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Firm Entry, Inflation and the Monetary Transmission Mechanism

Vivien Lewis
Ghent University and Goethe University Frankfurt, IMFS
Céline Poilly
Université catholique de Louvain, IMMAQ-IRES

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Firm Entry, Inflation and the Monetary Transmission Mechanism[*]

Vivien Lewis[†]

Ghent University and Goethe University Frankfurt, IMFS

Céline Poilly[‡]

Université catholique de Louvain, IMMAQ-IRES

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Abstract

This paper estimates a business cycle model with endogenous firm entry by matching impulse responses to a monetary policy shock in US data. Our VAR includes net business formation, profits and markups. We evaluate two channels through which entry may influence the monetary transmission process. Through the competition effect, the arrival of new entrants makes the demand for existing goods more elastic, and thus lowers desired markups and prices. Through the variety effect, increased firm and product entry raises consumption utility and thereby lowers the cost of living. This implies higher markups and, through the New Keynesian Phillips Curve, lower inflation. While the proposed model does a good job at matching the observed dynamics, it generates insufficient volatility of markups and profits. Estimates of standard parameters are largely unaffected by the introduction of firm entry. Our results lend support to the variety effect; however, we find no evidence for the competition effect.

Key words: entry, inflation, monetary transmission, monetary policy, extensive margin
JEL codes: E32, E52

1 Introduction

This paper investigates how the extensive margin alters the monetary transmission mechanism by estimating a dynamic stochastic general equilibrium (DSGE) model with endogenous firm entry. Recent work on business cycle analysis puts forward firm and product turnover as an important factor affecting the transmission of shocks, see for example Bilbiie et al (2007) and Bergin and Corsetti (2008). This research has been mainly theoretical up to now, creating a need for empirical model validation. We contribute to filling this gap by answering three questions. First, how well does the model replicate the dynamics of profits, markups and entry? These variables are typically ignored by standard DSGE models. Second, how does endogenous entry affect the relative importance of different frictions in the transmission of monetary policy shocks? Bilbiie et al (2007) suggest that the stock of firms, through its sluggish adjustment to shocks, is a source of endogenous propagation that increases inflation persistence, thereby reducing the importance of price rigidities. Finally, we evaluate two channels through which entry might dampen inflation: the competition effect and the love of variety hypothesis. We explain these two effects in turn.

First, when there are only few producers in an industry, the arrival of a new entrant can lead to stronger competition, which reduces the price markups that firms are able to charge. This 'competition effect' of entry has been documented in the industrial organisation literature by Campbell and Hopenhayn (2005). It improves the capacity of business cycle models to replicate the unconditional moments of markups and profits, see Colciago and Etro (2010). Standard models predict that desired markups - the difference between prices and marginal costs in the absence of price rigidities - are constant. In contrast, the competition effect introduces variations in desired markups which are positively related to inflation. Cecioni (2010) shows that a rise in the number of firms significantly lowers US inflation.

Second, if consumer preferences display 'love of variety', this implies that a larger range of available products raises utility. Assuming that each entrant introduces a new differentiated good into the market, firm entry is associated with a more diverse consumption bundle. Consequently, a cost-of-living index that takes proper account of the variety effect, by tracking the composition of the consumption basket, should fall. If the prices of individual goods are unchanged while the price index falls, markups and profits increase. Under price stickiness, the markup and inflation are negatively related through the New Keynesian Phillips Curve. Thus, the variety effect implies that an increase in the number of firms has a negative effect on inflation. The Dixit and Stiglitz

(1977) preference specification adopted by the vast majority of business cycle models displays love of variety. In addition, Broda and Weinstein (2010) present scanner data evidence suggesting that the variety effect gives rise to a significant bias in the US price index.

Using US data, we estimate a structural VAR with net business formation, markups and real profits in addition to a set of standard macroeconomic variables (real GDP, real investment, real consumption, wage inflation, price inflation, and the interest rate). We identify a monetary policy shock using a conventional recursive method. The resulting impulse response functions are presented in Section 2.

We then develop a medium-sized DSGE model with endogenous entry that we subsequently confront with the data. The model extends Bilbiie et al (2007) to include wage rigidities, physical capital investment, indexation of prices and wages, investment adjustment costs, variable capital utilisation, working capital and habit persistence. Section 3 lays out the linearised model.

As explained in Section 4, we estimate the model using a minimum distance estimation (MDE) approach. More specifically, we search for the parameter values that minimise the distance between the model-based and the VAR-based impulse responses functions. Our exercise is comparable to Christiano et al (2005).

In Section 5, we discuss the estimation results. First, we evaluate the performance of the model at replicating the VAR impulse responses, in particular of net business formation, profits and markups. Second, we assess whether and how our parameter estimates are modified by the introduction of entry in the model. To do so, we compare our estimation results to an estimated model without entry. Third, we evaluate the two channels of how entry affects inflation: the love of variety effect and the competition effect. Finally, we report the results of various counterfactual exercises.

Our findings, summarised in Section 6, are the following. The model does a very good job at matching the empirical responses of all variables to monetary policy shocks. However, a substantial part of the volatility of markups and profits remains unexplained. The introduction of firm entry does not significantly alter the estimates of standard model parameters. Our results support the love of variety hypothesis, but not the competition effect.

2   SVAR Evidence

This section presents evidence on the responses of macroeconomic aggregates to a contractionary monetary policy shock. During the MDE procedure, these impulse response functions (IRFs) correspond to the empirical moments the model has to replicate. The recursively identified structural

VAR (SVAR) includes the following variables: real GDP, real investment, real consumption, wage inflation, price inflation, net business formation, corporate profits, markups, commodity prices and the nominal interest rate. Our model-consistent markup measure is inversely related to the labour share.[1] The purpose of using commodity prices in the regression is to mitigate the price puzzle by which inflation rises at first in response to a monetary contraction.[2] Let us define the data vector x_t,

$$
x_t = \begin{bmatrix}
\ln(RGDP_t) \\
\ln(RFPI_t) \\
\ln(RPCE_t) \\
WINFL_t \\
PINFL_t \\
\ln(NBF_t) \\
\ln(RPROFITS_t) \\
\ln(MARKUP_t) \\
\ln(CRB_t) \\
FEDFUNDS_t
\end{bmatrix}.
$$

The data series are listed in Table 1. A detailed description of the data sources is provided in Table 2. The SVAR model is estimated using US quarterly data over the period 1954Q4-1995Q2. The sample is not updated due to a lack of more recent data on net business formation. All the variables are linearly detrended. First, we estimate the following canonical VAR(p) model

$$
x_t = \Omega_1 x_{t-1} + ... + \Omega_p x_{t-p} + \varepsilon_t,
$$

where x_t is an $(n \times 1)$ data vector with $n = 10$, p is the maximum lag (set to $p = 4$) and $\varepsilon_t \sim iid(0, \Sigma)$, where Σ is a symmetric positive definite matrix. Second, we identify monetary policy shocks. The relation between the reduced form residuals ε_t and the structural innovations η_t can be expressed by the linear combination

$$
A\varepsilon_t = \eta_t,
$$

where A is a nonsingular matrix. We adopt a recursive identification strategy by which all variables are included in the information set of the monetary authority and react to a monetary policy shock with a one-period lag. This implies that A is lower triangular.

The empirical $(n \times 1)$ vector of IRFs of the variables to a monetary policy shock j periods ago, denoted by Φ_j, are

$$
\Phi_j = \frac{\partial x_{t+j}}{\partial \eta_t^R},
$$

---

[1] See Appendix 1 for details.

[2] Their dynamics are not reported here since they are not included in the model's estimation process.

where η_t^R is the structural innovation corresponding to the line associated with the Federal Funds rate and Φ is defined as

$$\Phi = \text{vec}(\Phi_0, ..., \Phi_h),$$

where the vec $(\cdot)$ operator transforms an $(n \times m)$ matrix into an $(nm \times 1)$ vector by stacking the columns of the original matrix and h is the final horizon set to $h = 20$ quarters.[3] Let $\hat{\Phi}_T$ denote the empirical estimate of Φ, resulting from the estimated VAR model where T is the sample size.

[insert Figure 1 here]

Figure 1 exhibits the estimated IRFs to a contractionary one-standard-deviation monetary policy shock. The observed dynamics of most variables are well-known. After an initial hike, the interest rate declines gradually, reaching steady state after about two years. Wage and price inflation are characterised by a negative hump-shaped response, reaching their lowest point only after the interest rate is back to its pre-shock level. Capital investment, consumption and output also fall gradually before returning to steady state in a hump-shaped fashion, though displaying less persistence than wage and price inflation. Capital investment decreases more than output, which in turn falls more than consumption. Regarding the extensive margin, we observe that the response of net firm entry is similar in shape and magnitude to that of capital investment. This is in line with Bergin and Corsetti (2008), Uusküla (2008) and Lewis (2009). Real profits also feature a downward hump-shaped pattern that is significant over two years. The response of markups, despite not being very accurately estimated, appears to be procyclical on impact and countercyclical over medium horizons. In the following, we develop a DSGE model with the goal of accounting quantitatively for the observed dynamics.

3   Model

Our starting point is the model of Bilbiie et al (2007), BGM hereafter, which features endogenous entry of firms subject to a fixed labour requirement, a constant firm exit rate, and sticky prices à la Rotemberg (1982).

In our model, firm entry affects inflation in two ways. First, an increase in the number of differentiated products lowers the welfare-based price index through the so-called variety effect. When preferences display love of variety, a more diverse consumption bundle gives rise to higher utility

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[3]The lines corresponding to predetermined variables for the monetary shock are zero in vector Φ_0. Thus, they are removed from vector Φ before estimation.

and therefore it costs less to attain a given welfare level. Holding nominal product prices constant, markups rise. Since markups and inflation are negatively related under price stickiness, the variety effect implies that entry dampens inflation. Second, as in Floetotto and Jaimovich (2008), we allow for strategic interactions between firms, resulting in a goods price markup that depends negatively on the number of competitors.[4] This so-called competition effect, combined with pro-cyclical entry, makes markups countercyclical, which could help to capture the medium-run markup movement observed in Figure 1. In the industrial organisation literature, there is evidence of such a relationship, see Campbell and Hopenhayn (2005). Higher competitive pressure and lower desired markups due to entry reduce inflation. Cecioni (2010) finds evidence for such an effect in US data. The estimation procedure will help us to test the relevance of these two effects in the transmission of monetary policy shocks.

We add several empirically motivated frictions to make the model estimable, in line with Christiano et al (2005). These are external habit persistence in consumption, monopolistic competition in labour markets and sticky wages, price and wage indexation, physical capital to produce firms and intermediate goods, adjustment costs in intensive and extensive margin investment, variable capital utilisation and working capital.

The equilibrium is symmetric such that all households and all firms are identical. In addition, the timing of events is consistent with the recursive identification scheme adopted in the previous section. This means that all the optimisation decisions of households and firms are made before the realisation of the monetary policy shock, except household decisions concerning assets. This specification implies that production, investment, consumption, prices, wages and firm entry decisions are predetermined with respect to the shock.[5]

Below, we lay out the model in linearised form.[6] A hat above a variable denotes its deviation from the deterministic steady state. A variable without a hat or a time subscript denotes its steady state level.

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[4] We do not adopt a translog preference specification as in BGM (2007), but note that such a model is observationally equivalent to ours.

[5] To be precise, all variables in t (except the interest rate) are chosen on the basis of information in period $t-1$, including forward variables $E_t\{x_{t+1}\}$, where $E_t\{\cdot\}$ is the expectation operator conditional on information available at t.

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

3.1 Firms

There is a fixed range of industries of measure 1, indexed by $i \in [0, 1]$. Within each industry, there is a mass N_t of firms, each producing one differentiated intermediate good, indexed by $f \in [0, N_t]$. The firms' intermediate goods are bundled into an industry good according to a constant elasticity of substitution (CES) aggregator, with elasticity θ_f. The final good is a CES composite of the industry goods which have an elasticity of substitution θ_i.

Suppose for now that nominal rigidities are absent. We assume that each industry is an oligopolistic market. The number of firms is small, such that each firm takes into account the effect of its pricing decision on the industry price. The type-(i, f) firm takes as given the prices of other firms in the industry and the price levels of other industries. Strategic interactions between firms imply that the price elasticity of demand (multiplied by -1) is given by [7]

$$\varepsilon_t^{yp} = \theta_f - (\theta_f - \theta_i) \frac{1}{N_t}. \tag{1}$$

Equation (1) shows that for $\theta_f > \theta_i$, the firms' price setting power is eroded by the arrival of new entrants, such that their desired markup falls. Recall that the desired markup is the markup that firms charge optimally when there are no price setting frictions. In a standard New Keynesian model, it is constant over time. Broda and Weinstein (2006) present evidence that empirically, goods are less substitutable across industries than within an industry, such that $\theta_f > \theta_i$ is a reasonable assumption. Consider the steady state markup,

$$\mu = \frac{\varepsilon^{yp}(N)}{\varepsilon^{yp}(N) - 1}.$$

For future reference, we define the elasticity of the steady state markup to the number of firms (multiplied by -1),

$$\eta = \frac{\partial \mu / \mu}{\partial N / N}.$$

The parameter η measures the competition effect of entry. If $\eta > 0$, more firms imply a lower markup in steady state. The competition effect vanishes if $\eta = 0$. As we shall see below, the competition effect has an impact on the model's short-run inflation dynamics.

Intermediate firms set prices as a markup $\widehat{\mu}_t$ over marginal costs,

$$\widehat{\rho}_t = \widehat{\mu}_t + \widehat{mc}_t, \tag{2}$$

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[7]This expression is obtained by differentiating the demand for firm (i, f)'s goods with respect to its price and assuming symmetry across firms. See model appendix for details.

where $\widehat{mc}_t$ denotes the real marginal cost and $\widehat{\rho}_t$ is the product price relative to the welfare-based price index, i.e. $\rho_t = p_t/P_t$. In a model with endogenous firm entry, the relative product price of an intermediate good, denoted by p_t, differs from the welfare-based consumer price index P_t when the latter incorporates the variety effect. More precisely, the real product price is related to the number of firms through

$$\widehat{\rho}_t = (\nu_v - 1)\,\widehat{N}_t, \tag{3}$$

where $\nu_v \geq 1$ captures the degree of 'love of variety' defined as the increase in consumption utility from spreading a certain amount of consumption over a greater number of differentiated products (see Bénassy, 1996; and the working paper version of Dixit and Stiglitz, 1977). This means that a rise in the range of available goods raises consumption utility more than proportionately. For example, $\nu_v = \frac{\theta_f}{\theta_f - 1}$ as in Dixit and Stiglitz (1977) implies a particular calibration for the love of variety. Then the relative product price is positively related to the number of firms; in this particular case, $\widehat{\rho}_t = \frac{1}{\theta_f - 1}\widehat{N}_t$. An autonomous increase in product diversity (driven, for example, by a country opening up to trade) results in a fall in the price index but does not change product prices. Instead, setting $\nu_v = 1$ as in Floetotto and Jaimovich (2008), eliminates the variety effect. This implies an aggregate production function that is linear in the number of intermediate goods. Then the nominal product price and the price index are equal, and thus $\widehat{\rho}_t = 0$.

Let us turn to the pricing decision of intermediate goods producers. As in Rotemberg (1982), we assume that a firm that wishes to change its price incurs an adjustment cost proportional to its real revenues. Price adjustment costs are higher, the higher is the parameter κ_p and the more the change in the firms' nominal price diverges from the term $\lambda_p\widehat{\pi}_{p,t-1}^C + (1 - \lambda_p)$, where $\widehat{\pi}_{p,t}^C$ is the change in the welfare-based price index. Perfectly flexible prices are given by $\kappa_p = 0$. We introduce indexation as in Ravn et al (2010). When λ_p is equal to zero, there is no indexation to past inflation and we have the case of a purely forward-looking New Keynesian Phillips Curve. When $\lambda_p > 0$, the price adjustment cost is a function of the difference between the firms' price change and a weighted average of past inflation (with weight λ_p) and steady state inflation, where the latter is equal to 1. For simplicity, we assume that entrants, too, face this price adjustment cost.[8] Under these assumptions, the change in nominal product prices, denoted by $\widehat{\pi}_{p,t}$, is a positive function of its expected future value and a negative function of the markup $\widehat{\mu}_t$. With indexation, $\widehat{\pi}_{p,t}$ also depends on current and lagged welfare-based inflation.

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[8] Bilbiie et al (2007) show that the impulse responses to shocks change negligibly under the alternative assumption that entrants can change their price costlessly.

The New Keynesian Phillips Curve (NKPC) is therefore,

$$\widehat{\pi}_{p,t} - \lambda_p \widehat{\pi}_{p,t-1}^C = -\phi_p \left(\eta \widehat{N}_t + \widehat{\mu}_t \right) + \beta \left(1 - \delta_N \right) \mathrm{E}_t \{ \widehat{\pi}_{p,t+1} - \lambda_p \widehat{\pi}_{p,t}^C \}, \tag{4}$$

where $\phi_p = (\varepsilon^{yp} - 1)/\kappa_p$ is its slope and the discount factor $\beta \left(1 - \delta_N \right)$ is the product of the households' subjective discount factor β and the firms' exogenous survival rate $(1 - \delta_N)$. The term $-\phi_p \eta \widehat{N}_t$ captures the competition effect, i.e. the negative effect of the number of firms on inflation through desired markups. Substituting the price setting equation (2) and price index (3) into the NKPC (4) to replace $\widehat{\mu}_t$, we have an alternative inflation equation,

$$\widehat{\pi}_{p,t} - \lambda_p \widehat{\pi}_{p,t-1}^C = -\phi_p \left([\eta + (\nu_v - 1)] \, \widehat{N}_t - \widehat{mc}_t \right) + \beta \left(1 - \delta_N \right) \mathrm{E}_t \{ \widehat{\pi}_{p,t+1} - \lambda_p \widehat{\pi}_{p,t}^C \}. \tag{5}$$

Through the variety effect, the markup is no longer the inverse of real marginal costs, but also depends positively on the number of firms, see (2). This version of the NKPC shows that in the presence of love of variety ($\nu_v > 1$) or the competition effect ($\eta > 0$), inflation fluctuates inversely with the number of goods and firms. We test below whether these two effects are important in the transmission of monetary policy shocks.

Firm profits $\widehat{d}_t$ depend positively on the markup, on the real product price and on intermediate firm output $\widehat{y}_t$,

$$\widehat{d}_t = \left(\varepsilon^{yp} - 1 \right) \widehat{\mu}_t + \widehat{\rho}_t + \widehat{y}_t, \tag{6}$$

where the latter varies negatively with the real product price and positively with final output $\widehat{Y}_t^C$,

$$\widehat{y}_t = -\theta_f \widehat{\rho}_t + \widehat{Y}_t^C + [(\theta_f - 1) \nu_v - \theta_f] \, \widehat{N}_t. \tag{7}$$

Final output, $\widehat{Y}_t^C = \widehat{\rho}_t + \widehat{y}_t + \widehat{N}_t$, is a weighted average of private consumption $\widehat{C}_t$ and exogenous government consumption, which we assume is constant,

$$\widehat{Y}_t^C = (1 - \Gamma) \widehat{C}_t.$$

The parameter Γ denotes the steady state share of government consumption in final output.

We now describe the production function and cost minimisation by firms. The model features two sectors denoted by j, where $j = C, E$. The subscript C refers to the sector producing goods, the subscript E refers to the sector producing firms. Differentiated intermediate goods and new firms are produced using labour and physical capital according to a Cobb-Douglas technology with α denoting the (common) capital share. $K_{j,t}^s$ are capital services and $L_{j,t}$ is the labour input into production in sector j. The aggregate production function for goods is given by

$$\widehat{y}_t + \widehat{N}_t = \alpha \widehat{K}_{C,t}^s + (1 - \alpha) \, \widehat{L}_{C,t}.$$

Similarly, the aggregate production function for new firms is

$$\widehat{N}_{E,t} = \alpha \widehat{K}^s_{E,t} + (1 - \alpha) \widehat{L}_{E,t},$$

where $\widehat{N}_{E,t}$ is the number of entrants. Factors are rented in competitive markets; their prices are equal to their marginal revenue products. It follows that the ratio of the wage bill to the rental bill is constant,

$$\widehat{r}^k_t + \widehat{K}^s_{C,t} = \widehat{w}_t + \widehat{R}^w_t + \widehat{L}_{C,t},$$

where $\widehat{r}^k_t$ is the real rental rate on capital and $\widehat{w}_t$ is the real wage. Because a fraction ν_w of the wage costs must be paid ahead of production, the wage bill includes the interest rate $\widehat{R}^w_t$ given by

$$\widehat{R}^w_t = \frac{\nu_w R}{\nu_w R + (1 - \nu_w)} \widehat{R}_t,$$

where $\widehat{R}_t$ is the gross rate of return on riskfree nominal bonds. This specification follows Christiano et al (2010) and allows us to estimate the strength of the working capital channel. Real marginal costs are given by the expression

$$\widehat{mc}_t = \alpha \widehat{r}^k_t + (1 - \alpha) \left(\widehat{w}_t + \widehat{R}^w_t \right).$$

Due to perfect cross-sectoral factor mobility, factor prices are equalised across sectors and so is the capital-labour ratio,

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

3.2   Households

Households maximise expected lifetime utility. Period t utility is increasing in consumption with σ_C denoting the degree of risk aversion. Furthermore, consumption displays external habit persistence of degree b, such that marginal consumption utility is given by

$$\widehat{U}_{C,t} = -\frac{\sigma_C}{1 - b} \left(\widehat{C}_t - b\widehat{C}_{t-1} \right).$$

Utility depends negatively on hours worked $\widehat{L}_t$, such that marginal labour disutility is

$$\widehat{U}_{L,t} = -\sigma_L \widehat{L}_t,$$

where σ_L is the inverse elasticity of labour supply to the real wage. Households have access to three assets. First, they buy riskfree nominal one-period bonds at the price of one currency unit

per bond, which pay a gross return $\widehat{R}_t$ in the next period. The first order condition for bonds is the familiar Euler equation

$$\widehat{U}_{C,t} = \widehat{R}_t - \mathrm{E}_t\{\widehat{\pi}^C_{p,t+1} - \widehat{U}_{C,t+1}\}.$$

Second, households buy shares at price $\widehat{v}_t$ and sell them one period later. The return on shares is given by firm profits, paid out as dividends, and the capital gain realised in the next period, discounted appropriately, such that the optimality condition on shares is

$$\widehat{v}_t = \mathrm{E}_t\{\widehat{U}_{C,t+1} - \widehat{U}_{C,t} + [1 - \beta(1 - \delta_N)]\widehat{d}_{t+1} + \beta(1 - \delta_N)\widehat{v}_{t+1}\}.$$

Firm entry is subject to a flow adjustment cost measured by the parameter φ_N. This specification allows us to capture the gradual response of entry to shocks, which is consistent with empirical evidence on the diffusion of production innovations documented in the industrial organisation literature, see Gort and Klepper (1982). The parameter $0 < \varphi_N^{-1} < 1$ can be also interpreted as the fraction of entrants that are unsuccessful. In Beaudry et al's (2006) gold rush model for instance, an exogenous expansion of product varieties can lead to an inefficient scramble of startups to produce these new varieties. In the process, resources are wasted as some of these startups fail. Here, we also assume a non-zero failure rate of startups. We model the failure rate as a positive function of the change in entry. Therefore, whenever a shock opens up profitable opportunities that stimulate firm entry, the failure rate is high initially, but declines as entry rates decelerate. Under these assumptions, the number of entrants has a forward-looking and a backward-looking component and depends positively on firm value less the entry cost,

$$\widehat{N}_{E,t} - \widehat{N}_{E,t-1} = \varphi_N(\widehat{v}_t - \widehat{mc}_t) + \beta\mathrm{E}_t\{\widehat{N}_{E,t+1} - \widehat{N}_{E,t}\}. \tag{8}$$

It takes one period for a successful entrant to turn into a producer. Each period, a fraction δ_N of active firms and new entrants exit the market, such that the stock of firms evolves according to the law of motion

$$\widehat{N}_t = (1 - \delta_N)\widehat{N}_{t-1} + \delta_N\widehat{N}_{E,t-1}. \tag{9}$$

The third asset is physical capital, which agents rent out to firms and entrants. Capital is bought at price $\widehat{q}_t$ today and is sold tomorrow at a return given by the rental rate $\widehat{r}^k_{t+1}$, in addition to the capital gain $\widehat{q}_{t+1}$, discounted appropriately. The first order condition for capital purchases is

$$\widehat{q}_t = \mathrm{E}_t\{\widehat{U}_{C,t+1} - \widehat{U}_{C,t} + [1 - \beta(1 - \delta_K)]\widehat{r}^k_{t+1} + \beta(1 - \delta_K)\widehat{q}_{t+1}\}.$$

Capital services depend on the stock of capital $\widehat{K}_t$ and its utilisation rate $\widehat{u}_t$,

$$\widehat{K}_t^s = \widehat{u}_t + \widehat{K}_t.$$

Households choose how intensively capital is utilised. As in Christiano et al (2005), changes in the utilisation rate are costly. At the optimum, utilisation is adjusted with elasticity σ_a^{-1} to changes in the rental rate of capital,

$$\widehat{u}_t = \sigma_a^{-1} \widehat{r}_t^k.$$

Allowing for variable capital utilisation dampens the response of the rental rate of capital to a shock, which in turn dampens the response of real marginal costs. Investment adjustment costs are captured by φ_K. Current investment $\widehat{I}_t$ depends on lagged investment, expected future investment and the real cost of capital,

$$\widehat{I}_t - \widehat{I}_{t-1} = \varphi_K \widehat{q}_t + \beta \mathrm{E}_t\{\widehat{I}_{t+1} - \widehat{I}_t\}.$$

The parameter φ_K measures the elasticity of investment with respect to current price of installed capital. Physical capital depreciates at rate δ_K, such that capital accumulation is given by

$$\widehat{K}_t = (1 - \delta_K)\,\widehat{K}_{t-1} + \delta_K \widehat{I}_{t-1}.$$

Finally, we introduce differentiated labour types into the model following Erceg et al (2000). Labour types are bundled according to a CES aggregator with elasticity θ_w. Quadratic wage adjustment costs (captured by κ_w) and indexation (captured by λ_w) are introduced, such that wage setting frictions are analogous to price setting frictions. Wage inflation in period t, $\widehat{\pi}_{w,t}$, depends positively on its expected future value and negatively on the difference between the real wage $\widehat{w}_t$ and the marginal rate of substitution between labour and consumption $\widehat{U}_{L,t} - \widehat{U}_{C,t}$. In the presence of wage indexation, wage inflation also depends on current and lagged welfare-based inflation,

$$\widehat{\pi}_{w,t} - \lambda_w \widehat{\pi}_{p,t-1}^C = -\phi_w[\widehat{w}_t - (\widehat{U}_{L,t} - \widehat{U}_{C,t})] + \beta \mathrm{E}_t\{\widehat{\pi}_{w,t+1} - \lambda_w \widehat{\pi}_{p,t}^C\}, \tag{10}$$

where $\phi_w = (\theta_w - 1)/\kappa_w$ is the slope of the wage inflation equation.

3.3 Market Clearing

In equilibrium, total labour supply equals the sum of labour used in the production of goods and labour used in the production of new firms, weighted by their respective steady state shares,

$$\widehat{L}_t = \frac{L_C}{L}\widehat{L}_{C,t} + \frac{L_E}{L}\widehat{L}_{E,t}.$$

Similarly, total capital is a weighted average of capital used in the production of goods and capital used in the production of new firms,

$$\widehat{K}_t = \frac{K_C}{K}\widehat{K}_{C,t} + \frac{K_E}{K}\widehat{K}_{E,t}.$$

The aggregate accounting identity is given by

$$
\begin{aligned}
&\frac{Y^C}{Y}\widehat{Y}_t^C + \frac{vN_E}{Y}\left(\widehat{mc}_t + \widehat{N}_{E,t}\right) + \frac{I}{Y}\widehat{I}_t + \frac{r^kK}{Y}\widehat{u}_t, \\
= \ &\frac{dN}{Y}\left(\widehat{d}_t + \widehat{N}_{t-1}\right) + \frac{wL}{Y}\left(\widehat{w}_t + \widehat{L}_t\right) + \frac{r^kK}{Y}\left(\widehat{r}_t^k + \widehat{K}_{t-1} + \widehat{u}_t\right),
\end{aligned}
$$

where Y is steady state GDP. Total expenditure comprises aggregate consumption, investment in new firms and new capital, and utilisation adjustment costs. Total income is the sum of dividend income, labour income and rental income.

3.4 Monetary Policy

Monetary policy is described by a Taylor rule with interest rate smoothing. The monetary authority adjusts the interest rate in response to changes in product price inflation, GDP, and last period's interest rate.[9] The feedback coefficients are, respectively, τ_π, τ_Y and τ_R, such that

$$\widehat{R}_t = \tau_R\widehat{R}_{t-1} + (1 - \tau_R)\tau_\pi\widehat{\pi}_{p,t} + (1 - \tau_R)\tau_Y\widehat{Y}_t + \eta_t^R,$$

where η_t^R is an exogenous monetary policy shock with autocorrelation coefficient ρ_η and standard error σ_η.

4 Estimation Method

4.1 Calibration

The model parameters are partitioned into two groups. The first collects the parameters which are calibrated. These include parameters given by first order moments in the data, as well as parameters that cannot be separately identified. Let

$$\psi^c = (\beta, \sigma_L, \alpha, \delta_K, \delta_N, \lambda_p, \lambda_w, \Gamma)'$$

denote the vector of calibrated parameters whose values are reported in Table 3.

[insert Table 3 here]

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[9]BGM (2007) and Bergin and Corsetti (2008) show that in the presence of appropriate corrective fiscal policies, the optimal monetary policy stabilises product prices rather than the welfare-based price index that varies with the number of differentiated goods. The latter is typically not observed by the central bank.

The subjective discount factor is set to $\beta = 0.99$, implying a steady-state annualised real interest rate of 4%. Following Christiano et al (2005), we assume a quadratic labour disutility function, implying $\sigma_L = 1$. As is conventional in the literature, the elasticity of output to capital is set to $\alpha = 0.33$. In addition, the value $\delta_K = 0.025$ implies an annual capital depreciation rate of 10%. Following BGM (2007), the firm exit rate δ_N is set to 0.025, so as to fit the job destruction rate of 10% per year observed in US data. That value is also close to the estimate of Cecioni (2010), who documents an annual firm exit rate of about 12% implying that $\delta_N = 0.03$. This parameter plays a key role for the model's persistence: a higher value of δ_N implies less persistent dynamics. We assume full indexation of prices and wages as in Christiano et al (2005) and set $\lambda_p = \lambda_w = 1$. When we estimated these parameters they were driven to their upper bound of unity. The parameters θ_w and κ_w cannot be separately identified since they appear only jointly in (10). Consequently, we estimate only ϕ_w, the slope of the wage inflation equation. The steady state government spending share in output Γ is set to 21%.

4.2 Minimum Distance Estimation

The second set of model parameters is estimated by minimum distance estimation. Let ψ denote the vector of estimated parameters

$$\psi = \left(\sigma_\eta, \rho_\eta, \sigma_C, b, \sigma_a^{-1}, \phi_p, \phi_w, \varphi_K, \varphi_N, \varepsilon^{yp}, \eta, \nu_w, \nu_v, \tau_R, \tau_\pi, \tau_Y\right)',$$

In a first step, a VAR is estimated as outlined in Section 2. Since the welfare-based price index, which includes the variety effect, is unobserved, we posit that measured inflation corresponds to the variable $\hat{\pi}_{p,t}$ in the model. We use the change in the GDP deflator to measure inflation; our conclusions are robust if we instead use consumer price inflation.

In a second step, the theoretical counterparts of vector Φ, denoted by $\Phi^m(\psi^c, \psi)$, are obtained from the theoretical system which has been solved with the AIM algorithm (Anderson and Moore, 1985). In the model, real variables are deflated by the welfare-based price index, which is not observed. To obtain data-consistent model variables, we divide each real variable by the real product price ρ_t. See BGM (2007) for details. Note that this transformation leaves the variety effect on welfare intact. Estimated values of ψ, denoted by $\hat{\psi}_T$, fulfil[10]

$$\hat{\psi}_T = \arg\min_{\psi \in \Psi} \ [\Phi^m(\psi^c, \psi) - \hat{\Phi}_T]' W_T [\Phi^m(\psi^c, \psi) - \hat{\Phi}_T], \tag{11}$$

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[10] Since commodity prices CRB_t have no counterpart in the DSGE model, the response of this variable is removed from Φ_T for the MDE procedure.

where W_T is a diagonal matrix with the inverse of the asymptotic variances of each element of $\hat{\Phi}_T$ along the diagonal. Following Christiano et al (2005), the standard errors of the estimated parameters are computed using the asymptotic delta function method applied to the first order condition associated with (11).

The goodness-of-fit of the model is quantified by resorting to bootstrap techniques so as to reveal the distribution of the minimum distance. Recall that since the weighting matrix W_T is not optimal, this statistic is not distributed as a χ^2 with $\dim(\hat{\Phi}_T) - \dim(\hat{\psi}_T)$ degrees of freedom. Bootstrapping the minimum distance allows us to circumvent this difficulty. For each model, 200 bootstrap replications of the VAR model are generated. For each replication, the parameters of the DSGE models are re-estimated and the value of the minimum distance is computed. Then, the bootstrapped distribution of this distance allows us to deduce a p-value for the overidentification test. This methodology enables us to check whether the DSGE model passes the overidentification test implied by the choice of moments.

5 Results

The discussion of our estimation results is in four parts. We first assess the overall performance of our model at reproducing the dynamic responses to a monetary policy shock. Second, we compare the estimation results of the benchmark model with those obtained from a model without firm entry, a summary of which is provided in Appendix 2. Third, we evaluate the two hypotheses of how entry affects inflation: love of variety and the competition effect. Finally, we carry out several counterfactual exercises where we vary one parameter at a time.

5.1 Overall Model Performance

Figure 2 compares the SVAR-based and model-based IRFs of the variables to a monetary policy shock in the model without firm entry. The variable net business formation has no counterpart in the model and is therefore removed from the SVAR prior to estimation.

[insert Figure 2 here]

As can be seen from Figure 2, the standard model, while being silent on firm dynamics, is rich enough to capture the other responses to a monetary policy shock very well. It reproduces the hump-shaped pattern of output, investment and consumption and it does a good job at matching the persistence of inflation. The magnitude of the response of profits is quite well replicated, while

the model fails to reproduce the countercyclical response of markups over the medium run. The performance of the no-entry model is satisfactory, with a p-value of the overidentification test equal to 36% (see Table 4).

Figure 1 above compares the empirical and theoretical responses of the variables in the benchmark model with endogenous firm entry. The goodness-of-fit of the model is satisfactory; the model-based impulse responses stay within the 95% confidence bands of the empirical responses. With a p-value of 26%, the J-test for overidentification confirms that the data do not reject the model. The model does a very good job at replicating price and wage inflation, investment, consumption, output, and net entry. It is worth noticing that the benchmark model generates less persistence in the response of profits, in comparison with the no-entry model. It does better at replicating the response of markups, especially over the short run. However, the theoretical responses of profits and markups are smaller than their empirical counterparts. This confirms the volatility puzzle emphasised in Colciago and Etro (2010).

5.2 Parameter Estimates

We discuss the estimates of the benchmark model parameters, contrasting them with the parameters of the no-entry model whenever there is a notable difference. Table 4 reports the two sets of estimates.

[insert Table 4 here]

Most of the parameter estimates are significantly different from zero, which implies that the corresponding friction in the model is needed to match the data impulse responses. One notable exception is the elasticity of capital utilisation with respect to the rental rate of capital (σ_a^{-1}) that is not significant. As explained in Christiano et al (2005), this friction is important to generate a rise in labour productivity in response to a monetary loosening. Intuitively, variable capital utilisation allows firms to expand production with only a small increase in hours. Since we do not include productivity in our VAR, this may explain our result.

Consider the estimates of the shock process and the coefficients of the interest rate rule. The standard error and autocorrelation of the shock are estimated at $\sigma_\eta = 0.15$ and $\rho_\eta = 0.86$, respectively. Interest rate smoothing by the central bank, τ_R equals 0.14 and it is insignificant. Thus, monetary policy shocks are persistent over the sample, while monetary policy exhibits a negligible degree of inertia. This is consistent with the finding in Carrillo et al (2007), who argue that the dynamics of

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price and wage inflation are useful for discriminating between policy inertia and persistent shocks. The point estimate of the interest rate rule coefficient on inflation τ_π is above unity ($\tau_\pi = 1.42$), suggesting that monetary policy is active. In the no-entry model, the corresponding parameter estimate is 1.23 and it is not significant. Finally, the estimated interest rate rule coefficient on output τ_Y is driven to its lower bound of zero.

We now turn to the parameters relating to tastes and technology. Consistent with much of the literature, including Christiano et al (2005) and Smets and Wouters (2007), our estimate of the degree of habit persistence, b, is 0.71. It is slightly lower in the no-entry model ($b = 0.66$) that roughly corresponds to the estimates by Christiano et al (2005). This friction helps to reproduce the sluggishness of consumption. The inverse of the elasticity of intertemporal substitution is estimated at $\sigma_C = 3.22$. By assuming a log utility function, Christiano et al (2005) implicitly calibrate $\sigma_C = 1$. Our fairly high estimate may reflect the fact that the consumption series in our VAR does not include durables. The greater smoothness in consumption calls for a lower intertemporal substitution elasticity in the model.

Capital investment adjustment cost are somewhat higher in the benchmark model ($\varphi_K = 7.18$) than in the no-entry model ($\varphi_K = 5.76$). These values are higher than Christiano et al (2005) but consistent with the result in Poilly (2010). At the extensive investment margin, adjustment costs are estimated at $\varphi_N = 8.22$, which is thus comparable to adjustment costs in physical capital investment. This can be explained by the fact that the empirical responses of investment and net entry have a similar magnitude. To our knowledge, this is the first attempt to quantify adjustment costs in firm entry. Our estimate therefore implies that around 14% of startups are unsuccessful. Note that this parameter is distinct from the exit shock that hits a fraction δ_N of entrants as well as established firms.

The working capital channel is parameterised by ν_w, the fraction of the wage bill that must be financed ahead of production. This parameter is driven to its upper bound of unity in the benchmark model. Interestingly, in the no-entry model, the estimate of ν_w is smaller ($\nu_w = 0.59$), suggesting that the working capital channel is weaker. The intuition behind this result is the following. A procyclical impact response of the markup is needed for the model to replicate the observed markup dynamics over the short run, in addition to the price puzzle and the size of the reduction in profits. This requires an increase in marginal costs in response to a monetary contraction, which is delivered through the working capital channel as marginal costs rise along with borrowing costs. Therefore,

the good fit of the short-run markup response in the benchmark model is explained by the larger estimated strength of the working capital channel. For a discussion on how the working capital channel helps to reproduce the price puzzle, see Rabanal (2007) and Henzel et al (2009).

The price elasticity of demand ε^{yp} shows up in conjunction with the price stickiness parameter κ_p in the slope of the NKPC, but it also appears in the profit equation. Consequently, this parameter can be identified using profit data. Our estimate of ε^{yp} is 2.48 in the benchmark model and 5.10 in the no-entry model. A higher elasticity in the no-entry model reinforces the link between profits and markups, see (6). This explains the higher impact response of profits in the no-entry model, in comparison with the benchmark model. Two further comments are in order. First, a steady state markup as high as 60% is not unreasonable in a model with entry costs. This is because firms price at average cost (including entry costs), such that profits in excess of the entry costs are zero in the free-entry equilibrium. In Smets and Wouters' (2007) model with fixed costs, the steady state markup is estimated at 60%, consistent with our result. Second, evidence based on microeconomic data suggests that the empirically relevant range of average markups across sectors is rather wide and includes the values reported here. For instance, Christopoulou and Vermeulen (2008) report 7% for Textiles and 79% for Public Administration and Defence. The same holds true for estimates of substitution elasticities across goods ranging from 1.2 for Footwear to 17 for Crude oil (see Broda and Weinstein, 2006).[11] Our estimate of ε^{yp} is, however, inconsistent with one of the great ratios in the model itself. As we show in a separate model appendix, the inverse of the demand elasticity equals the steady state profit share in consumption output, $\frac{dN}{YC} = \frac{1}{\varepsilon^{yp}}$. For the US, the average profit share in post-WWII data is consistent with $\varepsilon^{yp} \approx 9$ rather than 2.5. We leave the resolution of this puzzle to future research.

Regarding the nominal frictions, we report the slopes of the wage and price inflation curves in Table 4. The New Keynesian Phillips Curve is slightly flatter in the benchmark model than in the no-entry model; the estimated slope ϕ_p is 0.07 and 0.12, respectively. Given our estimates of ε^{yp}, this implies a Rotemberg price stickiness parameter κ_p of 22 and 35, respectively. These figures are low in comparison with the maximum likelihood estimates in Ireland (2001).[12] Interestingly, this suggests that prices are less sticky in a model with endogenous entry, as suggested by BGM (2007).

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[11]Notice that the within-industry substitution elasticity θ_f is equal to the price elasticity of demand ε^{yp} in the absence of the competition effect, i.e. if $\eta = 0$, which is what we find empirically.

[12]We cannot compare this figure with the numerous estimates of price stickiness that use the Calvo price setting restriction, because the latter relies on a constant population of price setters.

The slope of the wage inflation curve ϕ_w, is significantly estimated at 0.01 in the benchmark model (0.03 in the no-entry model).[13] We confirm Lewis' (2009) result that wage stickiness is key for an endogenous-entry model to generate a negative, and hence empirically plausible, response of firm entry to monetary contractions. The reason is the following. The labour requirement for firm startups makes entry costs depend on real wages. Potential entrants compare entry costs with the present value of profits (i.e., firm value). Firm value decreases through a no-arbitrage condition across assets: the return on shares needs to increase to match the interest rate rise. This happens through a drop in today's share price relative to tomorrow's. Entry decreases only if entry costs fall by less than firm value. Wage stickiness suitably dampens the reaction of real wages and, in turn, of entry costs, resulting in the required drop in entry. While Christiano et al (2005) stress the importance of wage rigidities to dampen marginal production costs, it is the same friction that produces realistic entry dynamics through its attenuating effect on entry costs.

We note that most of the individual parameter estimates are not significantly different across the two models. For all parameters, except the slope of the NKPC, the 95% confidence intervals of the two models overlap. We now investigate the two potential mechanisms through which entry affects inflation.

5.3 Love of Variety and Competition Effect

We estimate ν_v and η in addition to the usual model parameters. These two parameters measure the variety effect and the competition effect, respectively, and thus govern the elasticity of inflation to the number of firms, see (5). They can be separately identified using data on markups and entry. Indeed, ν_v corresponds to the elasticity of markups to net entry, see the price setting equation (2) and the price index equation (3). We can infer ε^{yp} from the elasticity of profits to the markup, see (6). The within-industry substitution elasticity θ_f is determined residually; it is related to the competition effect parameter η and the steady-state demand elasticity ε^{yp} as follows,

$$\theta_f = [\eta(\varepsilon^{yp} - 1) + 1]\varepsilon^{yp}.$$

Our estimation results indicate that η is not significantly different from zero. This suggests that strategic interactions and the competition effect do not help to reproduce the impulse responses to a monetary policy shock. We offer two explanations for this result. First, Figure 1 shows that on

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[13]In the wage setting case, it is valid to compute the Calvo stickiness probability from the estimated slope of the wage inflation curve. Using the relation $\frac{\theta_w - 1}{\kappa_w} = \frac{(1-\beta\alpha_w)(1-\alpha_w)}{\alpha_w(1+\theta_w/\sigma_L)}$, and assuming a wage mark-up of 10% (i.e. $\theta_w = 11$), the corresponding Calvo wage stickiness parameter α_w equals 0.75 in the benchmark model.

impact, the markup reacts pro-cyclically to a monetary policy shock in the data. Therefore, the model with a competition effect fits the data less well at short horizons since it produces a (more) countercyclical markup. Second, a monetary policy shock leads to a procyclical response of net business formation. In the model, however, a high value of η implies a strong negative elasticity of inflation to entry, through the NKPC. The negative co-movement between these two variables is at odds with the empirical dynamics resulting from interest rate shocks. Cecioni (2010) estimates the NKPC (4) and reports $\eta = 1.10$. Her estimates suggest that a 1% increase in the number of firms lowers annual inflation significantly by 0.14 percentage points. This finding is not necessarily inconsistent with our results if the competition effect is more important in the presence of other types of shocks, e.g. technology shocks.

Our estimate of the degree of love for variety is $\nu_v = 1.48$. This is slightly lower than the Dixit-Stiglitz (1977) value $\nu_v = \theta_f / (\theta_f - 1)$ used in BGM (2007), which in our estimation is 1.67. However, our estimate is significantly higher than the calibration in Floetotto and Jaimovich (2008), who implicitly assume $\nu_v = 1$. Consequently, our finding suggests that the variety effect is supported by the data. We are not aware of any other study that estimates the degree of love of variety.

5.4   Counterfactual Exercises

To build intuition for the functioning of our model, we conduct several counterfactual exercises. We use the benchmark parameter estimates and vary one parameter at a time to derive the model-based impulse response functions (i.e., without re-estimation). Figures 3 and 4 show the IRFs of profits, net entry, inflation and the markup for different specifications of the working capital channel (ν_w), nominal rigidities (ϕ_p and ϕ_w), the competition effect (η) and the love of variety (ν_v). Each specification is analysed in detail in the next subsections.

[insert Figure 3 here]

Working Capital

We have seen that the working capital channel is much stronger in the endogenous-entry model than in the no-entry model. Here we show that it is a key assumption to replicate the sign of the markup response on impact. This is because the interest rate influences the markup through its effect on real marginal costs; an increase in R_t implies a negative response of markups. In the left panel of Figure 3, we set the parameter ν_w to 1, 0.5 and 0.

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From the figure, it is clear that a stronger working capital channel makes the markup more pro-cyclical while making profits more volatile. In particular, profits are only slightly responsive to monetary policy shocks for $\nu_w = 0$. Interestingly, the larger the value of ν_w, the stronger the net entry response. Again, the increase in the interest rate has a positive impact on real marginal costs that reduces net entry. Equation (8) shows that this effect is dampened when the adjustment cost, φ_N, is high.

Nominal Rigidities

In the following, we investigate how price and wage rigidities affects the model's dynamics. We consider the model IRFs under the assumption of sticky wages and flexible prices (setting $\phi_p = 0$), as well as under sticky prices and flexible wages (setting $\phi_w = 0$). See the left panel of Figure 3. In the sticky-wage model, markups and profits hardly respond to a monetary policy shock, while the response of net entry is larger in comparison with the benchmark model. We notice a counterfactual pattern of inflation, which rises on impact. This can be explained by the presence of the working capital channel that drives up real marginal costs. Setting price stickiness κ_p to a small value makes inflation very responsive to the pattern of real marginal costs.

The sticky-price model produces counterfactual increases in markups and profits. This happens because wages are flexible, such that real wages fall, reducing in turn real marginal costs. Through the NKPC, inflation mirrors the markup response. The rise in profits dampens the drop in entry. These findings underline the importance of wage stickiness in the endogenous-entry model.

[insert Figure 4 here]

Competition Effect

We now analyse how the competition effect modifies the transmission of monetary policy shocks by setting η to 1.1. As expected, a higher value of η makes markups more countercyclical over the medium run, and more persistent. The fall in net entry also becomes more persistent. In addition, the output drop is stronger (not shown), amplifying the fall in inflation, even if the elasticity of inflation to the number of firms is higher. These results confirm that the competition effect is a key model element to generate countercyclical movements of markups.

Variety Effect

How does love of variety change the propagation mechanism of the model? Our benchmark estimate of parameter ν_v is 1.48. The right panel of Figure 4 shows the IRFs of our variables in the benchmark estimation and when love of variety is absent, corresponding to $\nu_v = 1$. Recall that, since the number of firms is predetermined, the variety effect is zero on impact and small in the short run. Net entry falls by less and returns to steady state faster when the love of variety is higher. Without the variety effect, the responses of entry and profits remain persistently negative. In other words, the variety effect reduces persistence. This is because by lowering the welfare-based price index, entry raises the stochastic discount factor (the growth rate of the marginal utility of one currency unit). The dampening effect on inflation is visible here in that inflation declines less when the variety effect is present. The response of markups is not strongly affected by the love of variety parameter. This explains why our model with endogenous entry does not improve by much the fit of the markup response as compared with the no-entry model.

6   Conclusion

The growing literature on endogenous entry and the extensive margin in business cycles has been mainly theoretical up to now. We estimate a medium-scale DSGE model which includes endogenous firm entry as in Bilbiie et al (2007) in addition to many other frictions. More specifically, we minimise the distance between the model impulse responses to a monetary policy shock and their empirical counterparts in an identified vector autoregression. The exercise is comparable to Christiano et al (2005), who abstract from firm dynamics. Our VAR includes profits, markups and net business formation along with other standard macroeconomic variables. The model is successful at matching the empirical impulse responses, especially that of firm entry. However, the predicted responses of markups and profits are smaller than in the data, confirming the volatility puzzle noted in Colciago and Etro (2010). Our parameter estimates are largely unaffected by the introduction of firm entry. There is no evidence of a competition effect by which a rise in the number of firms reduces desired markups and hence dampens inflation in an expansion. Indeed this effect does not help to capture the countercyclical movement of markups observed in the data. Instead, our results support the love of variety effect: increased product diversity through firm entry lowers the welfare-based price index. Thus, markups rise and under sticky prices, inflation declines.

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Appendix 1: Markup Measure

In this section, we show how to compute an empirical measure of the goods price markup derived from our model.[14] Our markup proxy, denoted by $\widetilde{\mu}_t$, is based on the inverse labour share. It is close to the concept proposed by Rotemberg and Woodford (1991) that corrects for overhead labour, i.e. labour used to set up new production lines. This measure has been used in many studies, including BGM (2007) and Colciago and Etro (2010) in the endogenous-entry literature. The first order condition for labour demand can be manipulated to produce a relation between the markup and the inverse labour share,

$$\widetilde{\mu}_t = \frac{(1-\alpha)\frac{L_t}{L_{C,t}}}{s_t^L R_t^w},$$

where $s_t^L = \frac{w_t L_t}{Y_t^C}$ denotes the ratio of the wage bill to consumption output. Following Colciago and Etro (2010), we assume that the share of workers employed in startup activities $\frac{L_{E,t}}{L_t}$ is constant at 0.2, such that $\frac{L_t}{L_{C,t}} = 1.25$. The parameter α is set to 0.33, as before. The interest rate R_t^w is not

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[14]In a model without firm entry, the markup is simply expressed as the inverse labor share.

observed. Recall that this variable reflects the borrowing costs to firms that have to pay a fraction ν_w of the wage bill in advance. Given our estimate $\nu_w = 1$, we set this borrowing cost equal to the Federal Funds Rate.

Appendix 2: DSGE Model without Entry

$$\widehat{Y}_t^C = \alpha \widehat{K}_t^s + (1 - \alpha) \widehat{L}_t$$

$$\widehat{R}_t^w = \frac{\nu_w R}{\nu_w R + (1 - \nu_w)} \widehat{R}_t$$

$$\widehat{r}_t^k + \widehat{K}_t^s = \widehat{w}_t + \widehat{R}_t^w + \widehat{L}_t$$

$$\widehat{mc}_t = \alpha \widehat{r}_t^k + (1 - \alpha) \left(\widehat{w}_t + \widehat{R}_t^w \right)$$

$$\widehat{Y}_t^C = (1 - \Gamma) \widehat{C}_t$$

$$0 = \widehat{\mu}_t + \widehat{mc}_t$$

$$\widehat{d}_t = (\theta_f - 1) \widehat{\mu}_t + \widehat{y}_t$$

$$\widehat{\pi}_{p,t} - \lambda_p \widehat{\pi}_{p,t-1} = -\phi_p \widehat{\mu}_t + \beta E_t \{ \widehat{\pi}_{p,t+1} - \lambda_p \widehat{\pi}_{p,t} \}$$

$$\widehat{U}_{C,t} = -\frac{\sigma_C}{1 - b} \left(\widehat{C}_t - b \widehat{C}_{t-1} \right)$$

$$\widehat{U}_{L,t} = -\sigma_L \widehat{L}_t$$

$$\widehat{K}_t^s = \widehat{u}_t + \widehat{K}_t$$

$$\widehat{u}_t = \sigma_a^{-1} \widehat{r}_t^k$$

$$\widehat{U}_{C,t} = \widehat{R}_t - E_t \{ \widehat{\pi}_{p,t+1} - \widehat{U}_{C,t+1} \}$$

$$\widehat{q}_t = E_t \left\{ \widehat{U}_{C,t+1} - \widehat{U}_{C,t} + [1 - \beta (1 - \delta_K)] \widehat{r}_{t+1}^k + \beta (1 - \delta_K) \widehat{q}_{t+1} \right\}$$

$$\widehat{I}_t - \widehat{I}_{t-1} = \varphi_K \widehat{q}_t + \beta E_t \{ \widehat{I}_{t+1} - \widehat{I}_t \}$$

$$\widehat{\pi}_{w,t} - \lambda_w \widehat{\pi}_{p,t-1} = -\phi_w [\widehat{w}_t - (\widehat{U}_{L,t} - \widehat{U}_{C,t})] + \beta E_t \{ \widehat{\pi}_{w,t+1} - \lambda_w \widehat{\pi}_{p,t} \}$$

$$\frac{wL}{Y} \left(\widehat{w}_t + \widehat{L}_t \right) + \frac{r^k K}{Y} \left(\widehat{r}_t^k + \widehat{K}_t + \widehat{u}_t \right) = \frac{Y^C}{Y} \widehat{Y}_t^C + \frac{I}{Y} \widehat{I}_t + \frac{r^k K}{Y} \widehat{u}_t$$

$$\widehat{K}_t = (1 - \delta_K) \widehat{K}_{t-1} + \delta_K \widehat{I}_{t-1}$$

$$\widehat{R}_t = \tau_R \widehat{R}_{t-1} + (1 - \tau_R) \tau_\pi \widehat{\pi}_{p,t} + (1 - \tau_R) \tau_Y \widehat{Y}_t + \eta_t^R$$

$$\widehat{\pi}_{p,t} = \widehat{\pi}_{w,t} - (\widehat{w}_t - \widehat{w}_{t-1})$$

Table 1. Data Series

Series ID	Variable	Description	Construction
Variables used in Vector Autoregression			
$RGDP_t$	Real GDP	real gross domestic product	$\frac{GDP_t}{GDPDEF_t}$
$RFPI_t$	Real Investment	real fixed private investment	$\frac{FPI_t}{GDPDEF_t}$
$RPCE_t$	Real Consumption	real personal consumption expenditures on services and non-durable goods	$\frac{PCESV_t+PCND_t}{GDPDEF_t}$
$WINFL_t$	Wage Inflation	growth rate of hourly compensation	$\Delta \log\left(COMPNFB_t\right)$
$PINFL_t$	Price Inflation	growth rate of GDP deflator	$\Delta \log\left(GDPDEF_t\right)$
NBF_t	Net Entry	net business formation index	average of monthly figures
$RPROFITS_t$	Real Profits	real corporate profits	$\frac{CPROFIT_t}{GDPDEF_t}$
$MARKUP_t$	Markup	model-consistent markup measure	$\widetilde{\mu}_t$
CRB_t	Commodity Prices	commodity price index	CRB_t
$FEDFUNDS_t$	Interest Rate	Effective Federal Funds Rate	avg of monthly figures
Variables used in Markup Measure			
s_t^L	Labour Share	labour share in consumption output	$\frac{COE_t}{PCEC_t+GCE_t}$

For details on how the markup is constructed, see Appendix 1.

Table 2. Data Sources

Series Titel	Units, Frequency, Seasonal Adjustment	FRED Series ID	Source
Gross Domestic Product	Billions of $, Q, SAAR	GDP	BEA
Fixed Private Investment	Billions of $, Q, SAAR	FPI	BEA
Personal Consumption Expenditures: Services	Billions of $, Q, SAAR	PCESV	BEA
Personal Consumption Expenditures: Nondurable Goods	Billions of $, Q, SAAR	PCND	BEA
Gross Domestic Product: Implicit Price Deflator	Index, Q, SA	GDPDEF	BEA
Effective Federal Funds Rate	Percent, M, n.a.	FEDFUNDS	Board
Compensation Per Hour (Nonfarm Business Sector)	Index, Q, SA	COMPNFB	BLS
Net Business Formation	Index, M, none	n.a.	BEA
Corporate Profits with IVA and CCAdj.	Billions of $, Q, SAAR	CPROFIT	BEA
CRB Raw Industrials Sub-index	Index, M, none	n.a.	Bridge CRB
National Income: Compensation of Employees, Paid	Billions of $, Q, SAAR	COE	BEA
Personal Consumption Expenditures	Billions of $, Q, SAAR	PCEC	BEA
Government Consumption Expenditures & Gross Investment	Billions of $, Q, SAAR	GCE	BEA

Notes: FRED = Federal Reserve Economic Data. BEA = U.S. Department of Commerce: Bureau of Economic Analysis. BLS = U.S. Department of Labor: Bureau of Labor Statistics. Board: Board of Governors of the Federal Reserve System. Bridge CRB = Bridge Commodity Research Bureau. Data on Net Business Formation are from the BEA Survey of Current Business. Q = quarterly, M = monthly, SA = seasonally adjusted, SAAR = seasonally adjusted annual rate.

Table 3. Calibrated Parameters

β	Discount factor	0.99
σ_L	Inverse elasticity of labour supply to real wage	1
α	Capital share in production	0.33
δ_K	Depreciation rate of capital	0.025
δ_N	Firm exit rate	0.025
λ_p	Price indexation	1
λ_w	Wage indexation	1
Γ	Steady-state government spending share in output	0.21

Table 4. Results of Minimum Distance Estimation (1954Q4-1995Q2)

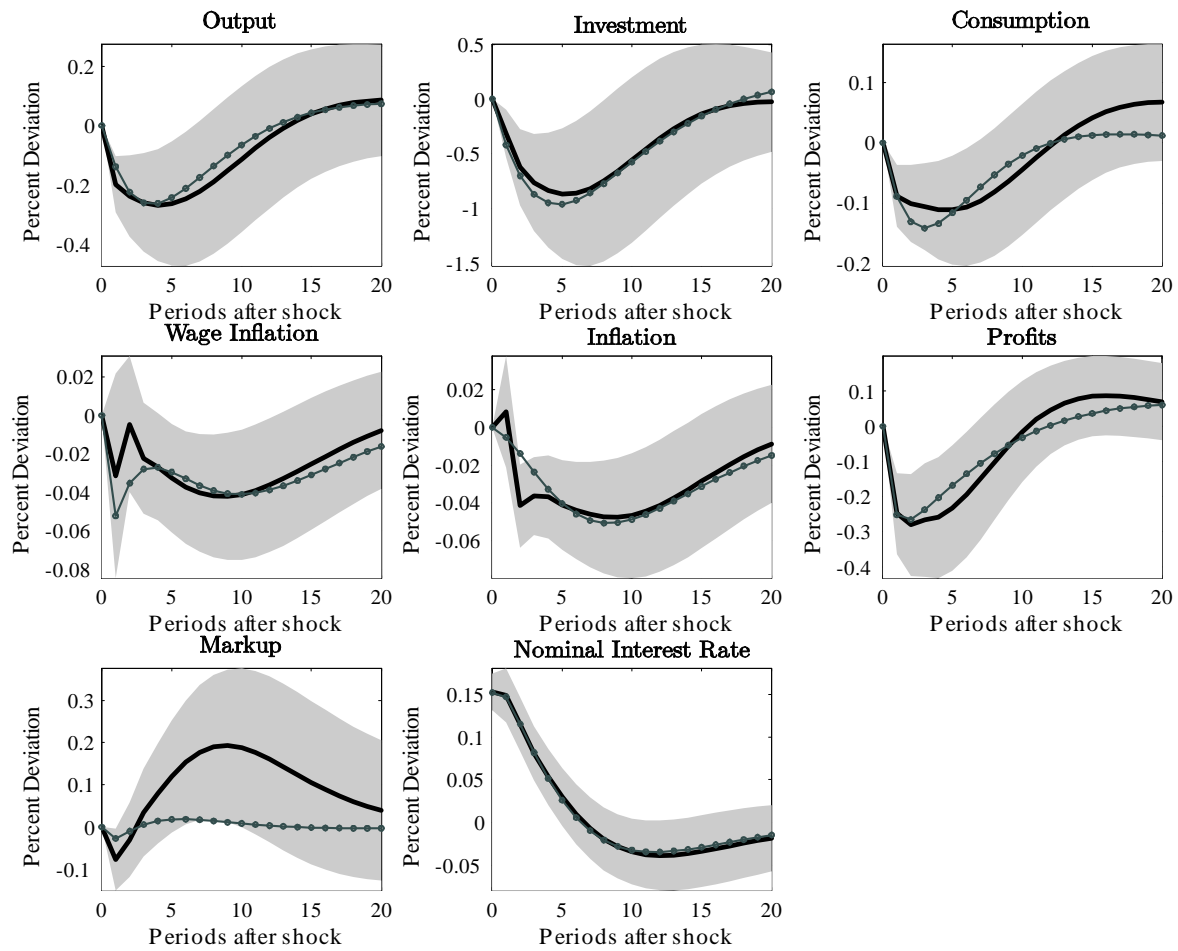|		Entry Model	No-Entry Model
Monetary Policy Shock			
σ_η	Standard error	0.154 (0.012) [0.13,0.18]	0.152 (0.013) [0.13,0.18]
ρ_η	Autocorrelation	0.856 (0.043) [0.77,0.94]	0.824 (0.190) [0.45,0.99]
Nominal and Real Frictions			
σ_C	Inverse elast. of intertemporal substitution	3.221 (0.762) [1.73,4.71]	3.319 (0.649) [2.05,4.59]
b	Habit persistence	0.714 (0.090) [0.54,0.89]	0.664 (0.087) [0.49,0.83]
σ_a^{-1}	Elasticity of utilisation w.r.t. rental rate	1.444 (0.956) [0.00,3.32]	0.087 (0.184) [0.00,0.45]
κ_p	Rotemberg price stickiness	21.749 (10.210) [1.74,41.76]	34.750 (24.022) [0,81.83]
ϕ_p	Elasticity of price inflation w.r.t. markup	0.068 (0.001) [0.07,0.07]	0.118 (0.003) [0.11,0.12]
ϕ_w	Elast. of wage inflation w.r.t. labour wedge	0.007 (0.004) [0.00,0.01]	0.030 (0.014) [0.00,0.06]
φ_K	Investment adjustment cost	7.183 (1.730) [3.79,10.57]	5.763 (0.962) [3.88,7.65]
φ_N	Entry adjustment cost	8.223 (1.796) [4.70,11.74]	n.a.
ε^{yp}	Price elasticity of demand	2.478 (0.638) [1.23,3.73]	5.098 (2.419) [0.36,9.84]
ν_w	Fraction of wage bill paid in advance	1.000 (∗)	0.589 (0.190) [0.22,0.96]
ν_v	Love of variety	1.485 (0.205) [1.15,1.82]	n.a.
η	Competition effect	0.000 (∗)	n.a.
Monetary Policy Rule			
τ_R	Interest rate smoothing	0.145 (0.088) [0.00,0.32]	0.177 (0.234) [0.00,0.64]
τ_π	Interest rate rule coefficient on inflation	1.417 (0.518) [0.40,2.43]	1.228 (1.186) [0.00,3.55]
τ_Y	Interest rate rule coefficient on output	0.000 (∗)	0.000 (∗)
$\mathcal{J}-stat$		65.871 (0.257)	49.671 (0.365)

The numbers in parentheses are the standard errors of the parameter estimates and the p-values of the J-statistics, respectively. A star (∗) refers to a constraint imposed during the estimation stage to avoid convergence problems. The numbers in square brackets are the 95% confidence intervals around each point estimate.

Figure 1: **Entry Model** : Impulse Response Functions to a Monetary Policy Shock.
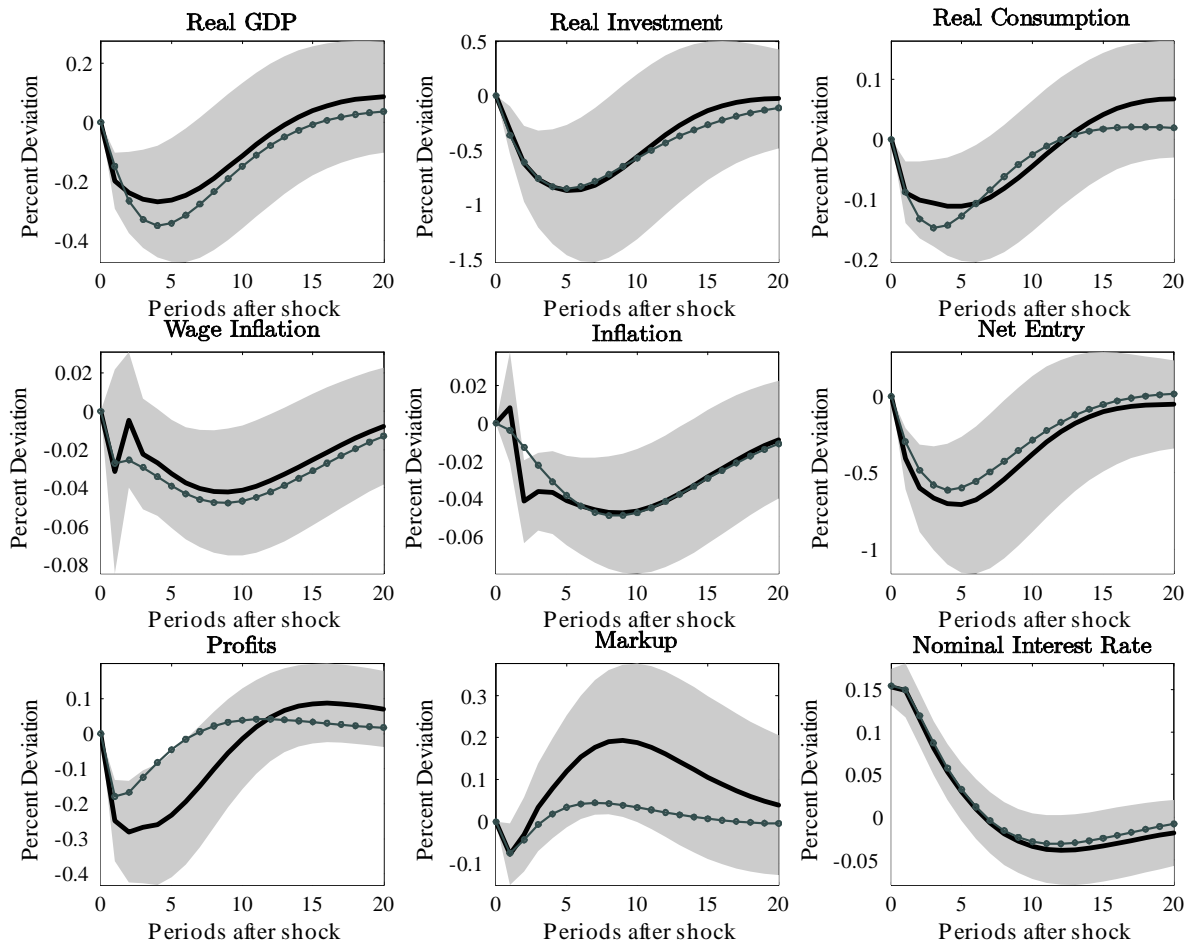

Entry Model: SVAR-based IRFs (solid lines) and model-based IRFs (lines with circles) (multiplied by 100). Grey areas correspond to 95% confidence intervals.

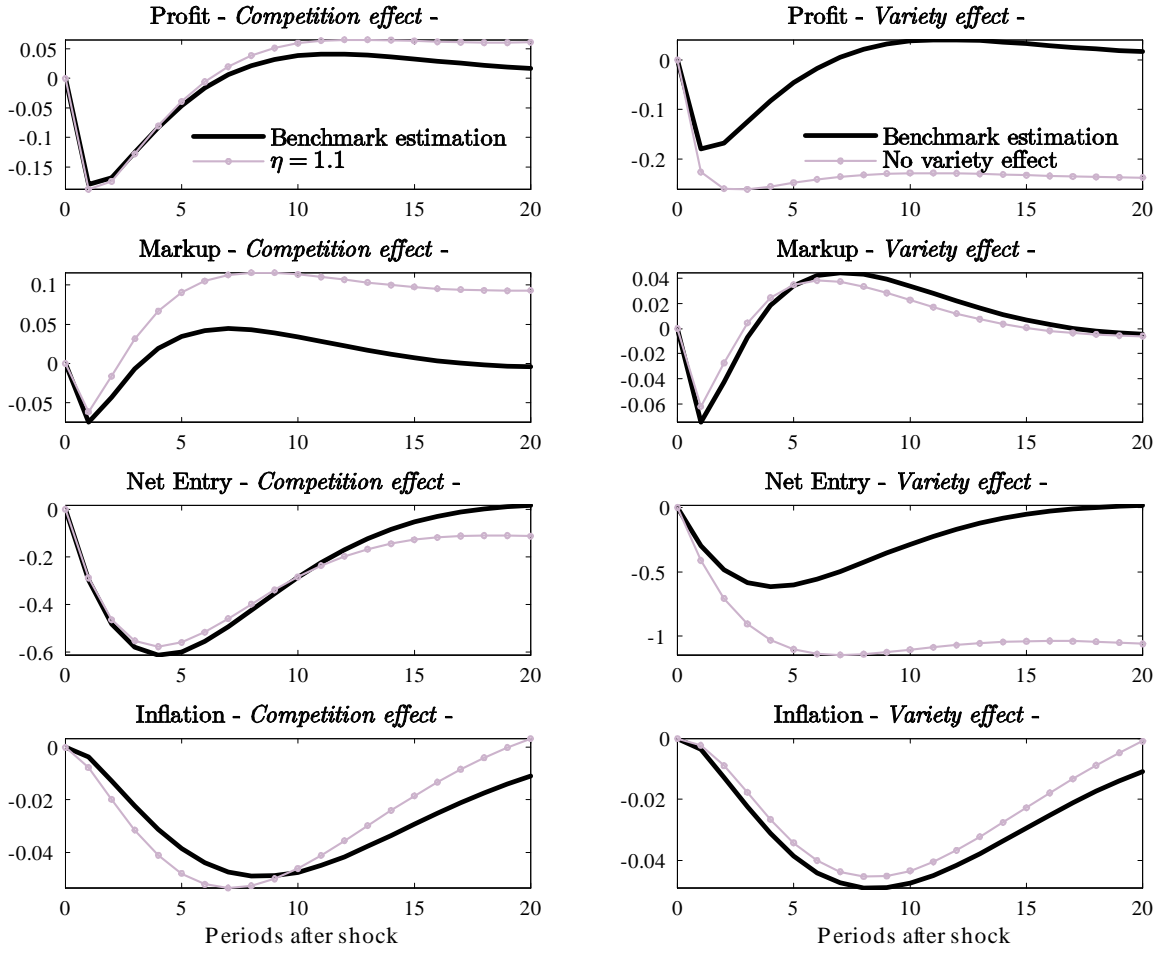Figure 2: **No-Entry Model**: Impulse Response Functions to a Monetary Policy Shock.

No-entry Model: SVAR-based IRFs (solid lines) and model-based IRFs (lines with circles) (multiplied by 100). Grey areas correspond to 95% confidence intervals.

Figure 3: **Counterfactual Exercises.**
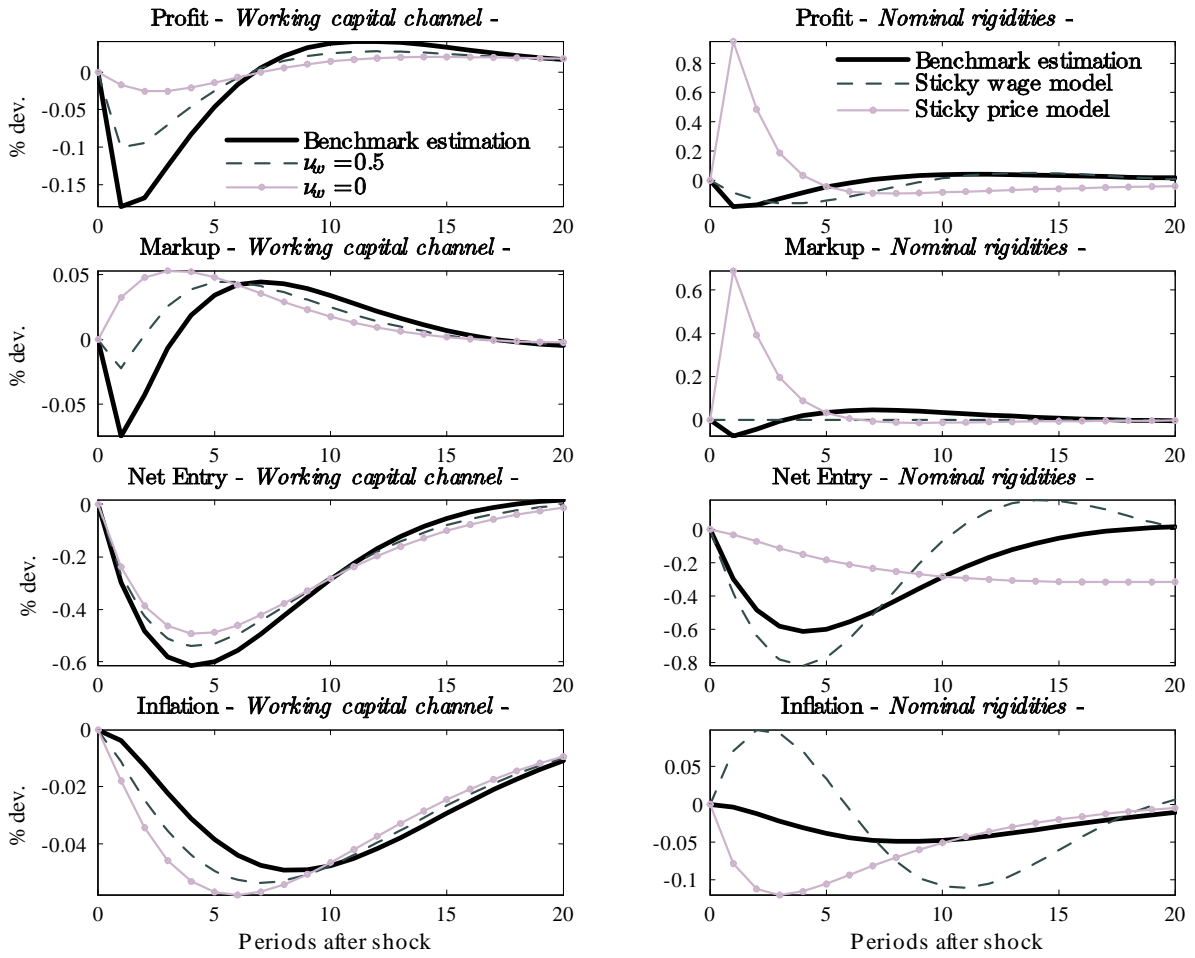
Counterfactual Exercises: Left panel: change in working capital channel (ν_w). Right panel: change in price stickiness (ϕ_p) and in wage stickiness (ϕ_w).

Figure 4: **Counterfactual Exercises.**

Profit - *Competition effect* -

Profit - *Variety effect* -

Markup - *Competition effect* -

Markup - *Variety effect* -

Net Entry - *Competition effect* -

Net Entry - *Variety effect* -

Inflation - *Competition effect* -

Inflation - *Variety effect* -

Periods after shock

Periods after shock

Benchmark estimation
$\eta = 1.1$

Benchmark estimation
No variety effect

Counterfactual Exercises: Left panel: change in competition effect (η). Right panel: change in love of variety (ν_v).