no entry. Lewis and Poilly (2012), whose set of observables includes a markup measure, also find a lower demand elasticity ($\varepsilon = 2.5$). In Section 5 we investigate the sensitivity of our results to alternative specifications and sets of observables.

Turning to the derived parameters, the posterior distribution of ε implies that the competition effect η, the inverse of the demand elasticity has a mean value of $\eta = 0.18$. Hence, desired markups fall by 0.18% in response to a 1% increase in the number of firms. Cecioni (2010) uses single-equation techniques to estimate the New Keynesian Phillips Curve (10). She finds a competition effect of 1.2. In her model, the competition effect is supply-driven and stems from an oligopolistic market structure. In contrast, our model with translog expenditure cannot generate a competition effect above unity given the lower bound the demand elasticity, $\varepsilon \geq 1$. While our estimate of the competition effect is statistically significant, we investigate below if this effect is also economically important in driving inflation. From the model's steady state, we can compute the steady state number of firms. Given the relation between the demand elasticity ε and the number of firms N (which we compute using the

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calibrated parameters and the posterior mean of ε) in (5), we derive the price-elasticity of the spending share $\gamma = 0.52$. Thus, in response to a 1% price increase for an individual variety, the spending share drops by 0.52%.

3 Markups and the Competition Effect

This section analyzes markup dynamics in the presence of the competition effect as predicted by the model. First, we highlight how the competition effect works conditional on a specific shock. Second, we examine the unconditional properties of the model-implied markup, in particular its cyclicality.

3.1 Transmission Channels

The eight structural shocks are grouped as follows. TFP shocks $\hat{\eta}_t^Z$, entry cost shocks $\hat{\eta}_t^E$ and shocks to wage inflation $\hat{\eta}_t^W$ constitute 'supply shocks', which affect marginal costs of production in (one of) the two sectors. Government spending shocks $\hat{\eta}_t^G$, investment-specific technology shocks $\hat{\eta}_t^I$ and time preference shocks $\hat{\eta}_t^T$ are classified as 'demand shocks'. Monetary policy shocks $\hat{\eta}_t^R$ and desired markup shocks $\hat{\eta}_t^P$ are treated as separate categories. Note that we consider expansionary shocks throughout; all shocks have been normalized to produce a(n eventual) rise in GDP.

3.1.1 Supply Shocks

Figure 1a depicts the impulse responses of selected variables to the three supply shocks. Consider the first two panels showing the dynamics triggered by shocks to TFP and wage markups. Favorable movements in both shocks, i.e. positive TFP shocks and negative wage markup shocks, lower real marginal costs in both sectors. Prices are sticky and do not fall by the same amount. Therefore, actual markups rise, which increases profits through (8). The fall in entry costs induced by the shock leads to entry (16) and a gradual decline in desired markups via the competition effect (6). Consequently, in response to 'standard' supply shocks, the competition effect mitigates the procyclical effect of price stickiness on markups: actual and desired markups move in opposite directions.

[insert Figure 1a here]

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The transmission of entry cost shocks deserves special attention since this type of shock is specific to the endogenous-entry framework. An exogenous decrease in startup costs directly raises entry through (16). The number of producers and goods rises too, though only gradually and after a one-period lag, see (14). This leads to an eventual decrease in the desired markup through the competition effect (6). Initially, the rise in investment in new firms induces a reallocation of production factors from the manufacturing sector to new startups, implying a decrease in GDP on impact. However, the economic downturn is short-lived, as the rise in extensive margin investment eventually pushes output above steady state. The ensuing rise in aggregate demand raises marginal costs and prices. Due to price adjustment costs, prices rise less than marginal costs, such that actual markups decrease. Desired markups decrease by less than desired markups. Therefore, inflation rises through the New Keynesian Phillips Curve (9).

3.1.2   Demand Shocks

Next, we examine the propagation of demand shocks. We notice from Figure 1b that all three shocks generate strong crowding-out effects at the extensive margin; entry drops. The monetary policy tightening in reaction to expansionary demand shocks implies an increase in the real interest rate. This, in turn, lowers firm value through (15). Combined with an increase in entry costs (marginal costs increase together with aggregate demand), this leads to a fall in entry through (16), increasing desired markups via the competition effect (6). The dominant effect on markups, however, comes from price stickiness. An exogenous increase in demand raises marginal production costs more than prices, inducing actual markups to fall. The competition effect thus mitigates the countercyclical response of markups to demand shocks.

[insert Figure 1b here]

Expansionary shocks to government spending and investment-specific technology are followed by an (eventual) increase in profits. This is explained by the rise in output that dominates the decline in the actual markup in (8). In contrast, in response to time preference shocks, profits fall. This is because the output increase is smaller compare with the other two shocks.

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Hence the negative effect of falling markups on profits dominates. Notice also that the effects of the time preference shock are short-lived due to the low shock persistence ($\rho_T = 0.29$, see Table 2).

3.1.3 Monetary Policy Shocks

Concerning the monetary policy shock (displayed in the top panel of Figure 1c), two model predictions stand out. First, aggregate profits decrease following an expansionary monetary policy shock. This is in contrast to evidence reported in Lewis (2009) and Lewis and Poilly (2012). However, it is in line with Bilbiie, Ghironi and Melitz (2007). A decline in the interest rate leads to a marginal cost rise and, given that prices do not adjust fully, to a decrease in actual markups, which in turn depresses profits. The greater the price-elasticity of demand ε, the greater this effect of markups on profits, see (8). At the same time, a decline in the interest rate has expansionary effects on aggregate demand $\hat{Y}_t^C$, which raises profits. Our estimates imply that the first effect dominates the second effect, such that profits decrease on net.

Notice the difference with Lewis and Poilly (2012), who find that profits rise in response to a monetary expansion. There are two reasons for this difference. First, our demand elasticity ε is larger, which makes the first effect more important. Second, the model in Lewis and Poilly (2012) includes working capital. Thus, if $\hat{R}_t$ decreases, marginal costs do not rise as much given that the interest rate decline puts downward pressures on marginal costs.

Second, despite the decrease in profits, entry rises in reaction to a loosening of monetary policy. This is in line with the evidence reported in Bergin and Corsetti (2008), Lewis (2009) and Lewis and Poilly (2012). The explanation is that the interest rate decline leads to a decrease in the expected return on shares to eliminate arbitrage across assets. The expected return on shares falls through a rise in the current relative to the future share price. This rise in firm value exceeds the rise in marginal costs (i.e. entry costs). On balance therefore, entry expands, which in turn decreases the desired markup through (6). As a result, the competition effect augments the countercyclical effect of price stickiness on markups in the case of monetary policy shocks.

[insert Figure 1c here]

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3.1.4 Desired Markup Shocks

The bottom panel in Figure 1c shows the effects of an exogenous drop in desired markups (an increase in $\hat{\eta}_t^P$). By (11), the spending share becomes more price-elastic and via (6) the desired markup decreases. This lowers inflation through the New Keynesian Phillips Curve (9) and boosts demand. The ensuing boom drives up real marginal costs; because of price stickiness, actual markups fall. Aggregate profits decrease, as the decrease in the actual markup $\hat{\mu}_t$ dominates the rise in demand $\hat{Y}_t^C$ in the profit expression (8). Entry costs rise by more than firm value, such that entry contracts.

To sum up, the model predicts a procyclical entry response to supply shocks and to monetary policy shocks, but a countercyclical response to demand shocks. As a result, through the competition effect, desired markups are countercyclical in response to supply shocks and monetary policy shocks, but procyclical following demand shocks. The competition effect therefore augments the countercyclical effect of price stickiness on markups in the case of monetary policy shocks, whereas it counteracts the sticky price effects on markups in response to supply and demand shocks. Exogenous disturbances to the desired markup eventually lead to countercyclical entry.

3.2 The Cyclicality of the Markup

Here we study the unconditional cyclicality of the markup implied by the model. Using the baseline estimates in Table 2, we back out the time series for the actual markup, $\hat{\mu}_t$ and for its 'sticky-price' counterpart, $\hat{\mu}_t^{SP}$. To compute the actual markup, we set the parameters to their posterior modes and feed the complete set of shocks into the model. To compute the sticky price markup, we set all parameters to their baseline values, except for the competition effect, which is set to zero ($\eta = 0$). We feed the shock series into the model, excluding the desired markup shock ($\hat{\eta}_t^P = 0$). The resulting markup series, denoted $\hat{\mu}_t^{SP}$, is the counterfactual markup that one would obtain if desired markups were constant.

Similar to Bilbiie, Ghironi and Melitz (2011), we then compute the correlation of the two markup series with output at various leads and lags. Since our model includes a whole array of structural shocks, this exercise should provide a realistic description of what a DSGE

model with endogenous entry implies for (unconditional) markup variations. Figure 2 plots $corr(\hat{Y}_{t+s}^R, \hat{\mu}_t)$ and $corr(\hat{Y}_{t+s}^R, \hat{\mu}_t^{SP})$ for $s = -5, -4, \ldots, 0, \ldots, 5$.

[insert Figure 2 here]

The actual markup is countercyclical, while the sticky-price markup is procyclical at all leads and lags. Thus, it is the combination of the competition effect and desired markup shocks that reverses the sign of the markup-output correlation. Recall from Figures 1a-c that entry is procyclical in response to supply shocks and monetary policy shocks (such that the competition effect leads to countercyclical markups), but countercyclical in response to demand shocks (such that the competition effect leads to procyclical markups). The result that $\hat{\mu}_t$ is countercyclical reflects the importance of supply shocks in driving aggregate fluctuations.

Figure 3 presents a forecast error variance decomposition for output $\hat{Y}_t^R$, inflation $\hat{\pi}_{p,t}$ and markups $\hat{\mu}_t$. For these three variables, TFP and wage markup shocks are an important source of volatility, while entry cost shocks hardly matter.[11]

[insert Figure 3 here]

Long run output variability is explained almost entirely by two supply shocks: wage markup shocks (50%) and TFP shocks (40%). In the short run, the sources of output fluctuations are more mixed: government spending shocks and TFP each account for one fifth, investment-specific technology for one third. The variation in the markup is mainly accounted for by a combination of TFP, wage markup shocks and price markup shocks.

To conclude, we find a minor role of demand-type shocks in driving output and markup fluctuations. Since demand shocks are the only source of markup procyclicality, the model-implied correlation between markups and output is negative overall.

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[11]Most of the variability in entry is explained by its own shock $\hat{\eta}_t^E$, which points to a poor performance of the model in generating firm dynamics endogenously. More detailed results are available from the authors upon request.

4   A Counterfactual Analysis of US Inflation Dynamics

This section examines in greater detail the sources of inflation dynamics in US data. We aim to assess the risk of misguided cyclical monetary policy when inflation fluctuations result from endogenous market structure changes.[12] To this end, we decompose US inflation, into a sticky-price component plus two components reflecting endogenous and exogenous variations in the desired markup.

Our premise here is that the objective of monetary policy is to close gaps, i.e. to stabilize inflation which fluctuates in response to markup variations induced, in turn, by nominal rigidities. This is the optimal prescription for monetary policy in the New Keynesian tradition, see Woodford (2003) and Galí (2008). Bergin and Corsetti (2008) and Bilbiie, Ghironi and Melitz (2007) show that this optimal policy prescription carries over to the more recent business cycle literature on endogenous entry, provided that fiscal instruments are used to address inefficiencies at the steady state. The consensus here is that the central bank should let number of firms fluctuate freely and should not respond to changes in inflation arising from entry and exit.[13]

Suppose the central bank observes a fall in inflation. It may face a signal extraction problem in that it cannot tell whether (part of) this fall is due to stronger competition from a larger number of producers that compresses desired markups. In response to receding inflationary pressures the central bank is set to loosen its monetary policy stance. In times of weakening aggregate demand, such a policy response is warranted. In this case, sticky-price firms are unable to fully adjust prices downward as they would under perfect price flexibility, such that actual markups increase and inflation drops. However, loosening monetary policy is not the right response if firm entry has risen, e.g. because market deregulation measures have lowered entry costs, decreasing desired markups and inflation through the competition

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[12]Note that we abstract from the implications of entry for the optimal long run inflation rate, which are analysed in Bilbiie, Fujiwara and Ghironi (2011).

[13]In fact, optimal cyclical monetary policy in the presence of endogenous entry is somewhat more complicated. There are two opposing effects on welfare: a positive variety effect (through increased product diversity) and a negative 'business stealing effect' (through decreased profits). While these two externalities exactly offset each other in the case of Dixit-Stiglitz preferences, they do not under translog preferences. We abstract from possible net externalties at the business cycle frequency by assuming that the central bank wishes not to target inflation changes due to the competition effect, which it regards as efficient.

effect. Thus, we wish to gauge the economic importance of the competition effect, in order to assess the likelihood of such mistaken policy actions.

In the following, we perform a counterfactual analysis of US inflation. We filter out the contribution of *exogenous* desired markup shocks to inflation. To this end, we feed the shock series $\hat{\eta}_t^P$ into the model, setting all other shocks to zero, and denote the resulting inflation series $\hat{\pi}_{p,t}^P$. In addition, we are interested in two types of *endogenous* driving forces of inflation. The first $\hat{\pi}_{p,t}^{SP}$ captures the endogenous sticky-price channel of inflation fluctuations that characterizes the (hybrid) New Keynesian model. Through this channel, current inflation is driven by marginal costs and expected future inflation (through price stickiness) and by lagged inflation (through indexation to past inflation). We set all parameter values to their baseline estimates in Table 2, except for the competition effect, which we set to zero, $\eta = 0$. Then, we feed the shocks into the model, excluding the desired markup shock $\hat{\eta}_t^P$. The resulting inflation path is what we call 'sticky-price inflation', determined through the modified New Keynesian Phillips Curve,

$$\hat{\pi}_{p,t}^{SP} - \lambda_p \hat{\pi}_{p,t-1}^{SP} = \frac{\varepsilon - 1}{\kappa_p}(-\hat{\mu}_t^{SP}) + \beta \left(1 - \delta_N\right) E_t\{\hat{\pi}_{p,t+1}^{SP} - \lambda_p \hat{\pi}_{p,t}^{SP}\}.$$

The 'sticky-price markup' $\hat{\mu}_t^{SP}$ is the counterfactual markup series that we obtain under constant desired markups, that is, in the absence of a competition effect and desired markup shocks. The second endogenous component $\hat{\pi}_{p,t}^{CE}$ denotes the competition effect of entry on inflation, and is computed as the actual inflation rate, less sticky-price inflation, less the contribution of desired markup shocks,

$$\hat{\pi}_{p,t}^{CE} = \hat{\pi}_{p,t} - \hat{\pi}_{p,t}^{SP} - \hat{\pi}_{p,t}^P.$$

Figure 4 plots the quarterly inflation rate in the US from 1957q1 to 1995q2 and its three components $\hat{\pi}_{p,t}^{SP}$, $\hat{\pi}_{p,t}^{CE}$ and $\hat{\pi}_{p,t}^P$.

[insert Figure 4 here]

Compared with the sticky-price component and the exogenous component, the competition effect plays a rather minor role in driving US inflation. Only in the 1970s and 1980s did the competition effect exert any noticeable (downward) pressure on inflation. Therefore, it is

unlikely that monetary policy reacts unwittingly to inflation changes unrelated to (endogenous or exogenous) price distortions. Furthermore, the competition effect appears to account mainly for low frequency movements in the inflation rate. This indicates that - to the extent that competition effect induce inefficiencies - these can be dealt with more appropriately with policy instruments other than monetary policy.

Figure 3 confirms the importance of desired price markup shocks for inflation. In the short run, such shocks account for over half of inflation fluctuations.

5 Sensitivity Analysis

This section focuses on the sensitivity of our demand elasticity estimate ε to four alternative model specifications. First, we replace the time preference shock with a risk premium shock that affects the real interest rate. Second, we treat profits as an additional observable variable and extend the model by adding a white-noise measurement error to (8). Third, we estimate the Dixit-Stiglitz (1977) model with a constant elasticity of substitution (CES) aggregator on our original set of observables. Fourth, we consider the asymmetric production structure favored by Bilbiie, Ghironi and Melitz (2011), where new firms are set up using labor services only.

[insert Table 3 here]

The results of these four robustness exercises are displayed in Table 3. We discuss them in turn.

5.1 Risk Premium Shock

Smets and Wouters (2007) propose a demand-type shock that generates co-movement between consumption and investment. Following this idea, we stipulate that the return to one-period nominal bonds is multiplied by a random variable η_t^{RP}, which in logarithmic terms follows a first-order autoregressive process with persistence ρ_{RP} and standard deviation σ_{RP}. We call this variable a 'risk premium shock'. It reflects an exogenous risk premium on bond holdings, which drives a wedge between the bond return and the risk-free rate set by the central bank. While the time preference shock of the baseline model affected only the

Euler equation for bonds, the risk premium shock enters all three asset pricing equations. In optimality condition for bonds (12), $\hat{\eta}_t^T$ is replaced with $\hat{\eta}_t^{RP}$. In the first order condition for capital (13) and equity (15), the shock $\hat{\eta}_t^{RP}$ enters the right hand side with a negative sign. Figure 5 shows the impulse responses of some key variables to an expansionary risk premium shock. As output and inflation move in the same direction, we consider this as a demand-type shock. However, in contrast with the three demand shocks in Figure 1b, the risk premium shock generates a procyclical response of entry and therefore a countercyclical competition effect, which dampens inflation.

[insert Figure 5 here]

The estimation results of this alternative model are shown in Table 3 in the column entitled 'Risk-P'. The parameter estimates are similar to the baseline estimates; all confidence intervals overlap. The only noteworthy difference between the two sets of estimates is that the risk premium shock itself is significantly bigger and more persistent than the time preference shock.

5.2   Using Profit Data in Estimation

In a second exercise, we investigate whether considering profit data in our estimation greatly changes the results. In particular, we add data-consistent aggregate profits $\hat{D}_t^R = \hat{d}_t + \hat{N}_t - \hat{\rho}_t$ to the set of observables $\mathbf{Y}_t$. To avoid stochastic singularity - a problem that arises when having more variables than shocks - we include an exogenous iid normal error term $\hat{\varepsilon}_t^D$ with mean zero and standard deviation σ_D in the measurement equation of firm profits, such that (8) becomes

$$\hat{D}_t^R = (\varepsilon - 1)\,\hat{\mu}_t + \hat{Y}_t^C - \hat{\rho}_t + \hat{\varepsilon}_t^D.$$

Quarterly data for corporate profits after taxes are taken from the NIPA tables. The parameter estimates are summarized in column 'P' of Table 3. The mean demand elasticity increases to about $\varepsilon = 8.38$ when we include profits, which lowers the competition effect.[14]

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[14]The value $\varepsilon = 8.38$ lies in the upper tail of the prior distribution. The cumulative probability at this value equals 0.998. Therefore, our prior distribution might be too restrictive relative to the information captured in the data. In an additional robustness check available upon request, we impose a looser prior on ε, namely a gamma distribution with mean 4 , standard deviation 2.5. In this case ε slightly increases to 8.88, which lies within the 90% confidence interval of the prior distribution.

This can be explained by the large volatility of profits in the data and confirms the 'profit volatility puzzle'. Small changes in the markup can generate large profit movements only if the corresponding elasticity, $\varepsilon - 1$, is large, see (8). From existing research we know that neither the fixed-variety DSGE model (see Christiano, Eichenbaum and Evans, 2005), nor the endogenous-entry model (see Colciago and Etro, 2010; Lewis and Poilly, 2012) succeeds in explaining well the observed profit dynamics.

5.3 CES Aggregator

In light of our result that the contribution of the competition effect to inflation dynamics is rather small, it is instructive to compare our baseline model featuring a translog expenditure function with the Dixit-Stiglitz (1977) model assuming CES aggregator. In the latter model, the demand elasticity ε is constant and equal to the elasticity of substitution between varieties. Consequently, desired markups are also constant, such that $\hat{\mu}_t^d = 0$. Another model feature is that the love of variety is equal to the net steady state markup $\mu - 1 = \frac{1}{\varepsilon - 1}$. The results are reported in column 'CES' of Table 3. None of our parameter estimates change significantly relative to our baseline model. Thus, allowing for competition effects and a variable demand elasticity does not change our conclusions about the short-run dynamics of macroeconomic variables, including net business formation.

5.4 Asymmetric Sectors

As a final robustness check, we consider an alternative specification for entry costs consisting only of labor costs. Concretely, in the technology with which new firms are produced (7), α_E is set to zero. The last column of Table 3 reports the parameter estimates under the heading 'AsymPF'. Two observations stand out. First, the demand elasticity increases relative to the baseline estimate. Second, as ε increases, the price indexation parameter λ_p also increases. A possible explanation is that, as noted by Bilbiie, Ghironi and Melitz (2007), the endogenous-entry NKPC entails more inflation persistence because the number of varieties N_t is a state variable. Hence, the higher is the demand elasticity, the smaller is the competition effect and the less important is the endogenous persistence generated by entry, necessitating a higher

degree of indexation.[15]

6 Conclusion

This paper analyzes the empirical importance of changes in market structure and competition for business cycle dynamics in the US. By 'competition effect' we mean an inverse relationship between markups and entry rates as observed in the industrial organization literature. In response to expanding profit opportunities, more firms and products enter, which heightens competitive pressures and reduces desired markups and inflation. To quantify the relevance of this mechanism for cyclical fluctuations, we estimate - using Bayesian methods - a sticky-price business cycle model with sunk-cost driven entry dynamics and a translog expenditure function. We obtain two main results. Our first finding is that the impact of the competition effect on markups and inflation is shock-dependent. In the case of supply shocks and monetary policy shocks, entry is procyclical. Thus, the competition effect generates countercyclical markups and dampens inflation. The opposite is true for demand shocks. Overall, the model-implied markup is countercyclical, due to a combination of desired markup shocks and the competition effect. In a counterfactual exercise where sticky prices are the only source of markup variations, the model-implied markup is, in contrast, procyclical. Second, the estimated competition effect equals 0.18. A 1 percent in the number of firms and goods decreases desired markups by 0.18 percent. US inflation is driven mainly by a combination of sticky prices and exogenous markup shocks. The contribution of the competition effect to inflation fluctuations is limited.

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[15]Note that love of variety also generates some additional persistence. Even after transforming the model as explained in Section 3.1, the variety effect does not vanish in the case where risk aversion σ_C is greater than 1 and/or habits b are greater than 0. See also Lewis and Poilly (2012).

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Table 1: Exogenous Shock Processes

Total factor productivity shock	$\hat{\eta}_t^Z = \rho_Z \hat{\eta}_{t-1}^Z + \hat{\varepsilon}_t^Z$
Investment-specific technology shock	$\hat{\eta}_t^I = \rho_I \hat{\eta}_{t-1}^I + \hat{\varepsilon}_t^I$
Time preference shock	$\hat{\eta}_t^T = \rho_T \hat{\eta}_{t-1}^T + \hat{\varepsilon}_t^T$
Government spending shock	$\hat{\eta}_t^G = \rho_G \hat{\eta}_{t-1}^G + \hat{\varepsilon}_t^G + \rho_{GZ} \hat{\varepsilon}_t^Z$
Price markup shock	$\hat{\eta}_t^P = \rho_P \hat{\eta}_{t-1}^P + \hat{\varepsilon}_t^P + \mu_P \hat{\varepsilon}_{t-1}^P$
Wage markup shock	$\hat{\eta}_t^W = \rho_W \hat{\eta}_{t-1}^W + \hat{\varepsilon}_t^W + \mu_W \hat{\varepsilon}_{t-1}^W$
Monetary policy shock	$\hat{\eta}_t^R = \rho_R \hat{\eta}_{t-1}^R + \hat{\varepsilon}_t^R$
Entry cost shock	$\hat{\eta}_t^E = \rho_E \hat{\eta}_{t-1}^E + \hat{\varepsilon}_t^E$

Note: In each shock process i, the innovations $\hat{\varepsilon}_t^i$ are independently and identically distributed random variables following a normal distribution with mean zero and variance σ_i^2.

Table 2: Estimation Results: Baseline

ESTIMATED STRUCTURAL PARAMETERS		Posterior			SHOCKS AR(1), MA(1)		Posterior	
Symbol	Description	Prior (P1,P2)	Mode	Mean [5th; 95th %ile]	Symbol	Prior (P1,P2)	Mode	Mean [5th; 95th %ile]
b	Consumption habit	B (0.70, 0.10)	0.57	0.57 [0.47; 0.67]	ρ_Z	B (0.50, 0.15)	0.98	0.98 [0.97; 0.99]
σ_c	Consumption utility	N (1.5, 0.375)	1.55	1.49 [1.12; 1.87]	ρ_T	B (0.50, 0.15)	0.25	0.29 [0.14; 0.43]
σ_l	Consumption labor	N (2.00, 0.75)	1.58	1.55 [0.84; 2.25]	ρ_I	B (0.50, 0.15)	0.41	0.41 [0.32; 0.51]
					ρ_G	B (0.50, 0.15)	0.89	0.89 [0.86; 0.92]
φ_K	Investment adj. cost	N (4.00, 1.50)	8.23	8.57 [6.55; 10.57]	ρ_P	B (0.50, 0.15)	0.77	0.75 [0.66; 0.84]
φ_N	Entry adj. cost	N (4.00, 1.50)	1.75	1.96 [1.37; 2.50]	ρ_W	B (0.50, 0.15)	0.98	0.97 [0.95; 0.99]
$\tilde{\sigma}_a$	Capacity util. cost	B (0.50, 0.15)	0.70	0.73 [0.59; 0.87]	ρ_R	B (0.50, 0.15)	0.23	0.24 [0.13; 0.34]
					ρ_E	B (0.50, 0.15)	0.84	0.85 [0.81; 0.89]
λ_p	Indexation prices	B (0.50, 0.15)	0.46	0.51 [0.30; 0.71]	ρ_{GZ}	B (0.50, 0.15)	0.77	0.74 [0.58; 0.91]
κ_p	Price rigidity	G (50.0, 5.00)	61.18	60.82 [48.31; 72.83]	μ_w	B (0.50, 0.15)	0.66	0.64 [0.49; 0.79]
λ_w	Indexation wages	B (0.50, 0.15)	0.55	0.53 [0.34; 0.72]	μ_p	B (0.50, 0.15)	0.52	0.49 [0.32; 0.65]
κ_w	Wage rigidity	G (50.0, 5.00)	59.10	61.60 [48.40; 74.38]				
ε	**Demand elasticity**	**N (4.00, 1.50)**	**5.38**	**5.64 [4.50; 6.77]**				
η	**Competition effect**		**0.17**	**0.18 [0.15; 0.22]**				
					SHOCK INNOVATIONS			
τ_R	Interest smoothing	B (0.75, 0.10)	0.71	0.72 [0.66; 0.77]				
τ_π	Policy inflation	G (1.50, 0.25)	1.68	1.76 [1.49; 2.02]	σ_Z	IG (0.10, 2)	0.82	0.83 [0.75; 0.91]
τ_y	Policy output	G (0.50, 0.25)	0.05	0.06 [0.02; 0.10]	σ_T	IG (0.10, 2)	0.23	0.23 [0.19; 0.28]
τ_{dy}	Policy lagged output	G (0.50, 0.25)	0.36	0.37 [0.28; 0.46]	σ_I	IG (0.10, 2)	1.39	1.41 [1.15; 1.66]
					σ_G	IG (0.10, 2)	3.19	3.21 [2.86; 3.56]
CALIBRATED STRUCTURAL PARAMETERS					σ_P	IG (0.10, 2)	0.26	0.28 [0.22; 0.35]
					σ_W	IG (0.10, 2)	0.39	0.38 [0.31; 0.45]
β	Discount factor			0.99	σ_R	IG (0.10, 2)	0.26	0.27 [0.23; 0.30]
α	Capital share in production			0.24	σ_E	IG (0.10, 2)	2.70	2.87 [2.40; 3.34]
δ_N	Firm exit rate			0.025				
δ_K	Capital depreciation rate			0.025				
θ_w	Elasticity of substitution labor types			3				
G/Y^c	Exogenous spending share			0.21				

Note: B = Beta, G = Gamma, IG = Inverse Gamma and N = Normal distributions. P1 = Mean and P2 = Standard deviation for all distributions. Posterior moments are computed using 960,000 draws from the distribution simulated by the Random Walk Metropolis Hastings algorithm.

Table 3: Sensitivity Analysis

Symbol	Description	PRIOR (P1,P2)	POSTERIOR DISTRIBUTION: Mean [5th; 95th %ile]			
			Risk-P	P	CES	Asym-PF
STRUCTURAL PARAMETERS						
b	Consumption habit	B (0.70, 0.10)	0.46 [0.36; 0.55]	0.56 [0.46; 0.66]	0.56 [0.47; 0.65]	0.51 [0.40; 0.62]
σ_c	Consumption utility	N (1.5, 0.375)	1.40 [1.15; 1.65]	1.54 [1.16; 1.92]	1.72 [1.40; 2.05]	1.66 [1.35; 1.95]
σ_l	Consumption labor	N (2.00, 0.75)	1.20 [0.60; 1.78]	1.69 [0.96; 2.40]	2.04 [1.29; 2.76]	1.64 [0.77; 2.50]
φ_K	Investment adj. cost	N (4.00, 1.50)	6.87 [4.99; 8.71]	8.40 [6.35; 10.50]	8.42 [6.49; 10.32]	8.25 [6.38; 10.12]
φ_N	Entry adj. cost	N (4.00, 1.50)	1.88 [1.38; 2.37]	2.66 [1.95; 3.35]	2.06 [1.39; 2.70]	1.47 [1.14; 1.80]
$\tilde{\sigma}_a$	Capacity util. cost	B (0.50, 0.15)	0.67 [0.52; 0.83]	0.74 [0.61; 0.88]	0.72 [0.59; 0.86]	0.89 [0.83; 0.96]
λ_p	Indexation prices	B (0.50, 0.15)	0.57 [0.36; 0.78]	0.59 [0.39; 0.79]	0.48 [0.28; 0.69]	0.89 [0.82; 0.96]
κ_p	Price rigidity	G (50.0, 5.00)	59.73 [47.5; 71.7]	63.70 [51.3; 76.0]	61.97 [49.4; 74.0]	70.38 [57.4; 83.3]
λ_w	Indexation wages	B (0.50, 0.15)	0.50 [0.31; 0.69]	0.55 [0.36; 0.74]	0.54 [0.35; 0.73]	0.64 [0.45; 0.82]
κ_w	Wage rigidity	G (50.0, 5.00)	59.15 [46.0; 71.7]	61.28 [47.9; 73.9]	63.22 [50.0; 76.1]	60.43 [47.9; 73.0]
ε	**Demand elasticity**	**N (4.00, 1.50)**	**5.84 [4.70; 7.00]**	**8.38 [7.41; 9.32]**	**5.61 [4.36; 6.82]**	**9.60 [8.25; 10.92]**
η	**Competition effect**		**0.17 [0.14; 0.21]**	**0.12 [0.11; 0.13]**	**XX**	**0.10 [0.09; 0.12]**
τ_R	Interest smoothing	B (0.75, 0.10)	0.77 [0.72; 0.82]	0.73 [0.68; 0.78]	0.73 [0.67; 0.78]	0.74 [0.69; 0.80]
τ_π	Policy inflation	G (1.50, 0.25)	2.13 [1.79; 2.46]	1.81 [1.53; 2.09]	1.76 [1.49; 2.02]	1.79 [1.47; 2.08]
τ_y	Policy output	G (0.50, 0.25)	0.11 [0.05; 0.16]	0.07 [0.03; 0.12]	0.05 [0.01; 0.09]	0.10 [0.03; 0.16]
τ_{dy}	Policy lagged output	G (0.50, 0.25)	0.39 [0.31; 0.48]	0.38 [0.29; 0.47]	0.37 [0.29; 0.46]	0.51 [0.39; 0.63]
AR(1), MA(1)						
ρ_Z	TFP	B (0.50, 0.15)	0.98 [0.98; 0.99]	0.98 [0.98;0.99]	0.98 [0.97;0.99]	0.98 [0.97;0.99]
ρ_T	Time Impatience	B (0.50, 0.15)		0.29 [0.14; 0.43]	0.28 [0.14; 0.42]	0.32 [0.16; 0.48]
ρ_{RP}	Risk Premium	B (0.50, 0.15)	0.55 [0.40; 0.71]			
ρ_I	Inv. Spec. Tech.	B (0.50, 0.15)	0.49 [0.39; 0.59]	0.43 [0.34; 0.52]	0.39 [0.31; 0.48]	0.46 [0.36; 0.56]
ρ_G	Gov. Spending	B (0.50, 0.15)	0.88 [0.86; 0.91]	0.89 [0.86; 0.92]	0.89 [0.86; 0.92]	0.88 [0.85; 0.91]
ρ_P	Price Markup AR(1)	B (0.50, 0.15)	0.74 [0.65; 0.83]	0.73 [0.65; 0.82]	0.74 [0.66; 0.83]	0.51 [0.41; 0.62]
ρ_W	Wage Markup AR(1)	B (0.50, 0.15)	0.98 [0.97; 0.99]	0.98 [0.96; 0.99]	0.98 [0.97; 0.99]	0.98 [0.97; 0.99]
ρ_R	Monetary Policy	B (0.50, 0.15)	0.21 [0.11; 0.31]	0.24 [0.13; 0.34]	0.23 [0.13; 0.33]	0.24 [0.14; 0.35]
ρ_E	Entry Cost	B (0.50, 0.15)	0.88 [0.86; 0.91]	0.85 [0.81; 0.89]	0.84 [0.79; 0.88]	0.83 [0.80; 0.86]
ρ_{GZ}	Corr. TFP – Gov.	B (0.50, 0.15)	0.74 [0.59; 0.91]	0.77 [0.62; 0.92]	0.74 [0.57; 0.90]	0.78 [0.64; 0.92]
μ_w	Wage Markup MA(1)	B (0.50, 0.15)	0.72 [0.61; 0.84]	0.66 [0.53; 0.80]	0.63 [0.50; 0.78]	0.66 [0.53; 0.81]
μ_p	Price Markup MA(1)	B (0.50, 0.15)	0.49 [0.32; 0.64]	0.45 [0.29; 0.61]	0.47 [0.30; 0.62]	0.31 [0.16; 0.45]
INNOVATIONS						
σ_Z	TFP	IG (0.10, 2)	0.81 [0.73; 0.89]	0.79 [0.72; 0.87]	0.83 [0.75; 0.91]	0.95 [0.85; 1.05]
σ_T	Time Impatience	IG (0.10, 2)		0.24 [0.19; 0.28]	0.23 [0.19; 0.28]	0.25 [0.19; 0.30]
σ_{RP}	Risk Premium	IG (0.10, 2)	0.71 [0.45; 0.96]			
σ_I	Inv. Spec. Tech.	IG (0.10, 2)	1.24 [0.99; 1.48]	1.22 [1.01; 1.41]	1.46 [1.21; 1.73]	1.10 [0.91; 1.29]
σ_G	Gov. Spending	IG (0.10, 2)	3.17 [2.82; 3.51]	2.95 [2.67; 3.24]	3.21 [2.85; 3.56]	2.86 [2.58; 3.13]
σ_P	Price Markup	IG (0.10, 2)	0.30 [0.24; 0.37]	0.33 [0.26; 0.39]	0.28 [0.21; 0.34]	0.53 [0.46; 0.61]
σ_W	Wage Markup	IG (0.10, 2)	0.38 [0.31; 0.46]	0.39 [0.32; 0.46]	0.39 [0.31; 0.46]	0.40 [0.32; 0.47]
σ_R	Monetary Policy	IG (0.10, 2)	0.27 [0.24; 0.30]	0.26 [0.23; 0.29]	0.27 [0.23; 0.30]	0.27 [0.23; 0.31]
σ_E	Entry Cost	IG (0.10, 2)	2.43 [2.02; 2.85]	3.27 [2.71; 3.81]	2.87 [2.40; 3.35]	2.90 [2.51; 3.29]
σ_D	Profit Meas. Error	IG (0.10, 2)		12.45 [11.3; 13.6]		

Note: 'Risk-P' replaces the time-impatience shock by the Smets and Wouters (2007) risk-premium shock which generates comovement between consumption and investment. 'P' uses profit data in the estimation and introduces a measurement error in equation (8). 'CES' is a model with constant elasticity of substitution between goods as in Dixit and Stiglitz (1977). 'Asym-PF' is a model with an asymmetric production structure for the entry and goods producing sector. B = Beta, G = Gamma, IG = Inverse Gamma and N = Normal distributions. P1 = Mean and P2 = Standard deviation for all distributions. Posterior moments are computed using 960,000 draws from the distribution simulated by the Random Walk Metropolis Hastings algorithm.
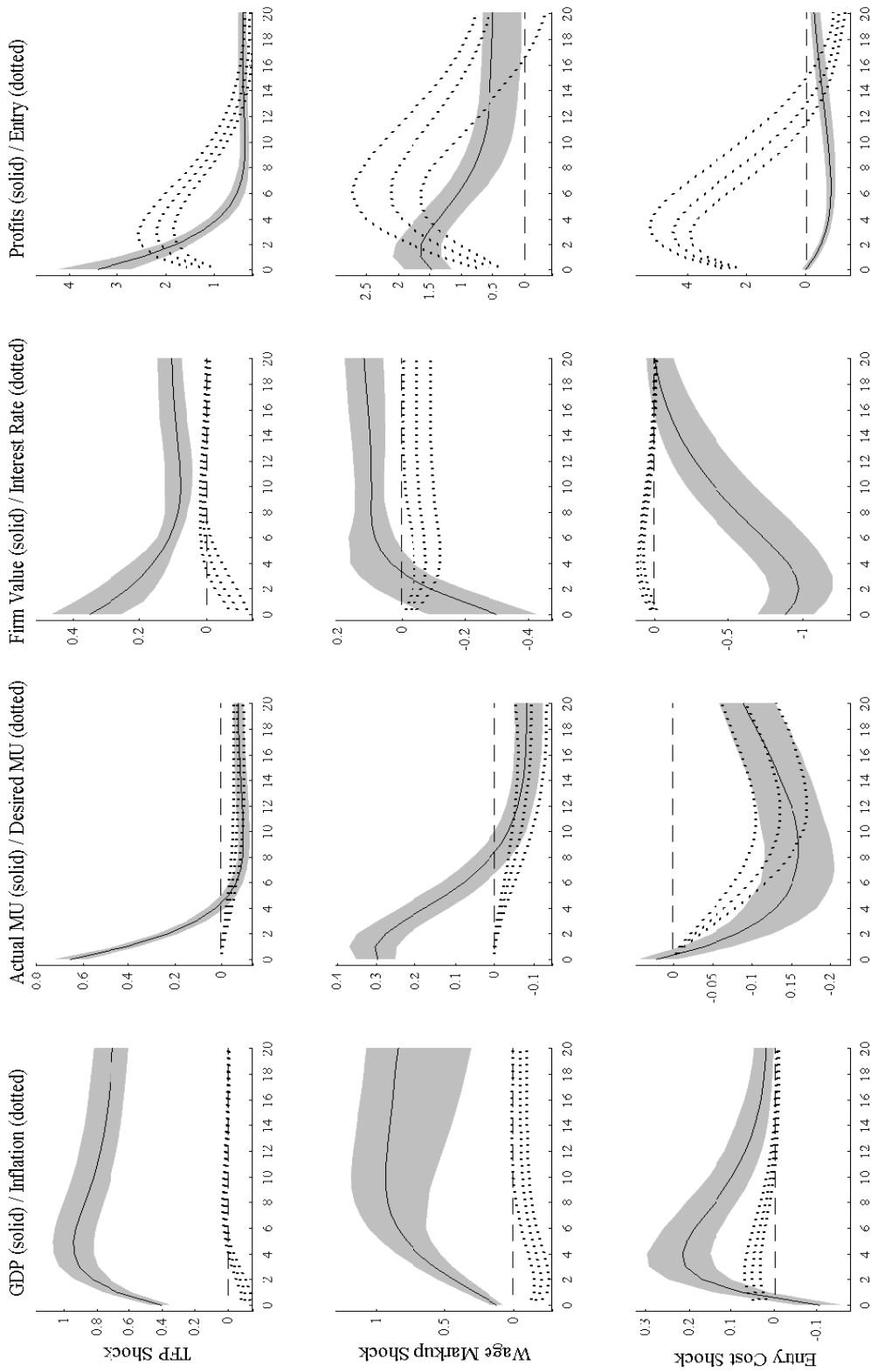
Figure 1a: Impulse Responses to Supply Shocks

Note: Impulse responses functions (IRFs) to a one standard deviation shock, measured in percentage deviations from steady state. Median IRF and 5th and 95th percentiles are based on 300 random draws from the posterior distribution. All shocks have been normalized to produce an increase in GDP.
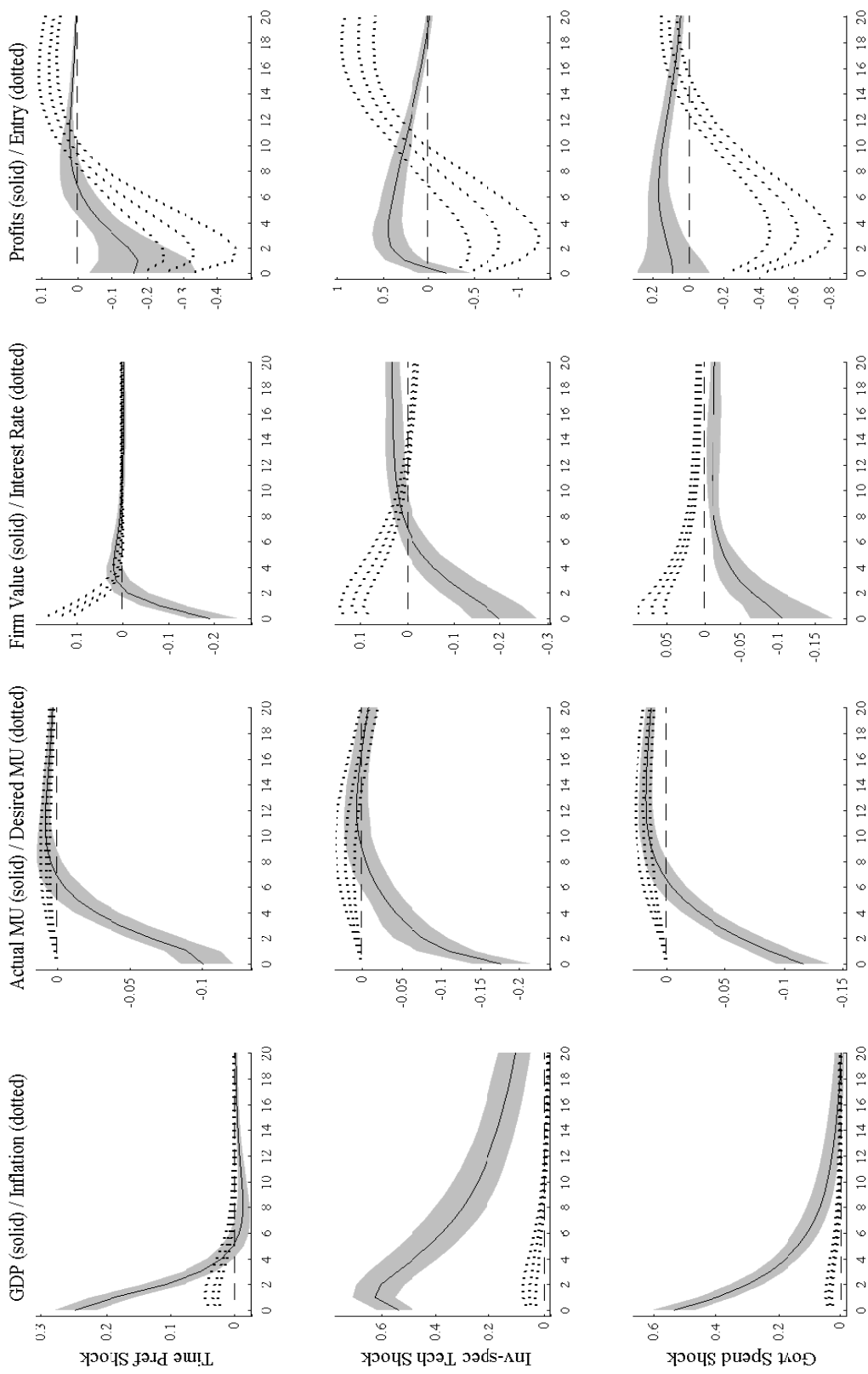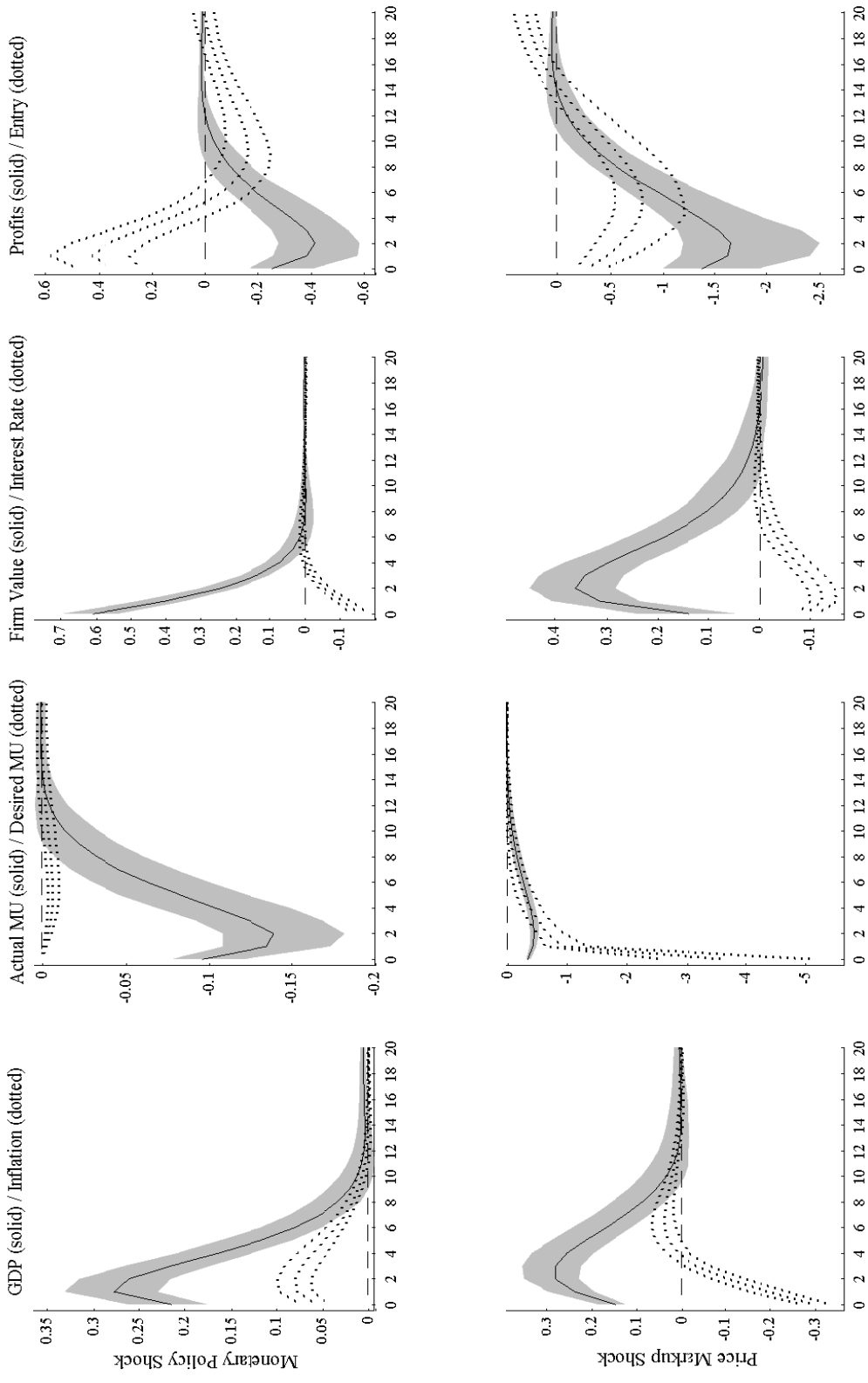
Figure 1b: Impulse Response to Demand Shocks

Note: Impulse responses functions (IRFs) to a one standard deviation shock, measured in percentage deviations from steady state. Median IRF and 5th and 95th percentiles are based on 300 random draws from the posterior distribution. All shocks have been normalized to produce an increase in GDP.

Figure 1c: Impulse Responses to Monetary Policy and Price Markup Shocks

Note: Impulse responses functions (IRFs) to a one standard deviation shock, measured in percentage deviations from steady state. Median IRF and 5th and 95th percentiles are based on 300 random draws from the posterior distribution. All shocks have been normalized to produce an increase in GDP.
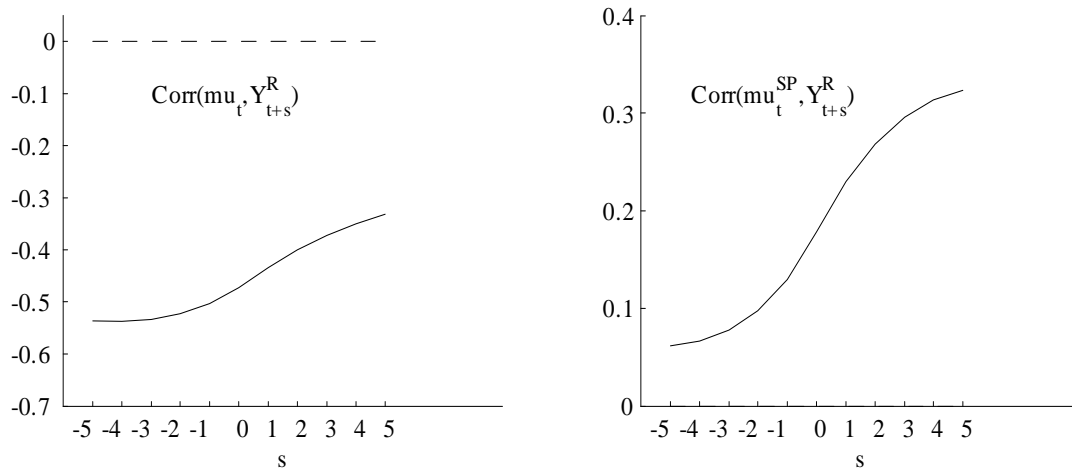
Figure 2: The Cyclicality of the Markup

Note: The figure shows the cyclicality of the model-implied markup at different leads and lags. The left panel depicts the actual markup $\hat{\mu}_t$ as implied by the model, while the right panel depicts the counterfactual 'sticky price' markup $\hat{\mu}_t^{SP}$, which is the markup we would obtain in the absence of desired markup shocks and the competition effect.
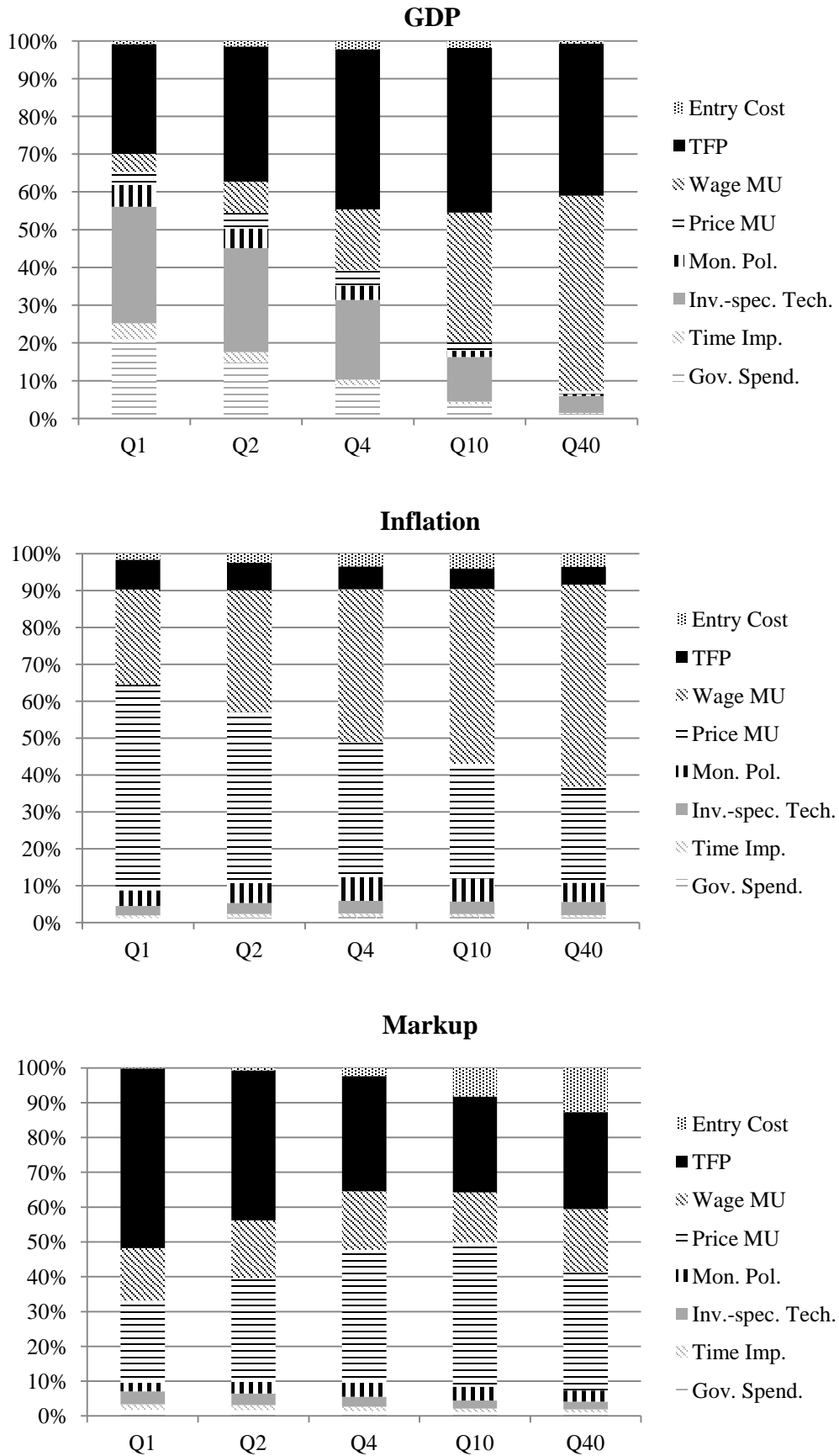
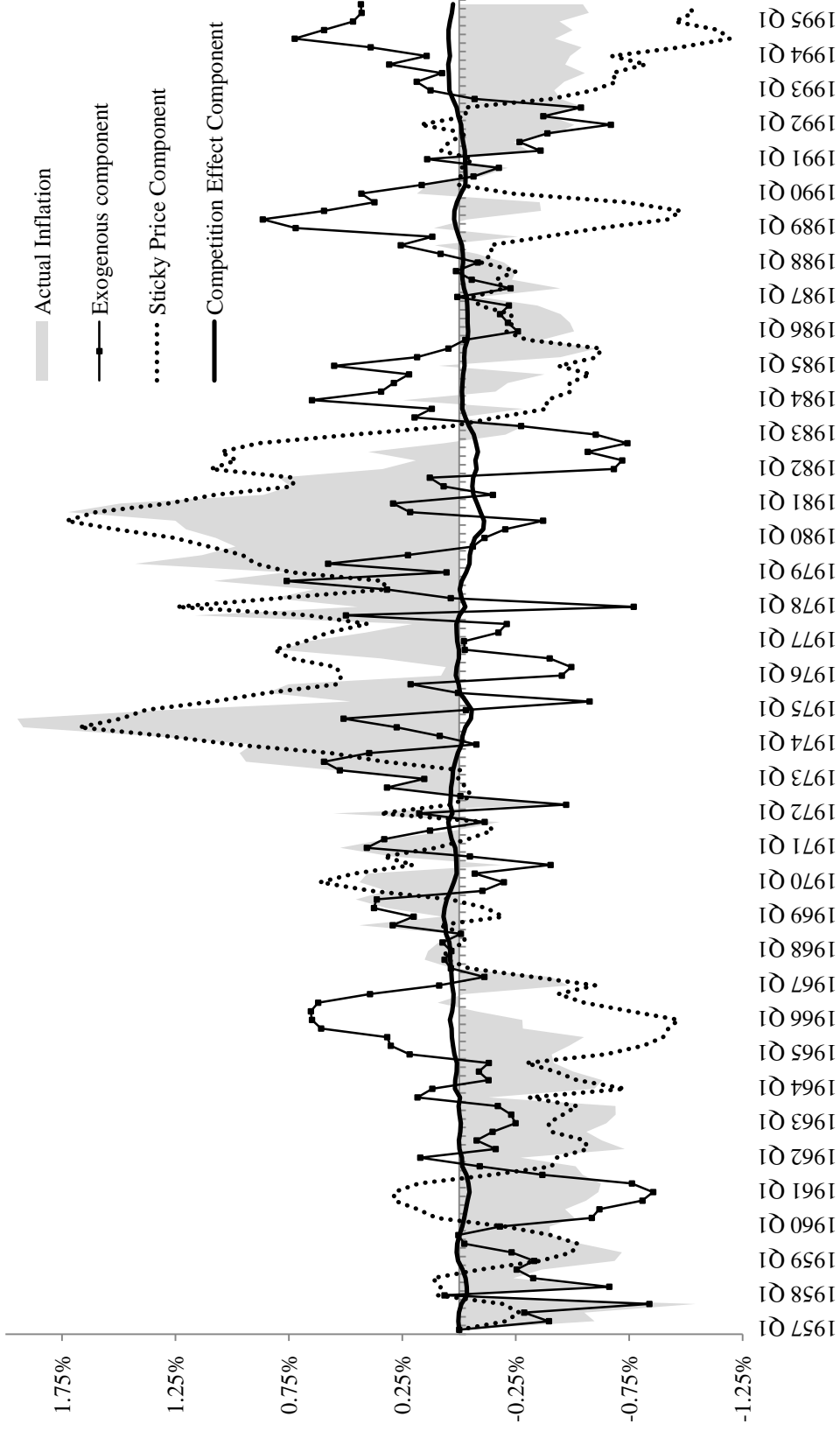Figure 3: Forecast Error Variance Decomposition (at posterior mode)

Figure 4: Counterfactual Decomposition of US Inflation

Note: The inflation rate and its components have been constructed by feeding the smoothed shocks into the model. The 'Exogenous component' represents the contribution of desired price markup shocks to inflation. The 'Sticky Price Component' captures the counterfactual inflation path when desired markups are constant. The 'Competition Effect Component' is the residual of the actual inflation rate less the two other components.
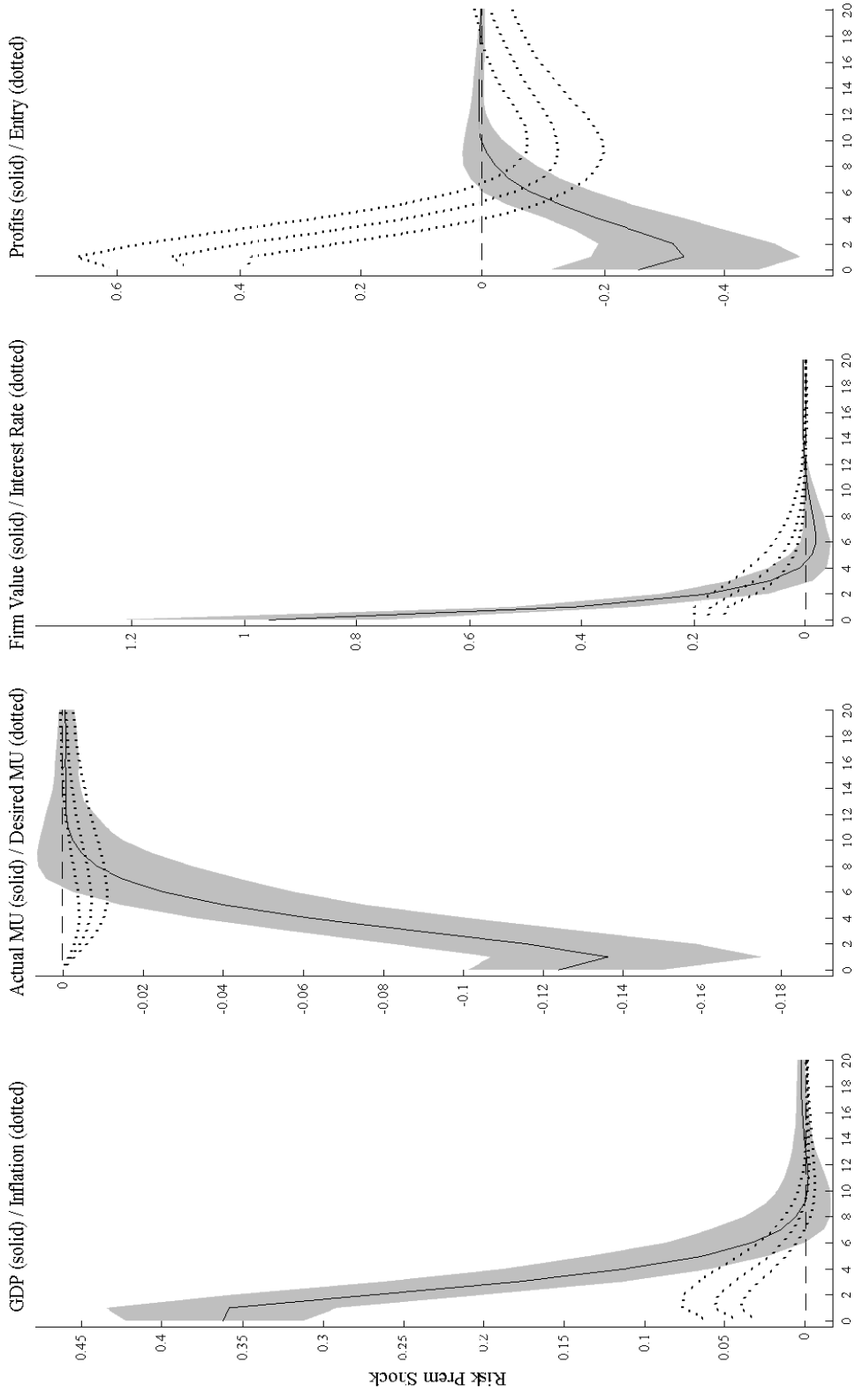
Figure 5: Sensitivity Analysis. Impulse Responses to Risk Premium Shock

Note: Impulse responses functions (IRFs) to a one standard deviation shock, measured in percentage deviations from steady state. Median IRF and 5th and 95th percentiles are based on 300 random draws from the posterior distribution. All shocks have been normalized to produce an increase in GDP.