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Entry and Markup Dynamics in an Estimated Business Cycle Model*

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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 extent to 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 0.17 percent. While markup fluctuations due to sticky prices or exogenous shocks account for a large proportion of US inflation variability, endogenous changes in desired markups also play a non-negligible role.

Keywords: Bayesian estimation, business cycles, competition, entry, markups.
JEL codes: C11, E23, E32

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1 Introduction

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 positive 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.[1] In particular, when an increase in the number of competitors reduces desired markups and inflation, this acts as an endogenous propagation and amplification mechanism.[2]

Portier (1995) and Cook (2001) are early examples of business cycle models where firm entry, which ensures zero profits each period, has a negative effect on markups. Floetotto and Jaimovich (2008) focus on the implications of that entry mechanism for the Solow residual. Bilbiie, Ghironi and Melitz (2012), henceforth BGM, show that a model with sunk-cost driven entry and translog consumption preferences outperforms the standard real business cycle (RBC) model in terms of matching second moments of certain variables in the data. Under this preference structure, the price-elasticity of demand is increasing in the number of available products. Colciago and Etro (2010) do a comparable exercise using a model with the BGM (2012) entry mechanism and different oligopolistic market structures.

This paper provides an empirical model validation exercise which is so far missing in the literature. It uses Bayesian techniques to estimate the effect of entry on markups in a dynamic stochastic general equilibrium (DSGE) model. We seek to answer two questions. First, how does endogenous entry influence the cyclical behavior of markups? Second, how important is this effect in explaining US inflation fluctuations? In accordance with the terminology used in Colciago and Etro (2010) and Lewis and Poilly (2012), we refer to the effect of a change in the number of competing firms or products on price markups as the 'competition effect' in the remainder of the paper.

Our first question relates to the dynamics of price-cost markups, which are key in business

[1] See e.g. Bergin and Corsetti (2008).

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

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 number of firms or products. The response of entry to a shock determines how this mechanism works. If an expansionary shock (i.e., one that raises output) leads to profit opportunities over and above entry costs, new firms and products enter. Then, desired markups fall and inflationary pressures are dampened. In contrast, if an expansionary shock crowds out entry, desired markups rise, putting upward pressure on prices which is absent in the no-entry case. Therefore, changes in competition through entry may amplify or dampen propagation in the New Keynesian model. This paper characterizes the conditional dynamics of entry (or 'extensive margin investment') and markups in response to an array of shocks.

Markups of prices over marginal cost are unobserved and therefore hard to measure. There is no agreement on the conditional properties of markups in the data, or even on their unconditional cyclicality. The influential work by Bils (1987) and 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. Kalman filtering techniques allow us to estimate the unobserved markup series. Using our parameter estimates, we then describe the cyclical behavior of the markup implied by the model. In addition, we quantify the contribution of changes in competition and desired markup shocks to the markup-output correlation.

Our second aim is to gauge the importance of the competition effect for hitherto unexplained inflation fluctuations, which are labelled 'cost-push shocks'. Cost-push shocks pose a challenge for central banks since they create a tradeoff for monetary policy between inflation and output stabilization.

Firm and product turnover has long 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 its effect on markups are taken into account. Lewis and Poilly (2012) estimate two variants of the endogenous-entry model 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 in the first model, entry has a significant effect on markups 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. Our analysis of transmission channels extends Bilbiie, Ghironi and Melitz (2007) and Bilbiie, Ghironi and Melitz (2012), who consider fewer shocks and a smaller set of frictions. The model-implied markup is countercyclical once endogenous entry and shocks to desired markups are taken into account. Second, we carry out a counterfactual analysis of US inflation, showing how the historical inflation path was altered by the competition effect.

One potential limitation of our exercise is that we measure entry as *firm* entry, i.e., net business formation, new incorporations and establishment births, rather than *product* entry. Bilbiie, Ghironi and Melitz (2012), as well as a number of trade-related studies referenced therein, emphasize the importance of product turnover for output dynamics. Although it would be desirable to estimate the model using product data, we are constrained by the lack of a long enough time series, covering the universe of products, to carry out such an analysis. To the extent that product-level dynamics matter more for markup and inflation fluctuations than firm entry and exit, our results may understate the importance of entry-induced markup fluctuations.

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

2 Model

Our model combines the entry mechanism and the translog expenditure function proposed by Bilbiie, Ghironi and Melitz (2012) with a set of real and nominal frictions as in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007). We include habit formation and investment adjustment costs / variable capital utilization. These model features are deemed necessary to replicate the dynamics of consumption and capital investment, respectively. Entry, which constitutes investment along the extensive margin, can only be captured adequately if the model accounts well for the other components of aggregate demand.

Most 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.

2.1 Preferences, Entry and Desired Markups

Aggregation over intermediate goods varieties takes the translog form as in Feenstra (2003), such that the elasticity of demand for an individual good ε_t is increasing in the number of

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

competing firms or goods N_t,[4]

$$\varepsilon_t = 1 + \gamma N_t, \tag{1}$$

where $\gamma \geq 0$ denotes the price-elasticity of the spending share on an individual good. 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 $\mu_t^d \equiv \frac{\varepsilon_t}{\varepsilon_t - 1}$ is also time-varying. In particular, $\mu_t^d = \frac{1+\gamma N_t}{\gamma N_t}$. The desired markup μ_t^d is distinct from the actual markup μ_t which is also affected by price setting frictions. In linearized form, the desired markup is

$$\hat{\mu}_t^d = -\eta \hat{N}_t + \hat{\zeta}_t^U, \text{ where } \eta = \frac{1}{1+\gamma N}. \tag{2}$$

The variable $\hat{\zeta}_t^U$ denotes a reduced form shock to desired markups, which is introduced as an empirical device to capture variations in inflation that remain unexplained by the model (see equation (8) below).[5] 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. Under a translog expenditure function, this parameter equals the inverse steady state demand elasticity, $\eta = \frac{1}{\varepsilon}$. The real product price ρ_t, defined as the ratio of the nominal product price p_t to the aggregate price index P_t, i.e., $\rho_t \equiv p_t / P_t$, is a positive function of the number of firms and products, N_t. In linearized form, this is

$$\hat{\rho}_t = \frac{1}{2\gamma N} \hat{N}_t. \tag{3}$$

The elasticity of the real product price to the number of firms/products captures 'love of variety', or the degree to which consumers can increase their utility by spreading their consumption expenditure across more differentiated goods. Love of variety is inversely related to the steady state number of firms and to the price-elasticity of the spending share γ.[6] The demand for a single variety is $\hat{y}_t = \hat{Y}_t^C - \hat{\rho}_t - \hat{N}_t$, where Y_t^C denotes the aggregate goods bundle.

[4] We use the terms 'goods' and 'firms' interchangeably throughout, assuming that each firm produces exactly one differentiated variety.

[5] In an additional robustness assessment available upon request, we structurally derive $\hat{\zeta}_t^U$ as a shock to the price-elasticity of the expenditure share γ. We find that our main results are robust to this alternative model environment.

[6] In Dixit and Stiglitz (1977) preferences, love of variety is $\frac{1}{\varepsilon - 1}$, 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, such that no utility gain arises from additional product diversity.

2.2 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 $\alpha_C \in (0,1)$,

$$\hat{Y}^C_t = \hat{\rho}_t + \alpha_C \hat{K}^s_{C,t} + (1-\alpha_C)\hat{L}_{C,t} + \hat{\zeta}^Z_t. \tag{4}$$

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

$$\hat{N}_{E,t} + \hat{\zeta}^E_t = \alpha_E \hat{K}^s_{E,t} + (1-\alpha_E)\hat{L}_{E,t} + \hat{\zeta}^Z_t. \tag{5}$$

The exogenous variable $\hat{\zeta}^E_t$ captures entry costs per firm, measured in terms of a composite of labor and capital services.[7] The production structure is symmetric such that the capital share is the same in the two sectors, $\alpha_C = \alpha_E = \alpha$.[8] Marginal costs $\widehat{mc}_t$ for producing both goods and firms are a weighted average of the rental rate of capital $\hat{r}^k_t$ and the real wage $\hat{w}_t$, less TFP, $\widehat{mc}_t = \alpha \hat{r}^k_t + (1-\alpha)\hat{w}_t - \hat{\zeta}^Z_t$. 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

$$\hat{d}_t + \hat{N}_t = (\varepsilon - 1)\hat{\mu}_t + \hat{Y}^C_t, \tag{6}$$

where $\varepsilon = 1 + \gamma N$ is the steady state price-elasticity of demand, see (1). Monopolistic firms set prices as a markup $\hat{\mu}_t$ over marginal costs, $\hat{\rho}_t = \hat{\mu}_t + \hat{m}c_t$. Price setters are subject to a quadratic price adjustment cost of the Rotemberg (1982)-type.[9] Non-adjusted prices are

[7] Entry costs may contain a cyclical component that is not modeled here. For instance, firm startups may be dependent on bank loans, with the costs of bank finance varying over the business cycle. This would be captured by the variable $\hat{\zeta}^E_t$.

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

[9] To facilitate aggregation, we assume that first-time price setters face adjustment costs just like incumbent firms. As Bilbiie, Ghironi and Melitz (2007) show, adopting the alternative assumption, i.e., that price setting is costless for entrants, does not greatly alter model predictions.

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,

$$\hat{\pi}_{p,t} - \lambda_p \hat{\pi}_{p,t-1} = \frac{\varepsilon - 1}{\kappa_p}(\hat{\mu}_t^d - \hat{\mu}_t) + \beta\,(1-\delta_N)\,E_t\{\hat{\pi}_{p,t+1} - \lambda_p \hat{\pi}_{p,t}\}, \tag{7}$$

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 and E_t denotes the expectations operator conditional on the information set at the beginning of period t. We substitute the desired markup (2) in (7) to obtain an alternative formulation of the NKPC,

$$\hat{\pi}_{p,t} - \lambda_p \hat{\pi}_{p,t-1} = \frac{\varepsilon - 1}{\kappa_p}(-\eta \hat{N}_t - \hat{\mu}_t) + \beta\,(1-\delta_N)\,E_t\{\hat{\pi}_{p,t+1} - \lambda_p \hat{\pi}_{p,t}\} + \hat{\zeta}_t^P, \tag{8}$$

where $\hat{\zeta}_t^P$, often referred to as a 'cost-push shock', is a transformation of the desired markup shock, $\hat{\zeta}_t^P = \frac{\varepsilon-1}{\kappa_p}\hat{\zeta}_t^U$. The variable $\hat{\zeta}_t^P$ thus represents an exogenous shift in price markups that is neither related to price stickiness nor to the arrival of new entrants.[10] We multiply the exogenous component of the desired markup in (2) by $\frac{\varepsilon-1}{\kappa_p}$ in order to have the price 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.

2.3 Households

Households derive utility from consuming $\hat{C}_t$ and disutility from working $\hat{L}_t$. The respective marginal utilities are given by $\hat{U}_{C,t} = -\frac{\sigma_C}{1-b}(\hat{C}_t - b\hat{C}_{t-1})$ and $\hat{U}_{L,t} = \sigma_L \hat{L}_t$, 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,

$$\hat{U}_{C,t} = E_t\{(\hat{R}_t - \hat{\pi}_{p,t+1}^C) + \hat{U}_{C,t+1}\} + \hat{\zeta}_t^T, \tag{9}$$

where $\hat{\pi}_{p,t}^C$ is the change in the welfare-based price index P_t. The 'time preference' shock $\hat{\zeta}_t^T$ reflects a disturbance to the growth rate of the marginal utility of consumption. Capital

[10] Using our estimation results below, we carry out a variance decomposition whereby we quantify the parts of markup variability that are accounted for by, respectively, price stickiness, the competition effect and exogenous factors.

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 $\hat{K}_{t+1} = (1-\delta_K)\hat{K}_t + \delta_K \hat{I}_t + \delta_K (1+\beta)\varphi_K \hat{\zeta}^I_t$, 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 term $\hat{\zeta}^I_t$ represents an exogenous shock to investment-specific technology. The optimal choice of physical capital gives rise to a q-equation,

$$\hat{q}_t = E_t\{-(\hat{R}_t - \hat{\pi}^C_{p,t+1}) + [1-\beta(1-\delta_K)]\,\hat{r}^k_{t+1} + \beta(1-\delta_K)\,\hat{q}_{t+1}\}, \tag{10}$$

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,

$$\hat{I}_t = \frac{1}{(1+\beta)\varphi_K}\hat{q}_t + \frac{\beta}{1+\beta}E_t\{\hat{I}_{t+1}\} + \frac{1}{1+\beta}\hat{I}_{t-1} + \hat{\zeta}^I_t, \tag{11}$$

where φ_K captures investment adjustment costs at the intensive margin. Extensive margin investment is determined analogously. The number of firms and goods evolves according to the following law of motion, $\hat{N}_{t+1} = (1-\delta_N)\hat{N}_t + \delta_N \hat{N}_{E,t}$, 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,

$$\hat{v}_t = E_t\{-(\hat{R}_t - \hat{\pi}^C_{p,t+1}) + [1-\beta(1-\delta_N)]\,\hat{d}_{t+1} + \beta(1-\delta_N)\,\hat{v}_{t+1}\}. \tag{12}$$

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

$$\hat{N}_{E,t} = \frac{1}{(1+\beta)\varphi_N}[\hat{v}_t - (\widehat{mc}_t + \hat{\zeta}^E_t)] + \frac{\beta}{1+\beta}E_t\{\hat{N}_{E,t+1}\} + \frac{1}{1+\beta}\hat{N}_{E,t-1}, \tag{13}$$

where φ_N captures investment adjustment costs at the extensive margin.[11] Total investment is the sum of intensive and extensive margin investment, $\widehat{TI}_t = \frac{I}{TI}\hat{I}_t + \frac{vN_E}{TI}(\widehat{mc}_t + \hat{N}_{E,t} + \hat{\zeta}^E_t)$.

[11] For a more detailed derivation of the dynamic entry equation (13), see Lewis and Poilly (2012).

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,

$$\hat{\pi}_{w,t} - \lambda_w \hat{\pi}_{p,t-1} = \frac{\theta_w - 1}{\kappa_w}[(\hat{U}_{L,t} - \hat{U}_{C,t}) - \hat{w}_t] + \beta E_t \{\hat{\pi}_{w,t+1} - \lambda_w \hat{\pi}_{p,t}\} + \hat{\zeta}_t^W, \tag{14}$$

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

2.4 Market Clearing

The aggregate goods bundle $\hat{Y}_t^C$ 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 $\hat{\zeta}_t^G$,

$$\hat{Y}_t^C = \frac{C}{Y^C}\hat{C}_t + \frac{I}{Y^C}\hat{I}_t + \frac{r^k K}{Y^C}\hat{u}_t + \hat{\zeta}_t^G. \tag{15}$$

Let $\hat{Y}_t$ denote total expenditure, which equals goods output and investment at the extensive margin, $\hat{Y}_t = \frac{Y^C}{Y}\hat{Y}_t^C + \frac{vN_E}{Y}(\hat{m}c_t + \hat{N}_{E,t} + \hat{\zeta}_t^E)$. The market clearing conditions for labor and capital services are, respectively, $\hat{L}_t = \frac{L_C}{L}\hat{L}_{C,t} + \frac{L_E}{L}\hat{L}_{E,t}$ and $\hat{K}_t^s = \frac{K_C}{K}\hat{K}_{C,t}^s + \frac{K_E}{K}\hat{K}_{E,t}^s$.

2.5 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,

$$\hat{R}_t = \tau_R \hat{R}_{t-1} + (1 - \tau_R)(\tau_\pi \hat{\pi}_{p,t} + \tau_Y \hat{Y}_t^{gap}) + \tau_{dy} \Delta \hat{Y}_t^{gap} + \hat{\zeta}_t^R \tag{16}$$

where Δ is the first difference operator and $\hat{Y}_t^{gap}$ is the output gap as measured by the central bank. An exact definition of the output gap is deferred to Section 3.1. The term $\hat{\zeta}_t^R$ represents an exogenous monetary policy shock. We estimate the model on data up to the start of the Great Recession. During a period where the economy is at the zero lower bound on nominal interest rates, the postulated monetary policy rule is no longer applicable. Including the most recent period would distort our estimates.

2.6 Exogenous Shock Processes

Table 1 summarizes the functional forms assumed for the eight exogenous shocks. We group these shocks as follows. TFP shocks $\hat{\zeta}_t^Z$, entry cost shocks $\hat{\zeta}_t^E$ and wage markup shocks $\hat{\zeta}_t^W$ constitute 'supply shocks', which affect marginal costs of production in (one of) the two sectors. Government spending shocks $\hat{\zeta}_t^G$, investment-specific technology shocks $\hat{\zeta}_t^I$ and time preference shocks $\hat{\zeta}_t^T$ are classified as 'demand shocks'. Monetary policy shocks $\hat{\zeta}_t^R$ and price markup shocks $\hat{\zeta}_t^P$ are treated as separate categories.

[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), disturbances to price and wage markups follow $ARMA(1,1)$ processes; the moving average terms pick up high-frequency movements in inflation. Government spending is also affected by the innovation in the TFP-process. This specification is designed to capture the unmodeled variations in net exports, which may be affected by domestic productivity developments.

3 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.[12] 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.

3.1 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,

[12] We use 600,000 iterations of the Random Walk Metropolis Hastings algorithm to simulate the posterior distributions and achieve acceptance rates of approximately 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).

given that consumption baskets are not updated frequently enough to fully take into account the welfare effects from product turnover. Moreover, even if the composition of the consumption basket were adjusted at an adequate frequency, the price index computed by the Bureau of Labor Statistics (BLS) would nevertheless be inconsistent with the translog expenditure function proposed here. Thus, 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 the monetary policy rule (16), the output gap is defined as the deviation of data-consistent output from steady state, $\hat{Y}_t^{gap} = \hat{Y}_t^R$.

In our baseline specification, we estimate the model using eight series of US quarterly data. 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

$$\mathbf{Y}_t = (\hat{Y}_t^R, \hat{C}_t^R, \widehat{TI}_t^R, \hat{N}_{E,t}, \hat{L}_t, \hat{w}_t^R, \hat{\pi}_{p,t}, \hat{R}_t). \tag{17}$$

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. As our benchmark measure of entry, we use net business formation. New incorporations and establishment births serve as robustness checks. Net business formation 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. New incorporations are obtained from the same source, with an almost identical sample period. This explains why the sample period in our baseline estimation (from 1957Q1 until 1995Q3) ends so early. The number of establishment births is available from the BLS from 1993Q2 onwards. Data for hours and wages are from the US Department of Labor - BLS. Following Chang, Gomes 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.

3.2 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/product exit rate is set to $\delta_N = 0.025$, so as to fit the job destruction rate observed in US data. This value is also consistent with an average product drop rate of 9% per year as reported by Bernard, Redding and Schott (2010). 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 coefficients, 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 7.5. 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 approximately 4.5 quarters in the Calvo model, a value which lies in the ballpark of estimates obtained from the New Keynesian Phillips Curve literature. Our results are robust to imposing a smaller prior mean for κ_p. 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 of 15% to 45% 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).

3.3 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 5^{th} and 95^{th} 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 estimates of investment adjustment costs and of capital utilization costs are somewhat higher at about $\varphi_K = 8.7$ 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, while 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 62 and 57, respectively, which corresponds to an average contract duration of approximately 4 quarters for prices and 2.5 quarters for wages in the Calvo analog.[13] These estimates are at the lower end of

[13] As seen in equation (7), the Rotemberg adjustment scheme delivers a coefficient $\frac{\varepsilon-1}{\kappa}$ on the markup gap in the NKPC. In the Calvo analog of the NKPC, this slope coefficient is $\frac{(1-\beta\xi)(1-\xi)}{\xi}$, where $\frac{1}{1-\xi}$ determines the duration of price stickiness. Therefore, it is possible to compare the slope coefficients given by the two

those obtained in the macro literature, but are in line with the micro evidence on the frequency of price adjustment, e.g., Blinder et al. (1998) and Nakamura and Steinsson (2008). The estimated monetary policy parameters are consistent with existing evidence: we observe substantial interest rate smoothing ($\tau_R = 0.73$) and a response coefficient on inflation that satisfies the Taylor Principle ($\tau_\pi = 1.49$). With $\tau_y = 0.01$, the response to output is barely significant.

Adjustment costs in entry are estimated at $\varphi_N = 2.42$. 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. This different result 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. In our steady state, entry costs are 10.5% of GDP, i.e., $\frac{vN_E}{Y} = 0.105$. Empirical estimates of the share of entry costs in output vary widely, with our figure lying somewhere in the middle. Barseghyan and DiCecio (2011) pin down entry costs using available estimates of the ratio of entry-to-operating cost ratio. For the US, they report a benchmark estimate of entry costs, as a fraction of output per worker, of 20.8%. An alternative calibration in Barseghyan and DiCecio (2011), using the evolution of firms' productivity over time, yields a smaller estimate of 12.15%. A third measure is constructed as follows. The World Bank's Doing Business project (www.doingbusiness.org) reports the number of days needed to register a firm. Dividing this number by 264 (22 working days per month, times 12 months), gives the time in years that represents an entrepreneur's opportunity cost of starting a business. For the US, we have an entry cost of 6/264=0.0227 years per capita, or 2.27% of annual GDP per capita. The World Bank reports that legal fees to register a business amount to 1.4% of per capita income in the US in the year 2011. Fourth, Ebell and Haefke (2009) compute a composite measure of entry costs in the US in 1997 equal to 0.59 months of output. This measure combines information on entry fees as well as entry delays (number of business days needed to fulfill entry requirements, weighted by the number of procedures) which are

price adjustment schemes, and to interpret the Rotemberg cost in price duration terms. Strictly speaking, however, we cannot compute an average price contract duration in our model, as this requires a constant population of price setters.

converted into lost output.

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 $\varepsilon = 6.1$ in our baseline estimation, which implies that price markups are 20% on average. While this estimate accords well with the results reported in many micro studies of average markups (e.g., Oliveira Martins and Scarpetta, 1999, and Christopoulou and Vermeulen, 2008), 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 $\eta = 0.17$. Hence, desired markups fall by 0.17% in response to a 1% increase in the number of firms. Cecioni (2010) uses single-equation techniques to estimate the New Keynesian Phillips Curve (8). She finds a value 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 value above unity given the lower bound on the demand elasticity, $\varepsilon \geq 1$. While our estimate of η is statistically significant, we investigate below if this effect is also economically important in driving inflation. Using the calibrated parameters and the posterior mean of ε, we can compute the steady state number of firms. Given the relation between the demand elasticity ε and the number of firms N in (1), we derive the price-elasticity of the spending share $\gamma = 0.61$. Thus, in response to a 1% price increase for an individual variety, the spending share drops by 0.61%.

4 Effect of Entry on Markups and Inflation

This section analyzes markup and inflation dynamics in the presence of endogenous entry as predicted by the model. First, we highlight how the competition effect works conditional on a specific expansionary shock. Second, we examine the unconditional properties of the model-implied markup, in particular its cyclicality. Third, we examine in greater detail the sources of US inflation dynamics based on a historical decomposition.

4.1 Transmission Channels

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 and firm value through (6) and (12), respectively. The fall in entry costs and the rise in firm value lead to entry (13) and a gradual decline in desired markups via the competition effect (2). Consequently, in response to 'standard' supply shocks, the competition effect mitigates the procyclical impact of price stickiness on markups. After approximately 6 to 8 quarters, the competition effect dominates and actual markups fall.

[insert Figure 1a here]

An exogenous decrease in entry costs directly raises entry through (13). This leads to an eventual decrease in the desired markup through the competition effect, see (2). Initially, there is a reallocation of production factors from the manufacturing sector to new startups, implying a decrease in GDP on impact. However, 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, actual markups decrease. Actual markups decline by more than desired markups. Therefore, inflation rises through the New Keynesian Phillips Curve (7).

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. The monetary tightening in reaction to expansionary demand shocks implies an increase in the real interest rate, which in turn lowers firm value through (12). This effect leads to a fall in entry through (13) and puts upward pressures on desired markups via the competition effect (2). The dominant effect on markups, however, stems 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]

The model predicts that aggregate profits decrease following an expansionary **monetary policy shock** (displayed in the upper panel of Figure 1c).[14] Despite the decrease in profits, entry rises. 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 entails 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).[15] On balance, therefore, entry expands and the desired markup falls through (2). As a result, the competition effect augments the countercyclical effect of price stickiness on markups in the case of monetary policy shocks.

Finally, the bottom panel in Figure 1c shows the effects of an expansionary **price markup shock** (a decrease in $\hat{\zeta}_t^P$), which lowers inflation through the New Keynesian Phillips Curve (7) and boosts demand. The ensuing boom drives up marginal costs; because of price stickiness, actual markups fall. Aggregate profits and entry decrease.

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 price markup eventually lead to countercyclical entry.

[14] An expansionary monetary policy shock engenders two opposing effects on profits. A decline in the interest rate leads to an increase in marginal costs and, given that prices do not adjust fully, to a decrease in actual markups $\hat{\mu}_t$. This first effect depresses profits. However, a decline in the interest rate also has expansionary effects on aggregate demand $\hat{Y}_t^C$, which raises profits. In accordance with Bilbiie, Ghironi and Melitz (2007), our estimates imply that the first effect dominates, such that profits decrease on net.

[15] This is in contrast with Bilbiie, Ghironi and Melitz (2007), where entry costs are very responsive to shocks due to full wage flexibility. In that model, entry drops after a monetary policy expansion.

4.2 The Cyclicality of the Markup

Here we study the unconditional cyclicality of the markup implied by the model. There are three reasons for the markup to vary. These are the effect of entry on desired markups (i.e., the competition effect), sticky prices, and exogenous price markup shocks. We conduct 300 stochastic simulations based on random draws from the posterior distribution and back out, for each of these simulations, first, the model-implied markup $\hat{\mu}_t$, second, the component driven by sticky prices and markup shocks $\hat{\mu}_t^{noE}$ (i.e., the counterfactual markup series obtained in the absence of entry), and, third, the 'sticky-price' component $\hat{\mu}_t^{SP}$. To compute $\hat{\mu}_t^{noE}$ we shut off firm entry and exit dynamics in the stochastic simulation by assuming a large entry adjustment cost parameter φ_N.[16] We then simulate the model using our benchmark parameter estimates, that is, without re-estimation. Finally, to compute the sticky-price component, we again assume $\varphi_N \gg 0$ and perform the stochastic simulation, excluding the price markup shock ($\hat{\zeta}_t^P = 0$). The resulting markup series, denoted $\hat{\mu}_t^{SP}$, reflects variations in the *model-implied* markup under constant *desired* markups.

Similar to Bilbiie, Ghironi and Melitz (2012), we then compute for each of the model simulations the correlation of the three 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 the mean and the 5th and 95th percentile correlations $corr(\hat{Y}_{t+s}^R, \hat{\mu}_t)$, $corr(\hat{Y}_{t+s}^R, \hat{\mu}_t^{noE})$ and $corr(\hat{Y}_{t+s}^R, \hat{\mu}_t^{SP})$ for $s = -5, -4, \ldots, 0, \ldots, 5$.

[insert Figure 2 here]

The model-implied markup is countercyclical at all leads and lags. If we switch off firm entry and the competition effect, the correlation between the markup and output rises; the contemporaneous correlation $corr(\hat{Y}_t^R, \hat{\mu}_t^{noE})$ is not significantly different from zero. If, in addition, we eliminate price markup shocks, the cyclicality turns positive: the sticky-price component is significantly procyclical. Thus, it is the combination of the competition effect and price markup shocks that reverses the sign of the markup-output correlation. Recall from

[16] The no-entry model is obtained as the limiting case of our benchmark model for an arbitrarily large entry cost parameter φ_N.

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.[17]

[insert Figure 3 here]

Long run output variability is explained almost entirely by two supply shocks: wage markup shocks and TFP shocks (each approximately 45%). In the short run, the sources of output fluctuations are more mixed: government spending shocks and TFP each account for around one fifth, investment-specific technology for one third. The variation in the markup is mainly accounted for by a combination of TFP and price markup shocks (each 30% in the long run); entry cost shocks and wage markup shocks each explain about 15% of markup fluctuations. To conclude, we find a major role for supply-type shocks in driving output and markup fluctuations. Since, through the competition effect, supply shocks are a source of markup countercyclicality, the model-implied correlation between markups and output is negative overall.

4.3 A Historical Decomposition of US Inflation

Within standard DGSE models, inflation fluctuations are mainly accounted for by cost-push shocks that capture exogenous variations in desired markups. Such shocks pose a challenge for central banks since they create a tradeoff for monetary policy between inflation and output stabilization. Policy makers want to understand the underlying causes of desired markup fluctuations. The competition effect we investigate in this paper is one such possible driving source. Therefore, in this section we aim the gauge the importance of this transmission channel for hirtherto unexplained inflation fluctuations.

[17] Most of the variability in entry is explained by its own shock $\hat{\eta}_t^E$. More detailed results are available from the authors upon request.

In the following, we perform a historical decomposition of US inflation. More specifically, we decompose US inflation into a sticky-price component plus two components reflecting endogenous and exogenous variations in the desired markup. The approach is similar to the markup decomposition of Section 4.2. We filter out the contribution of exogenous desired markup shocks to inflation. To this end, we feed the price markup shock series $\hat{\zeta}_t^P$ 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. Then, we feed the shocks into the model, excluding entry dynamics by assuming a large entry cost φ_N and setting the price markup shock to zero, $\hat{\zeta}_t^P = 0$. The resulting inflation path is what we call 'sticky-price inflation', determined through the modified New Keynesian Phillips Curve,

$$\hat{\pi}_{p,t}^{SP} - \lambda_p \hat{\pi}_{p,t-1}^{SP} = \frac{\varepsilon - 1}{\kappa_p} (-\hat{\mu}_t^{SP}) + \beta (1 - \delta_N) E_t \{ \hat{\pi}_{p,t+1}^{SP} - \lambda_p \hat{\pi}_{p,t}^{SP} \}. \tag{18}$$

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

$$\hat{\pi}_{p,t}^E = \hat{\pi}_{p,t} - \hat{\pi}_{p,t}^{SP} - \hat{\pi}_{p,t}^P. \tag{19}$$

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

[insert Figure 4a here]

Compared with the sticky-price component and the exogenous component, the competition effect plays a smaller, but nevertheless noticeable role in driving US inflation. In the late 1960s and between 1985 and 1995, inflation was reduced through the competition effect. A no-entry model would attribute this endogenous component of inflation to negative cost-push shocks. From the mid 1970s to the mid '80s, inflation rose as a result of changes in competition. An econometrician using a model without endogenous entry would in this case identify positive cost-push shocks to inflation.

As a robustness check, we estimated the model for the period 1993q2-2007q4 where entry $N_{E,t}$ is measured as the number of establishment births, see Section 5. Our previous finding is confirmed in the later sample: the competition effect is less important than the other two driving forces.

[insert Figure 4b here]

Figure 4b shows that, prior to 1997, changes in competition exerted a small positive effect on inflation. Between 1997 and 2002, and again from 2004 until 2007, the competition effect dampened inflation by as much as 0.1% on a quarterly basis. This endogenous negative cost-push shock helped to reduce the need for monetary policy tightening by the central bank in order to contain inflationary pressures.

5 Sensitivity Analysis

This section subjects our estimate of the demand elasticity ε to a thorough sensitivity analysis. In a first set of exercises, we investigate two alternative model specifications and compare their performance with the baseline specification in terms of marginal data densities. First, we estimate a flexible-price version of the model. Second, we consider the asymmetric production structure favored by Bilbiie, Ghironi and Melitz (2012), where new firms are set up using labor services only.

In a second set of exercises, we use alternative or additional data series in estimating our baseline model. First, we replace the GDP deflator with the producer price index (PPI) in our estimation. Second, we treat profits as an additional observable variable and extend the model by adding a white-noise measurement error to the profit function (6). Third, we introduce the inverse labor share as a measure of the price markup in the list of observables and add a measurement error to this additional observable in the model.

A final set of exercises considers different mappings between entry in the model and business formation in the data.

[insert Tables 3a to 3c here]

The results of these robustness exercises are displayed in Tables 3a to 3c. We discuss them in turn.

5.1 Alternative Model Specifications

Flexible-Price Model To begin with, consider the parameter estimates of the flexible-price model variant in column 'Flex-Price' of Table 3a. The estimation procedure imposes a negligible value for the price adjustment cost parameter, more specifically $\kappa_p = 0.01$. Because of this low calibrated value of κ_p, we no longer rescale the desired markup shock in the NKPC (8) by the factor $\frac{\varepsilon-1}{\kappa_p}$; i.e., in this alternative model specification we have $\hat{\zeta}_t^P = \hat{\zeta}_t^U$. Several estimates change significantly relative to the baseline results. Some of the empirically observed inflation fluctuations are now picked up by exogenous factors. When we take into account the differences in the scaling of the shock $\hat{\zeta}_t^P$ between the current robustness check and the baseline case, the innovation of the price markup shock rises significantly. Additionally, the price markup shock displays a lower moving average coefficient. The demand elasticity ε rises to 9, which reduces the competition effect η to 0.11. This result is somewhat surprising, since a reduction in κ_p is expected to lower ε to keep the slope of the NKPC unchanged. The absence of persistence through price indexation appears to be compensated to some degree by a higher wage indexation parameter, $\lambda_w = 0.82$.

[insert Figure 5 here]

In Figure 5, we redo the exercise evaluating the role of the competition effect in shaping markup cyclicality for the case of flexible prices. We notice that, similar to the sticky-price model, the competition effect in the flex-price model induces countercyclical markup variations. Moreover, relative to the baseline model, the countercyclicality of price markups is higher under flexible prices. We may interpret this finding as implying that price rigidity is redundant in producing countercyclical markup variations. However, importantly, the Bayes-factor analysis comparing the marginal data densities of the baseline and perturbed models indicates that the sticky-price model is superior to the flex-price model (see bottom of

Table 3a); specifically, the Bayes factor between these two model variants approaches infinity. The better performance of the baseline model can be seen from the reduced importance of the price markup shock in capturing inflation dynamics.

Asymmetric Sectors As a second 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 (5), the parameter α_E is set to zero. Bilbiie, Ghironi and Melitz (2012) remove capital from the production of new firms because their model has a unique non-explosive solution only for very high rates of capital depreciation.[18] We circumvent this problem by introducing adjustment costs in both intensive and extensive margin investment.[19] The last column of Table 3a 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.[20] Comparing the log marginal data densities, the model variant with asymmetric production structures does worse than the baseline model but better than the flexible-price model. See bottom of Table 3a.

5.2 Alternative and Additional Data Series

Producer Price Inflation Next, we re-estimate the baseline model, replacing the GDP deflator with the producer price index (PPI) as our price index measure. The idea here is that the PPI corresponds more closely to the index p_t in the model, which does not take variety effects on consumption utility into account. Quarterly data for the PPI of finished

[18] See the working paper version of Bilbiie, Ghironi and Melitz (2012).

[19] The model solution is indeterminate if the adjustment of *both* intensive and extensive margin investment is costless. Assuming adjustment costs along one of the two margins restores determinacy.

[20] 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).

goods are obtained from the BLS. The results are shown in Table 3b in the column entitled 'PPI'. The greater volatility of the PPI series in comparison to the GDP deflator shows up in several places. First and foremost, the greater data volatility is reflected in an increased price markup shock innovation σ_p, which more than doubles. The TFP innovation also increases. The persistence-inducing frictions lose importance, as evidenced by a decrease in price and wage indexation, consumption habits, and capacity utilization costs. The price adjustment cost parameter falls significantly, while demand becomes more elastic, ε rises to 8.6. As a consequence, the slope of the NKPC rises, reflecting a lower overall rigidity in price setting. The competition effect decreases somewhat to $\eta = 0.12$.

Using Profit Data in Estimation In a fourth 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 $\hat{\zeta}_t^D$ with mean zero and standard deviation σ_D in the measurement equation of firm profits, such that (6) becomes

$$\hat{D}_t^R = (\varepsilon - 1)\,\hat{\mu}_t + \hat{Y}_t^C - \hat{\rho}_t + \hat{\varepsilon}_t^D. \tag{20}$$

Quarterly data for corporate profits after taxes are taken from the NIPA tables. The parameter estimates are summarized in column 'Profits' of Table 3b. The mean demand elasticity increases to about $\varepsilon = 8.6$ when we include profits, which lowers the competition effect of entry.[21] 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 (6). 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.

[21] The value $\varepsilon = 8.6$ lies in the upper tail of the prior distribution. The cumulative probability at this value equals 0.999. Therefore, our prior distribution might be too restrictive relative to the information contained 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 and standard deviation 2.5. In this case, ε increases to 9.14, which lies within the 92% confidence interval of the prior distribution.

Using Markup Measure in Estimation The behavior of the markup is crucial for the findings of this paper. Critics may argue that one should include a markup proxy as an observable in the estimation exercise. To respond to this (justified) criticism, we add the least controversial measure of the markup, namely the inverse labor share, to the list of observables $\mathbf{Y}_t$. Again, we also need to add a measurement error so as to have an equal number of shocks and observables. Specifically, we include an iid normal error term $\hat{\zeta}_t^{\mu}$ in the measurement equation for price markups $\hat{\mu}$, such that the observable markup $\hat{\mu}^{obs}$ reads

$$\hat{\mu}^{obs} = \hat{\mu} + \hat{\zeta}_t^{\mu}. \tag{21}$$

The results can be found in the last column of Table 3b under the heading 'Markup'. None of the parameter estimates changes significantly when we include a markup measure in the estimation.

5.3 Mapping between Model and Data

Finally, we investigate whether the mapping of entry in the model and business formation in the data is important. We do this in order to address the concern that our net business formation index is a measure of *net* entry, while the model variable $N_{E,t}$ corresponds to *gross* entry.

Net Entry First, we match net business formation in the data with net entry in the model, which we define as $N_{NE,t}$. Net entry equals entry $N_{E,t}$ minus exit $\delta(N_t + N_{E,t})$. Net entry in steady state is zero. Therefore, we express net entry in deviations from the steady state number of entrants,

$$\hat{N}_{NE,t} = (1 - \delta)\,(\hat{N}_{E,t} - \hat{N}_t). \tag{22}$$

The estimation results are not strongly affected by this alternative mapping, see Table 3c, column 'Net Entry'. This is not surprising since exit is exogenous in the model.

New Incorporations Second, we match $N_{E,t}$ in the model with the number of 'New Incorporations', a data series provided by the BEA's Survey of Current Business together with net business formation. The sample period is almost the same as in the baseline estimation. We do not observe a large impact on estimation results (Table 3c, column 'NI') other than a drop in the entry adjustment cost parameter φ_N.

Establishment Births Third, we use an alternative measure of firm entry based on establishment data. The column 'Births' shows the estimation results when $N_{E,t}$ is measured as 'Establishment Births'. Data are obtained from the BLS and span the period 1993q2-2007q4. Also here, the entry adjustment cost drops significantly. In addition, the monetary policy response to output and the properties of some of the shock processes are changed. Importantly, the estimates of the key parameters of interest, ε and η, do not change significantly when we use establishment entry instead of firm entry.

In sum, our estimates of the demand elasticity and the competition effect are robust to alternative ways of mapping entry in the model to the data.

6 Conclusion

This paper analyzes the empirical importance of changes in market structure and competition for business cycle dynamics in the US. We allow for 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 entry on markups and inflation is shock-dependent. In the case of supply shocks and monetary policy shocks, entry is procyclical, which 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 markup shocks and changes in desired markups due to entry. In a counterfactual exercise where sticky prices are the only source of markup variations, the model-implied markup is, in contrast, procyclical. Second, our parameter estimates indicate that a one percent increase in the number of firms and goods decreases desired markups by

0.17 percent. While a substantial part of US inflation is driven by a combination of sticky prices and exogenous markup shocks, the contribution of the competition effect to inflation fluctuations is non-negligible. An interesting question for future research is to what extent the observed interest rate path was consistent with the optimal monetary policy prescription.

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Table 1: Exogenous Shock Processes

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

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 Model

ESTIMATED STRUCTURAL PARAMETERS — Posterior

Symbol	Description	Prior (P1,P2)	Mode	Mean [5th; 95th %ile]
b	Consumption habit	B (0.70, 0.10)	0.69	0.70 [0.64; 0.76]
σ_c	Consumption utility	N (1.5, 0.375)	1.58	1.46 [0.97; 1.92]
σ_l	Consumption labor	N (2.00, 0.75)	1.95	1.86 [0.89; 2.84]
φ_K	Investment adj. cost	N (4.00, 1.50)	8.55	8.71 [6.63; 10.82]
φ_N	Entry adj. cost	N (4.00, 1.50)	2.14	2.42 [1.70; 3.13]
$\tilde{\sigma}_a$	Capacity util. cost	B (0.50, 0.15)	0.73	0.73 [0.59; 0.88]
λ_p	Indexation prices	B (0.50, 0.15)	0.38	0.43 [0.23; 0.63]
κ_p	Price rigidity	G (50.0, 7.50)	51.84	62.01 [49.98; 74.18]
λ_w	Indexation wages	B (0.50, 0.15)	0.52	0.51 [0.32; 0.69]
κ_w	Wage rigidity	G (50.0, 7.50)	53.92	56.99 [44.61; 69.28]
$\boldsymbol{\varepsilon}$	**Demand elasticity**	**N (4.00, 1.50)**	**5.47**	**6.09 [4.76; 7.37]**
$\boldsymbol{\eta}$	**Competition effect**		**0.16**	**0.17 [0.13; 0.21]**
τ_R	Interest smoothing	B (0.75, 0.10)	0.73	0.73 [0.69; 0.78]
τ_π	Policy inflation	G (1.50, 0.25)	1.45	1.49 [1.32; 1.66]
τ_y	Policy output	G (0.50, 0.25)	0.01	0.01 [0.003; 0.02]
τ_{dy}	Policy lagged output	G (0.50, 0.25)	0.11	0.11 [0.08; 0.14]

CALIBRATED STRUCTURAL PARAMETERS

Symbol	Description	Value
β	Discount factor	0.99
α	Capital share in production	0.24
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

SHOCKS AR(1), MA(1) — Posterior

Symbol	Prior (P1,P2)	Mode	Mean [5th; 95th %ile]
ρ_Z	B (0.50, 0.15)	0.98	0.98 [0.97;0.99]
ρ_T	B (0.50, 0.15)	0.15	0.18 [0.08; 0.28]
ρ_I	B (0.50, 0.15)	0.43	0.42 [0.33; 0.52]
ρ_G	B (0.50, 0.15)	0.90	0.90 [0.87; 0.92]
ρ_P	B (0.50, 0.15)	0.79	0.77 [0.69; 0.85]
ρ_W	B (0.50, 0.15)	0.97	0.95 [0.89; 0.99]
ρ_R	B (0.50, 0.15)	0.16	0.17 [0.08; 0.25]
ρ_E	B (0.50, 0.15)	0.85	0.85 [0.81; 0.89]
ρ_{GZ}	B (0.50, 0.15)	0.78	0.75 [0.58; 0.91]
μ_w	B (0.50, 0.15)	0.59	0.58 [0.44; 0.73]
μ_p	B (0.50, 0.15)	0.52	0.49 [0.33; 0.65]

SHOCK INNOVATIONS

Symbol	Prior (P1,P2)	Mode	Mean [5th; 95th %ile]
σ_Z	IG (0.10, 2)	0.82	0.83 [0.74; 0.91]
σ_T	IG (0.10, 2)	0.27	0.27 [0.23; 0.31]
σ_I	IG (0.10, 2)	1.36	1.39 [1.14; 1.64]
σ_G	IG (0.10, 2)	3.13	3.15 [2.81; 3.48]
σ_P	IG (0.10, 2)	0.25	0.26 [0.20; 0.33]
σ_W	IG (0.10, 2)	0.43	0.43 [0.36; 0.50]
σ_R	IG (0.10, 2)	0.25	0.25 [0.23; 0.28]
σ_E	IG (0.10, 2)	3.19	3.37 [2.83; 3.90]

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 576,000 draws from the distribution simulated by the Random Walk Metropolis Hastings algorithm.

Table 3a: Sensitivity Analysis

Symbol	Description	PRIOR (P1,P2)	POSTERIOR DISTRIBUTION: Mean [5th; 95th %ile] Baseline	Flex-Price	Asym-PF
STRUCTURAL PARAMETERS					
b	Consumption habit	B (0.70, 0.10)	0.70 [0.64; 0.76]	0.68 [0.60; 0.77]	0.68 [0.62; 0.74]
σ_c	Consumption utility	N (1.5, 0.375)	1.46 [0.97; 1.92]	1.35 [0.82; 1.85]	1.98 [1.59; 2.35]
σ_l	Consumption labor	N (2.00, 0.75)	1.86 [0.89; 2.84]	2.34 [1.23; 3.40]	2.59 [1.66; 3.50]
φ_K	Investment adj. cost	N (4.00, 1.50)	8.71 [6.63; 10.82]	8.52 [6.33; 10.78]	7.70 [5.75; 9.59]
φ_N	Entry adj. cost	N (4.00, 1.50)	2.42 [1.70; 3.13]	3.69 [2.70; 4.62]	1.52 [1.18; 1.86]
$\tilde{\sigma}_a$	Capacity util. cost	B (0.50, 0.15)	0.73 [0.59; 0.88]	0.88 [0.81; 0.96]	0.88 [0.81; 0.96]
λ_p	Indexation prices	B (0.50, 0.15) 0	0.43 [0.23; 0.63]	 0	0.89 [0.82; 0.96]
κ_p	Price rigidity	G (50.0, 7.50) 0.01	62.01 [49.98; 74.18]	 0.01	69.60 [56.1; 82.3]
λ_w	Indexation wages	B (0.50, 0.15)	0.51 [0.32; 0.69]	0.82 [0.70; 0.94]	0.61 [0.43; 0.79]
κ_w	Wage rigidity	G (50.0, 7.50)	56.99 [44.61; 69.28]	49.60 [37.4; 61.4]	58.03 [45.8; 69.9]
$\boldsymbol{\varepsilon}$	**Demand elasticity**	**N (4.00, 1.50)**	**6.09 [4.76; 7.37]**	**9.06 [7.40; 10.66]**	**9.08 [7.71; 10.46]**
$\boldsymbol{\eta}$	**Competition effect**		**0.17 [0.13; 0.21]**	**0.11 [0.09; 0.13]**	**0.11 [0.10; 0.13]**
τ_R	Interest smoothing	B (0.75, 0.10)	0.73 [0.69; 0.78]	0.73 [0.68; 0.78]	0.77 [0.73; 0.80]
τ_π	Policy inflation	G (1.50, 0.25)	1.49 [1.32; 1.66]	1.50 [1.31; 1.68]	1.43 [1.28; 1.57]
τ_y	Policy output	G (0.50, 0.25)	0.01 [0.003; 0.02]	0.02 [0.01; 0.03]	0.06 [0.04; 0.08]
τ_{dy}	Policy lagged output	G (0.50, 0.25) 0	0.11 [0.08; 0.14]	 0	0.14 [0.10; 0.17]
AR(1), MA(1)					
ρ_Z	TFP	B (0.50, 0.15)	0.98 [0.97;0.99]	0.98 [0.98;0.99]	0.98 [0.98;0.99]
ρ_T	Time Preference	B (0.50, 0.15)	0.18 [0.08; 0.28]	0.24 [0.11; 0.36]	0.18 [0.08; 0.28]
ρ_I	Inv. Spec. Tech.	B (0.50, 0.15)	0.42 [0.33; 0.52]	0.47 [0.37; 0.58]	0.48 [0.40; 0.57]
ρ_G	Gov. Spending	B (0.50, 0.15)	0.90 [0.87; 0.92]	0.89 [0.86; 0.92]	0.89 [0.86; 0.92]
ρ_P	Price Markup AR(1)	B (0.50, 0.15)	0.77 [0.69; 0.85]	0.83 [0.78; 0.87]	0.54 [0.44; 0.65]
ρ_W	Wage Markup AR(1)	B (0.50, 0.15)	0.95 [0.89; 0.99]	0.94 [0.86; 0.99]	0.99 [0.98; 0.99]
ρ_R	Monetary Policy	B (0.50, 0.15)	0.17 [0.08; 0.25]	0.20 [0.11; 0.29]	0.09 [0.04; 0.15]
ρ_E	Entry Cost	B (0.50, 0.15)	0.85 [0.81; 0.89]	0.86 [0.83; 0.90]	0.84 [0.81; 0.87]
ρ_{GZ}	Corr. TFP – Gov.	B (0.50, 0.15)	0.75 [0.58; 0.91]	0.78 [0.64; 0.93]	0.79 [0.66; 0.93]
μ_w	Wage Markup MA(1)	B (0.50, 0.15)	0.58 [0.44; 0.73]	0.57 [0.43; 0.70]	0.52 [0.36; 0.68]
μ_p	Price Markup MA(1)	B (0.50, 0.15)	0.49 [0.33; 0.65]	0.12 [0.05; 0.19]	0.33 [0.18; 0.48]
INNOVATIONS					
σ_Z	TFP	IG (0.10, 2)	0.83 [0.74; 0.91]	0.80 [0.73; 0.88]	0.94 [0.84; 1.03]
σ_T	Time Preference	IG (0.10, 2)	0.27 [0.23; 0.31]	0.27 [0.22; 0.31]	0.29 [0.25; 0.33]
σ_I	Inv. Spec. Tech.	IG (0.10, 2)	1.39 [1.14; 1.64]	1.18 [0.97; 1.40]	1.17 [0.98; 1.37]
σ_G	Gov. Spending	IG (0.10, 2)	3.15 [2.81; 3.48]	2.91 [2.62; 3.19]	2.84 [2.57; 3.12]
σ_P	Price Markup	IG (0.10, 2)	0.26 [0.20; 0.33]	0.77 [0.70; 0.85]	0.51 [0.44; 0.59]
σ_W	Wage Markup	IG (0.10, 2)	0.43 [0.36; 0.50]	0.49 [0.41; 0.56]	0.42 [0.35; 0.49]
σ_R	Monetary Policy	IG (0.10, 2)	0.25 [0.23; 0.28]	0.26 [0.23; 0.28]	0.25 [0.23; 0.28]
σ_E	Entry Cost	IG (0.10, 2)	3.37 [2.83; 3.90]	4.06 [3.38; 4.70]	3.03 [2.59; 3.44]
MODEL COMPARISON					
Log Marginal Data Density			-1449.744953	-1598.083439	-1524.803954
Bayes Factor	$p(y/M_{Base}) / p(y/M_{Flex,Asym-PF})$		1	2.6460×10^{64}	3.9601×10^{32}

Note: ‘Flex-Price’ indicates the model variant with flexible prices. ‘Asym-PF’ features 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 576,000 draws from the distribution simulated by the Random Walk Metropolis Hastings algorithm.

Table 3b: Sensitivity Analysis (continued)

		PRIOR	POSTERIOR DISTRIBUTION: Mean [5th; 95th %ile]			
Symbol	Description	(P1,P2)	Baseline	PPI	Profits	Markup
STRUCTURAL PARAMETERS						
b	Consumption habit	B (0.70, 0.10)	0.70 [0.64; 0.76]	0.56 [0.48; 0.63]	0.71 [0.64; 0.78]	0.70 [0.64; 0.77]
σ_c	Consumption utility	N (1.5, 0.375)	1.46 [0.97; 1.92]	1.56 [1.23; 1.90]	1.37 [0.90; 1.85]	1.44 [0.94; 1.93]
σ_l	Consumption labor	N (2.00, 0.75)	1.86 [0.89; 2.84]	1.73 [0.81; 2.65]	1.74 [0.74; 2.69]	1.85 [0.86; 3.80]
φ_K	Investment adj. cost	N (4.00, 1.50)	8.71 [6.63; 10.82]	7.32 [5.35; 9.28]	8.64 [6.48; 10.73]	8.73 [6.56; 10.79]
φ_N	Entry adj. cost	N (4.00, 1.50)	2.42 [1.70; 3.13]	2.93 [2.12; 3.75]	3.21 [2.42; 4.00]	2.79 [1.98; 3.56]
$\tilde{\sigma}_a$	Capacity util. cost	B (0.50, 0.15)	0.73 [0.59; 0.88]	0.38 [0.22; 0.54]	0.74 [0.61; 0.88]	0.75 [0.62; 0.89]
λ_p	Indexation prices	B (0.50, 0.15)	0.43 [0.23; 0.63]	0.17 [0.06; 0.27]	0.49 [0.27; 0.70]	0.46 [0.25; 0.67]
κ_p	Price rigidity	G (50.0, 7.50)	62.01 [50.0; 74.1]	36.36 [27.0; 45.2]	65.55 [52.7; 77.9]	63.34 [50.8; 75.3]
λ_w	Indexation wages	B (0.50, 0.15)	0.51 [0.32; 0.69]	0.22 [0.12; 0.32]	0.53 [0.35; 0.72]	0.53 [0.34; 0.71]
κ_w	Wage rigidity	G (50.0, 7.50)	56.99 [44.6; 69.3]	59.57 [46.5; 72.0]	56.99 [44.1; 69.3]	57.04 [44.6; 69.4]
$\boldsymbol{\varepsilon}$	**Demand elasticity**	**N (4.00, 1.50)**	**6.09 [4.76; 7.37]**	**8.59 [6.77; 10.45]**	**8.57 [7.62; 9.51]**	**7.20 [5.83; 8.56]**
$\boldsymbol{\eta}$	**Competition effect**		**0.17 [0.13; 0.21]**	**0.12 [0.09; 0.15]**	**0.12 [0.10; 0.13]**	**0.14 [0.12; 0.17]**
τ_R	Interest smoothing	B (0.75, 0.10)	0.73 [0.69; 0.78]	0.80 [0.77; 0.84]	0.74 [0.69; 0.78]	0.74 [0.69; 0.78]
τ_π	Policy inflation	G (1.50, 0.25)	1.49 [1.32; 1.66]	1.53 [1.30; 1.75]	1.53 [1.35; 1.72]	1.52 [1.34; 1.70]
τ_y	Policy output	G (0.50, 0.25)	0.01 [0.003; 0.02]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]
τ_{dy}	Policy lagged output	G (0.50, 0.25)	0.11 [0.08; 0.14]	0.18 [0.15; 0.21]	0.11 [0.08; 0.14]	0.11 [0.08; 0.14]
AR(1), MA(1)						
ρ_Z	TFP	B (0.50, 0.15)	0.98 [0.97;0.99]	0.98 [0.98; 0.99]	0.98 [0.98;0.99]	0.98 [0.98;0.99]
ρ_T	Time Preference	B (0.50, 0.15)	0.18 [0.08; 0.28]	0.30 [0.17; 0.43]	0.18 [0.08; 0.28]	0.18 [0.07; 0.27]
ρ_I	Inv. Spec. Tech.	B (0.50, 0.15)	0.42 [0.33; 0.52]	0.42 [0.32; 0.51]	0.45 [0.36; 0.54]	0.43 [0.34; 0.52]
ρ_G	Gov. Spending	B (0.50, 0.15)	0.90 [0.87; 0.92]	0.89 [0.86; 0.92]	0.89 [0.86; 0.92]	0.90 [0.87; 0.92]
ρ_P	Price Markup AR(1)	B (0.50, 0.15)	0.77 [0.69; 0.85]	0.73 [0.65; 0.81]	0.75 [0.67; 0.83]	0.76 [0.68; 0.84]
ρ_W	Wage Markup AR(1)	B (0.50, 0.15)	0.95 [0.89; 0.99]	0.98 [0.97; 0.99]	0.93 [0.85; 0.99]	0.94 [0.86; 0.99]
ρ_R	Monetary Policy	B (0.50, 0.15)	0.17 [0.08; 0.25]	0.10 [0.04; 0.15]	0.18 [0.09; 0.27]	0.17 [0.08; 0.26]
ρ_E	Entry Cost	B (0.50, 0.15)	0.85 [0.81; 0.89]	0.87 [0.84; 0.91]	0.86 [0.82; 0.89]	0.85 [0.82; 0.89]
ρ_{GZ}	Corr. TFP – Gov.	B (0.50, 0.15)	0.75 [0.58; 0.91]	0.76 [0.61; 0.91]	0.76 [0.61; 0.92]	0.76 [0.61; 0.92]
μ_w	Wage Markup MA(1)	B (0.50, 0.15)	0.58 [0.44; 0.73]	0.64 [0.51; 0.78]	0.60 [0.46; 0.74]	0.59 [0.45; 0.73]
μ_p	Price Markup MA(1)	B (0.50, 0.15)	0.49 [0.33; 0.65]	0.37 [0.20; 0.54]	0.45 [0.29; 0.61]	0.46 [0.30; 0.62]
INNOVATIONS						
σ_Z	TFP	IG (0.10, 2)	0.83 [0.74; 0.91]	1.10 [0.99; 1.21]	0.79 [0.72; 0.87]	0.81 [0.73; 0.89]
σ_T	Time Preference	IG (0.10, 2)	0.27 [0.23; 0.31]	0.30 [0.24; 0.36]	0.28 [0.24; 0.31]	0.27 [0.23; 0.31]
σ_I	Inv. Spec. Tech.	IG (0.10, 2)	1.39 [1.14; 1.64]	1.25 [1.01; 1.48]	1.21 [1.00; 1.42]	1.31 [1.06; 1.54]
σ_G	Gov. Spending	IG (0.10, 2)	3.15 [2.81; 3.48]	2.97 [2.66; 3.27]	2.94 [2.66; 3.22]	3.03 [2.72; 3.34]
σ_P	Price Markup	IG (0.10, 2)	0.26 [0.20; 0.33]	0.62 [0.51; 0.72]	0.30 [0.23; 0.36]	0.28 [0.21; 0.34]
σ_W	Wage Markup	IG (0.10, 2)	0.43 [0.36; 0.50]	0.42 [0.34; 0.49]	0.43 [0.36; 0.50]	0.43 [0.36; 0.50]
σ_R	Monetary Policy	IG (0.10, 2)	0.25 [0.23; 0.28]	0.26 [0.23; 0.28]	0.25 [0.22; 0.28]	0.25 [0.23; 0.28]
σ_E	Entry Cost	IG (0.10, 2)	3.37 [2.83; 3.90]	3.61 [2.99; 4.18]	3.82 [3.24; 4.40]	3.57 [3.01; 4.13]
σ_D	Profit Meas. Error	IG (0.10, 2)			12.43 [11.2; 13.6]	
σ_μ	Markup Meas. Error	IG (0.10, 2)				2.07 [1.87; 2.26]

Note: 'PPI' estimates the model using producer price index as alternative to GDP deflator. 'Profits' uses profit data in the estimation and introduces a measurement error in (6). 'Markup' denotes the use of the inverse labor share as a markup measure and introduces a measurement error to price markups. 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 576,000 draws from the distribution simulated by the Random Walk Metropolis Hastings algorithm.

Table 3c: Sensitivity Analysis (continued)

Symbol	Description	PRIOR (P1,P2)	POSTERIOR DISTRIBUTION: Mean [5th; 95th %ile] Baseline	Net Entry	NI	Births
STRUCTURAL PARAMETERS						
b	Consumption habit	B (0.70, 0.10)	0.70 [0.64; 0.76]	0.71 [0.65; 0.76]	0.73 [0.67; 0.78]	0.63 [0.49; 0.78]
σ_c	Consumption utility	N (1.5, 0.375)	1.46 [0.97; 1.92]	1.45 [1.00; 1.87]	1.57 [1.05; 1.87]	1.76 [1.31; 2.22]
σ_l	Consumption labor	N (2.00, 0.75)	1.86 [0.89; 2.84]	1.85 [0.92; 2.75]	2.05 [1.10; 2.97]	2.40 [1.26; 3.51]
φ_K	Investment adj. cost	N (4.00, 1.50)	8.71 [6.63; 10.82]	8.81 [6.80; 10.81]	7.35 [5.43; 9.30]	4.83 [2.69; 6.98]
φ_N	Entry adj. cost	N (4.00, 1.50)	2.42 [1.70; 3.13]	2.28 [1.62; 2.93]	0.89 [0.69; 1.08]	0.52 [0.40; 0.65]
$\tilde{\sigma}_a$	Capacity util. cost	B (0.50, 0.15)	0.73 [0.59; 0.88]	0.76 [0.63; 0.90]	0.69 [0.54; 0.85]	0.68 [0.50; 0.86]
λ_p	Indexation prices	B (0.50, 0.15)	0.43 [0.23; 0.63]	0.41 [0.21; 0.60]	0.26 [0.18; 0.54]	0.36 [0.15; 0.57]
κ_p	Price rigidity	G (50.0, 7.50)	62.01 [50.0; 74.1]	61.78 [50.0; 73.9]	62.52 [50.6; 74.4]	63.71 [50.5; 76.2]
λ_w	Indexation wages	B (0.50, 0.15)	0.51 [0.32; 0.69]	0.51 [0.32; 0.69]	0.52 [0.33; 0.71]	0.47 [0.23; 0.72]
κ_w	Wage rigidity	G (50.0, 7.50)	56.99 [44.6; 69.3]	57.04 [44.8; 69.1]	56.87 [45.0; 69.1]	52.00 [40.1; 64.0]
$\boldsymbol{\varepsilon}$	**Demand elasticity**	**N (4.00, 1.50)**	**6.09 [4.76; 7.37]**	**5.76 [4.55; 6.95]**	**5.36 [4.51; 6.18]**	**4.52 [3.49; 5.49]**
$\boldsymbol{\eta}$	**Competition effect**		**0.17 [0.13; 0.21]**	**0.18 [0.14; 0.22]**	**0.19 [0.16; 0.22]**	**0.22 [0.17; 0.27]**
τ_R	Interest smoothing	B (0.75, 0.10)	0.73 [0.69; 0.78]	0.73 [0.69; 0.77]	0.75 [0.71; 0.79]	0.86 [0.82; 0.90]
τ_π	Policy inflation	G (1.50, 0.25)	1.49 [1.32; 1.66]	1.47[1.30; 1.63]	1.55 [1.36; 1.73]	1.90 [1.48; 2.30]
τ_y	Policy output	G (0.50, 0.25)	0.01 [0.003; 0.02]	0.01 [0.01; 0.02]	0.01 [0.01; 0.02]	0.21 [0.09; 0.34]
τ_{dy}	Policy lagged output	G (0.50, 0.25)	0.11 [0.08; 0.14]	0.11 [0.08; 0.14]	0.11 [0.08; 0.15]	0.07 [0.03; 0.10]
AR(1), MA(1)						
ρ_Z	TFP	B (0.50, 0.15)	0.98 [0.97;0.99]	0.98 [0.98; 0.99]	0.98 [0.98;0.99]	0.59 [0.46;0.73]
ρ_T	Time Impatience	B (0.50, 0.15)	0.18 [0.08; 0.28]	0.18 [0.08; 0.28]	0.17 [0.07; 0.26]	0.71 [0.58; 0.85]
ρ_I	Inv. Spec. Tech.	B (0.50, 0.15)	0.42 [0.33; 0.52]	0.40 [0.30; 0.50]	0.52 [0.43; 0.61]	0.46 [0.33; 0.59]
ρ_G	Gov. Spending	B (0.50, 0.15)	0.90 [0.87; 0.92]	0.89 [0.87; 0.92]	0.89 [0.86; 0.92]	0.88 [0.80; 0.96]
ρ_P	Price Markup AR(1)	B (0.50, 0.15)	0.77 [0.69; 0.85]	0.77 [0.70; 0.86]	0.77 [0.68; 0.86]	0.74 [0.62; 0.87]
ρ_W	Wage Markup AR(1)	B (0.50, 0.15)	0.95 [0.89; 0.99]	0.95 [0.91; 0.99]	0.96 [0.93; 0.99]	0.51 [0.32; 0.71]
ρ_R	Monetary Policy	B (0.50, 0.15)	0.17 [0.08; 0.25]	0.17 [0.08; 0.25]	0.15 [0.07; 0.22]	0.46 [0.31; 0.62]
ρ_E	Entry Cost	B (0.50, 0.15)	0.85 [0.81; 0.89]	0.85 [0.82; 0.89]	0.82 [0.78; 0.86]	0.55 [0.43; 0.67]
ρ_{GZ}	Corr. TFP – Gov.	B (0.50, 0.15)	0.75 [0.58; 0.91]	0.74 [0.58; 0.91]	0.72 [0.56; 0.90]	0.58 [0.36; 0.82]
μ_w	Wage Markup MA(1)	B (0.50, 0.15)	0.58 [0.44; 0.73]	0.59 [0.45; 0.74]	0.51 [0.34; 0.67]	0.47 [0.27; 0.65]
μ_p	Price Markup MA(1)	B (0.50, 0.15)	0.49 [0.33; 0.65]	0.49 [0.33; 0.69]	0.50 [0.34; 0.67]	0.45 [0.26; 0.66]
INNOVATIONS						
σ_Z	TFP	IG (0.10, 2)	0.83 [0.74; 0.91]	0.83 [0.75; 0.92]	0.85 [0.76; 0.93]	0.65 [0.53; 0.76]
σ_T	Time Impatience	IG (0.10, 2)	0.27 [0.23; 0.31]	0.27 [0.23; 0.31]	0.27 [0.23; 0.31]	0.08 [0.05; 0.11]
σ_I	Inv. Spec. Tech.	IG (0.10, 2)	1.39 [1.14; 1.64]	1.43 [1.17; 1.70]	1.16 [0.97; 1.36]	1.34 [0.98; 1.71]
σ_G	Gov. Spending	IG (0.10, 2)	3.15 [2.81; 3.48]	3.17 [2.83; 3.51]	3.24 [2.91; 3.58]	2.43 [2.01; 2.82]
σ_P	Price Markup	IG (0.10, 2)	0.26 [0.20; 0.33]	0.26 [0.20; 0.32]	0.25 [0.20; 0.30]	0.15 [0.10; 0.19]
σ_W	Wage Markup	IG (0.10, 2)	0.43 [0.36; 0.50]	0.43 [0.36; 0.49]	0.42 [0.35; 0.49]	0.84 [0.67; 1.01]
σ_R	Monetary Policy	IG (0.10, 2)	0.25 [0.23; 0.28]	0.25 [0.23; 0.28]	0.25 [0.23; 0.28]	0.09 [0.08; 0.11]
σ_E	Entry Cost	IG (0.10, 2)	3.37 [2.83; 3.90]	3.31 [2.79; 3.81]	3.31 [2.85; 3.78]	3.28 [2.60; 3.91]

Note: 'Net Entry' matches the series of net business formation with net entry in the model. 'NI' denotes the use of data on New Incorporations instead of data on net business formation. 'Births' estimates the model on a later sample using establishment data. 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 576,000 draws from the distribution simulated by the Random Walk Metropolis Hastings algorithm.

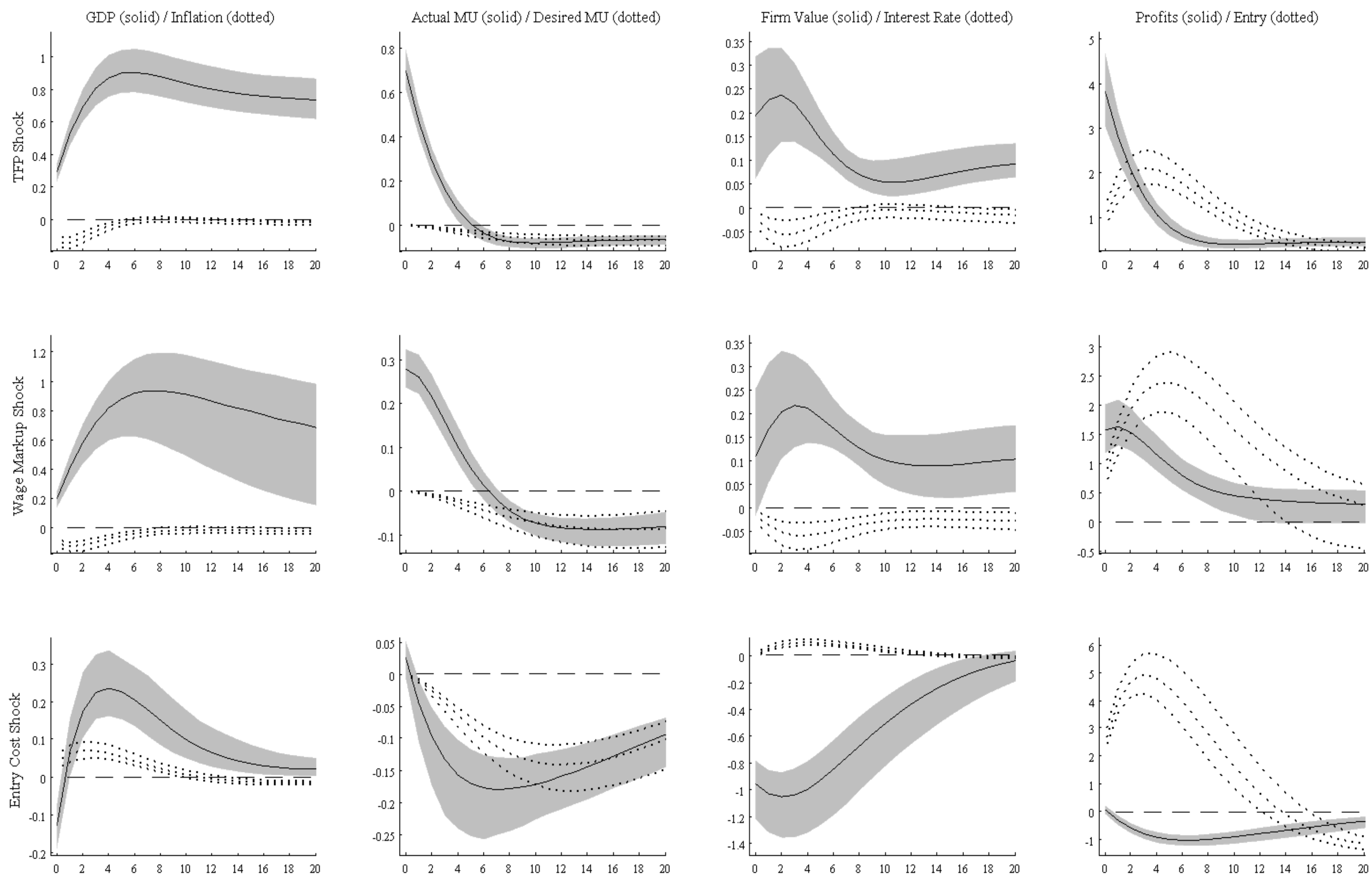

Figure 1a: Impulse Responses to Supply Shocks

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.

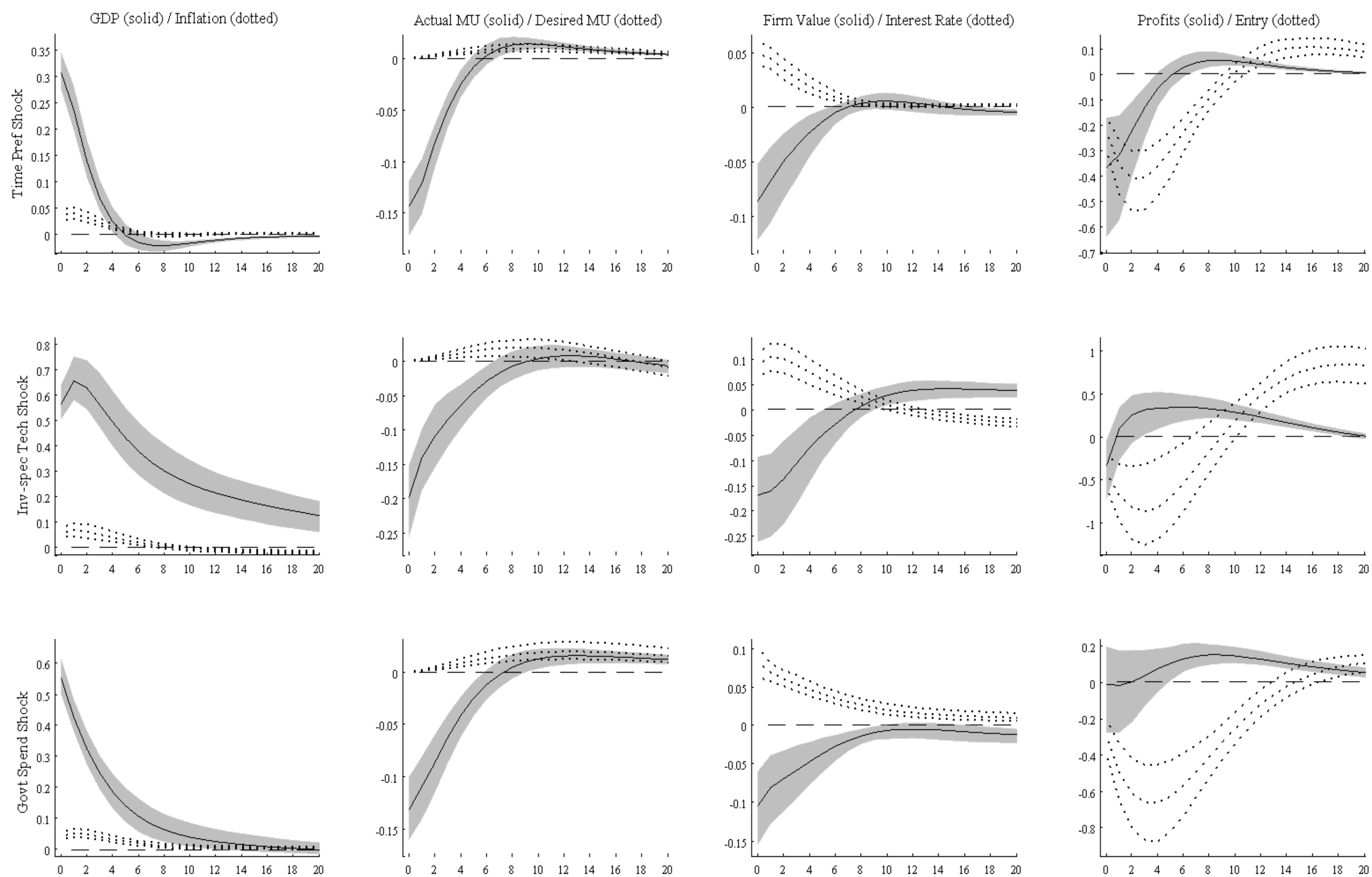

Figure 1b: Impulse Response to Demand Shocks

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.

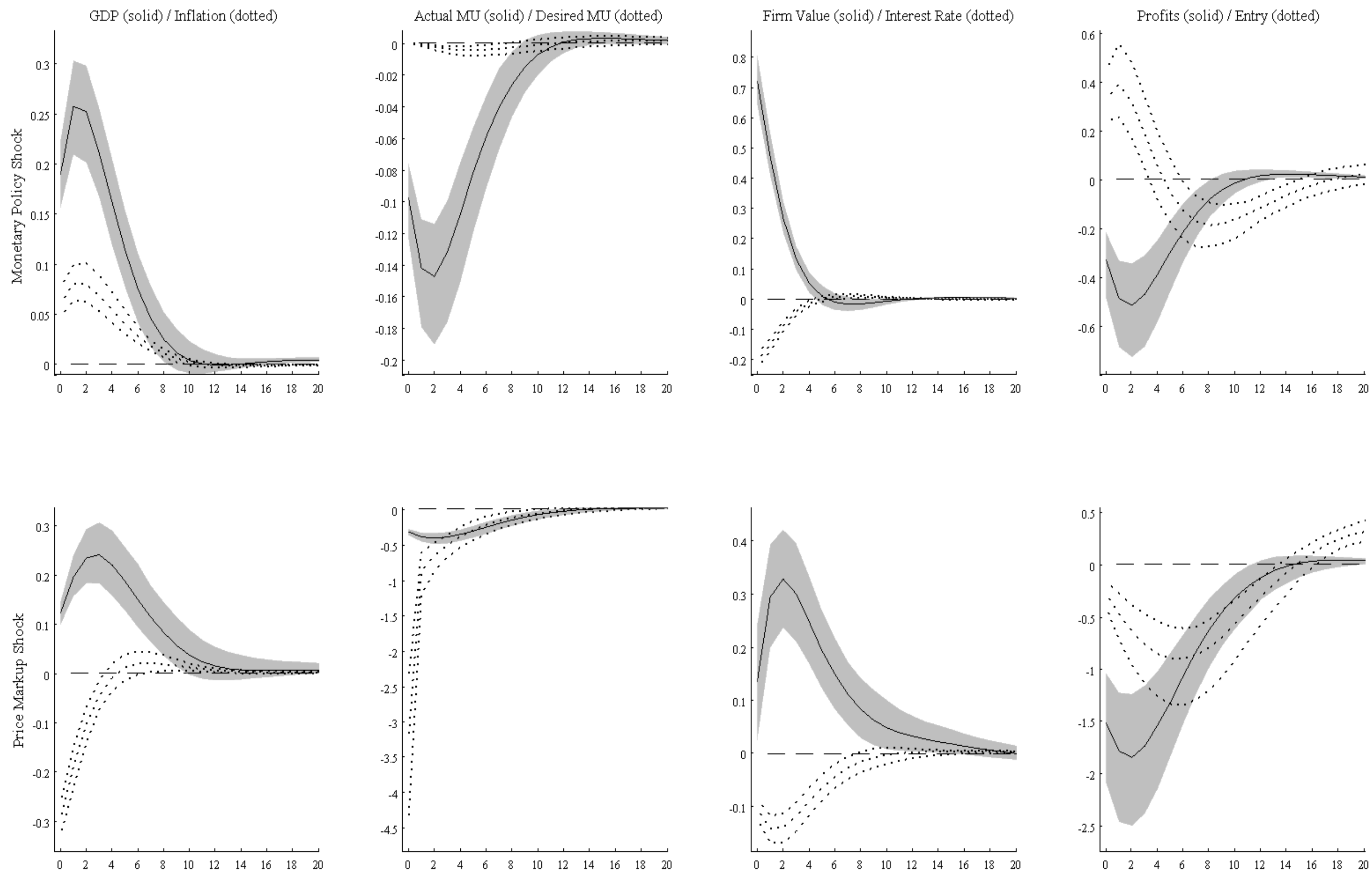

Figure 1c: Impulse Responses to Monetary Policy and Price Markup Shocks

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.

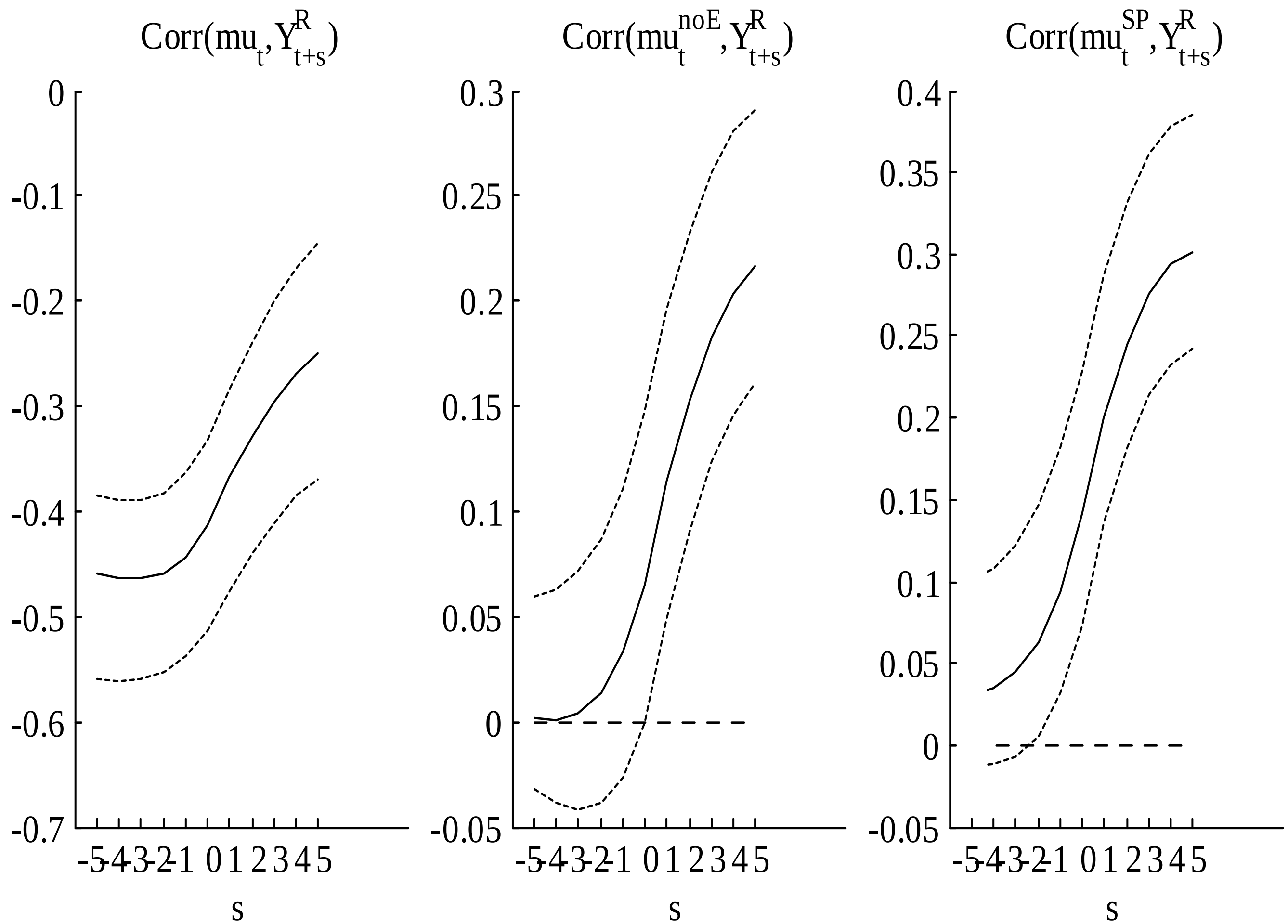

Figure 2: The Cyclicality of the Markup: Baseline Model

Note: The figure shows the cyclicality of the markup at different leads and lags as implied by the baseline model. The left panel depicts the model-implied markup $\hat{\mu}_t$. The center panel shows the counterfactual markup in the absence of entry, denoted $\hat{\mu}_t^{noE}$, which obtains when entry adjustment costs become arbitrarily large, $\varphi_N \to \infty$. The right panel depicts the 'sticky price' component $\hat{\mu}_t^{SP}$, which we would obtain in the absence of both entry and price markup shocks.

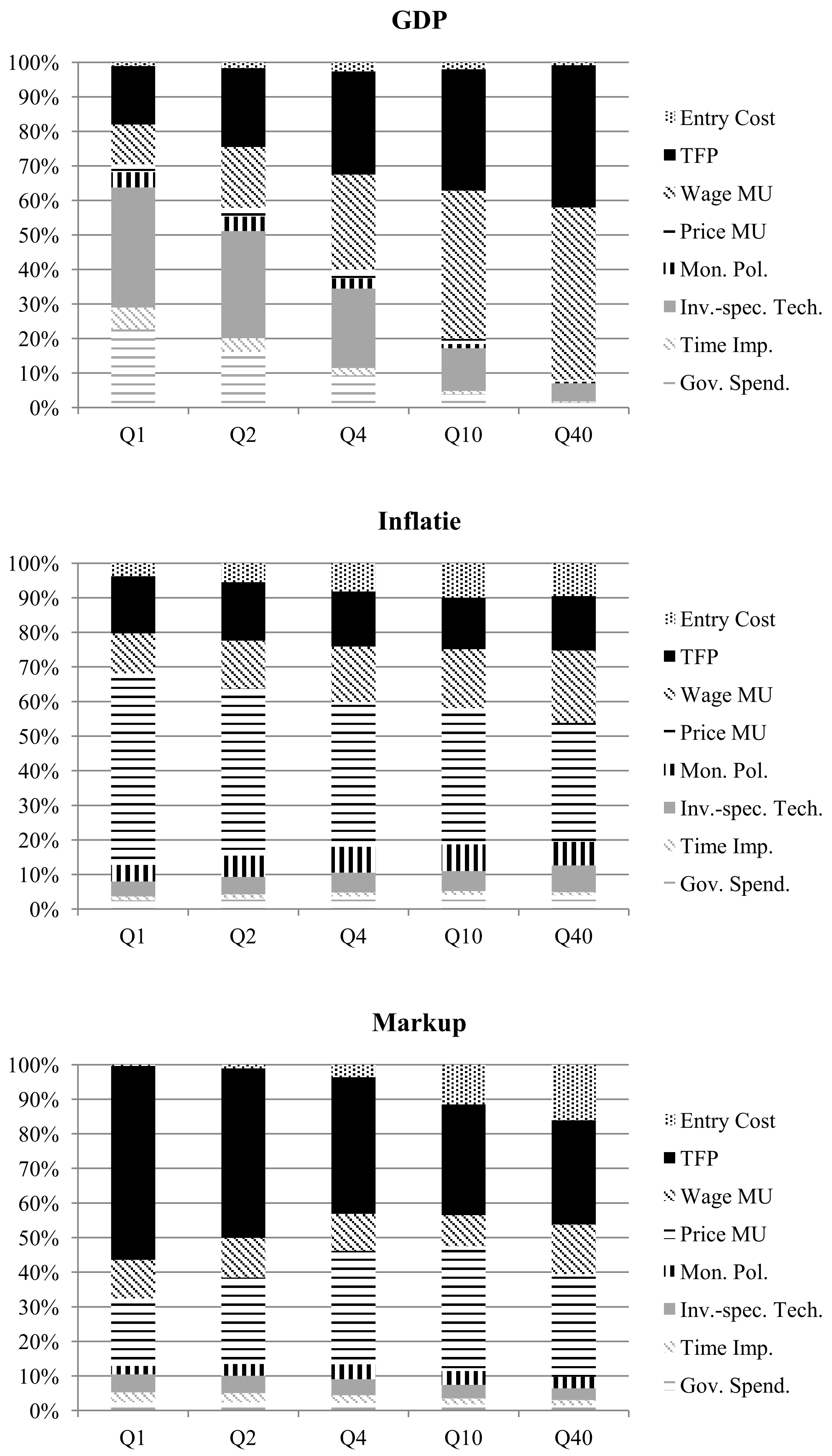

Figure 3: Forecast Error Variance Decomposition (at posterior mode)

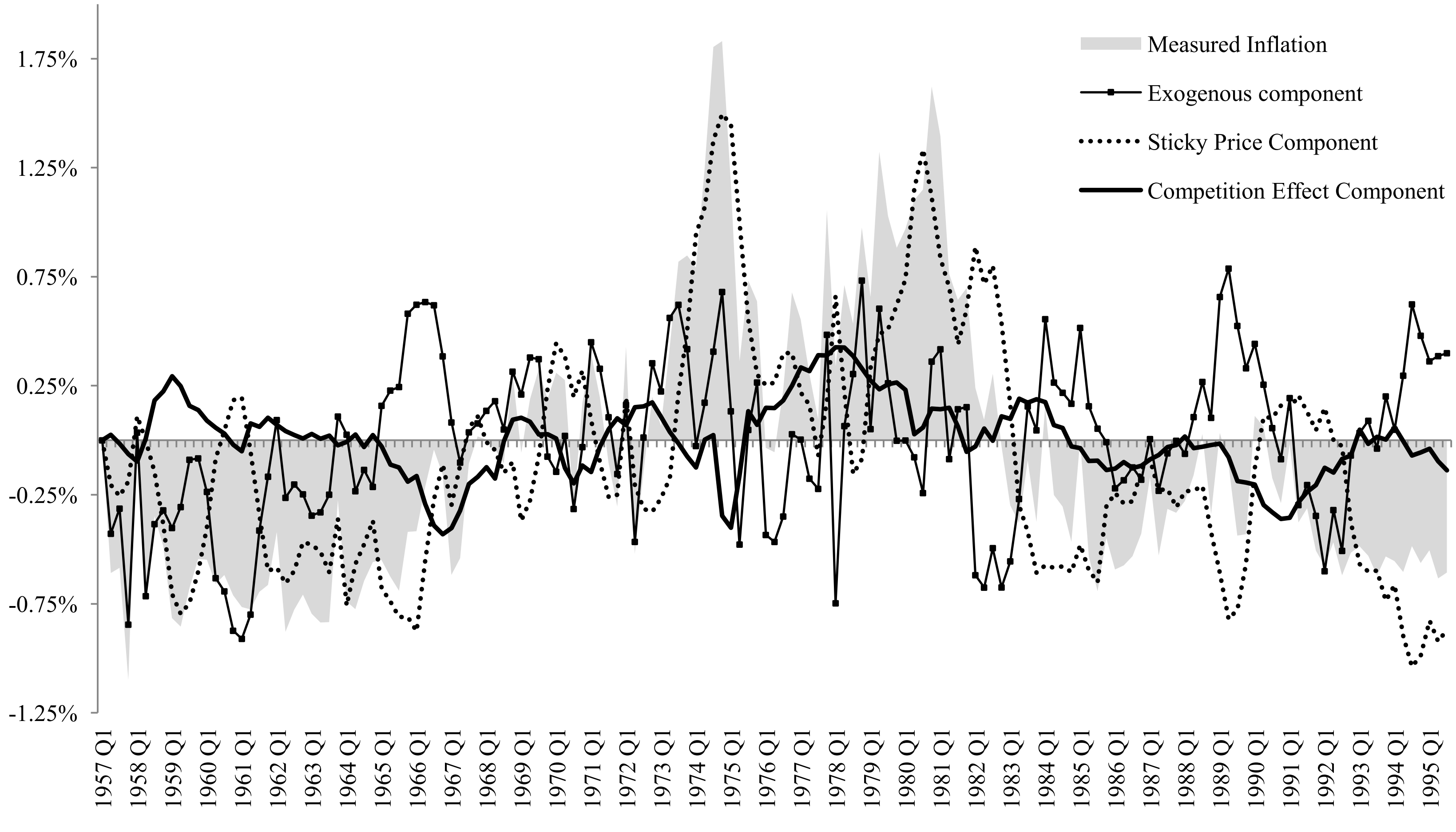

Figure 4a: Counterfactual Decomposition of US Inflation: Earlier Sample

Note: Entry is measured as net business formation. 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.

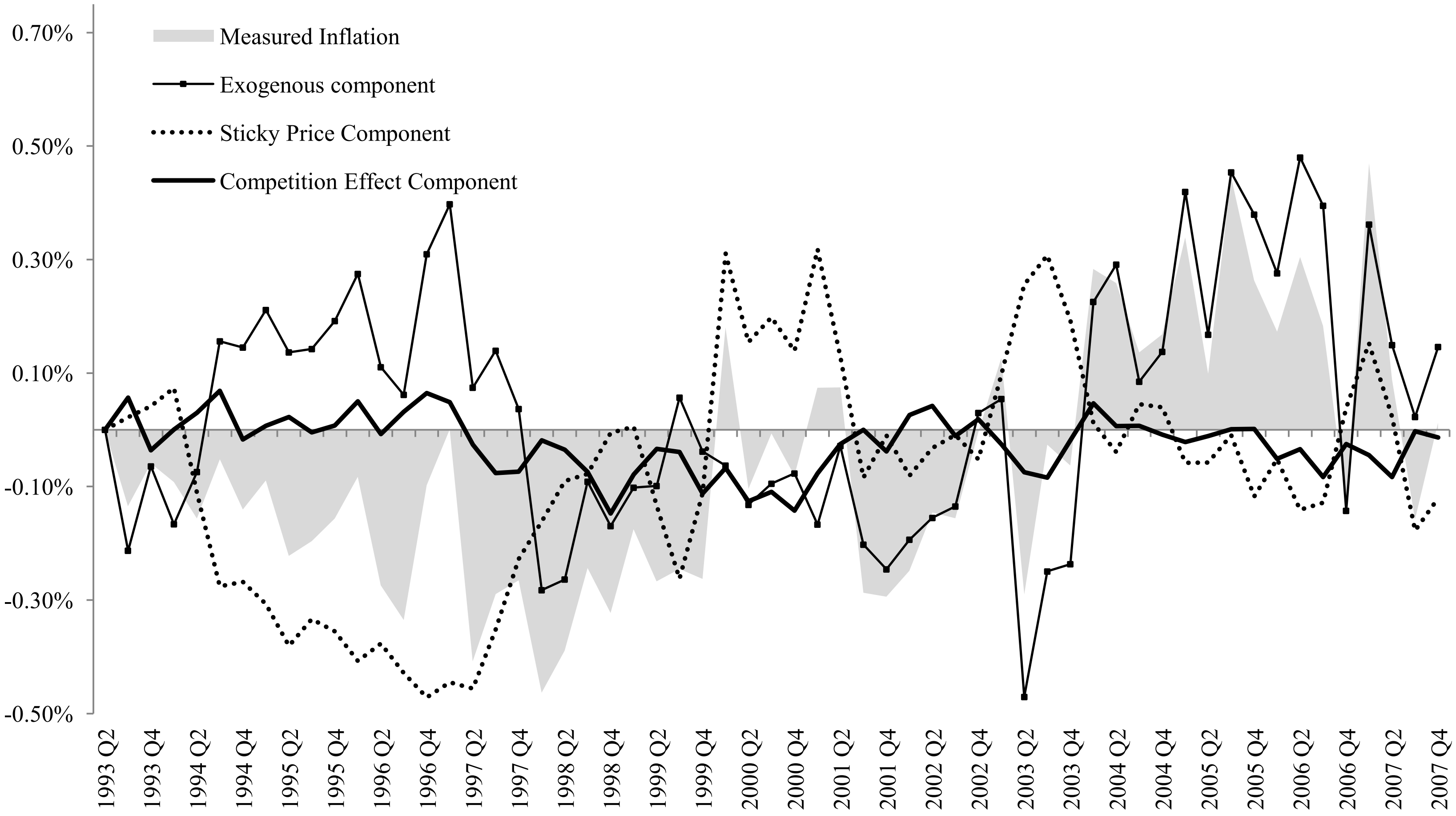

Figure 4b: Counterfactual Decomposition of US Inflation: Later Sample

Note: Entry is measured as establishment births. 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.

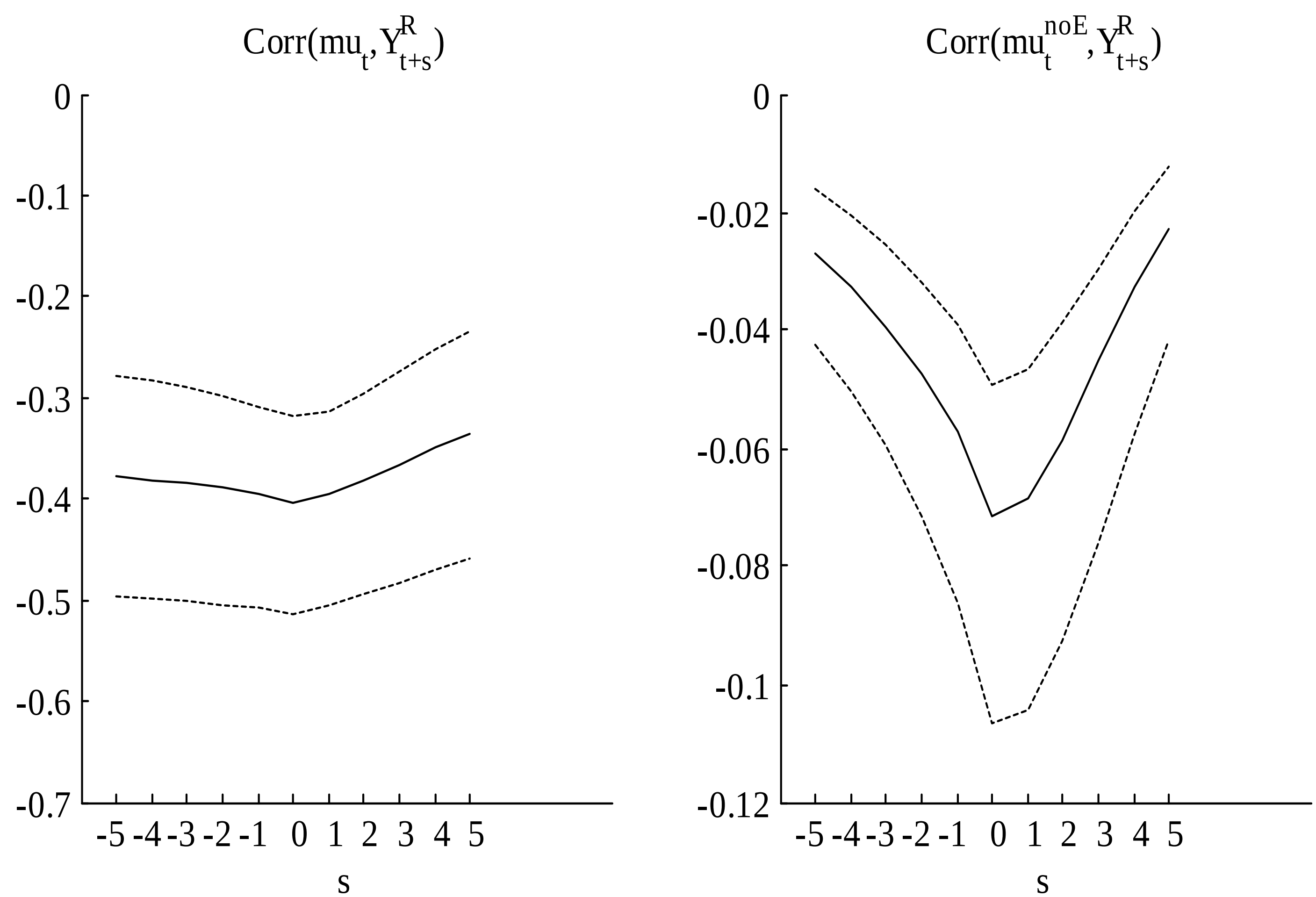

Figure 5: The Cyclicality of the Markup: Flexible-Price Model

Note: The figure shows the cyclicality of the markup at different leads and lags as implied by the flexible-price model. The left hand panel depicts the model-implied markup $\hat{\mu}_t$. The right hand panel shows the counterfactual markup in the absence of entry, denoted $\hat{\mu}_t^{noE}$, which obtains when entry adjustment costs become arbitrarily large, $\varphi_N \to \infty$.