Firm Turnover, Financial Friction and Inflation

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Abstract

This paper examines the role of firm turnover and financial friction in understanding inflation. I augment a standard New-Keynesian DSGE model with the two features and estimate with the Bayesian technique for the US economy. My findings demonstrate that entry cost and exogenous firm exit shocks are essential in explaining the dynamics of inflation at the business cycle frequency. Financial friction does not change relative importance of the structural shocks in explaining inflation, but helps the model to explain the effects of monetary shocks to firm turnover.

Keywords: inflation, New-Keynesian Phillips curve, firm turnover, financial friction

JEL codes: E32, C11, E23

1 Introduction

The New-Keynesian Phillips curve is one of the key equations in dynamic stochastic general equilibrium (DSGE) models. However the Phillips curve can explain only partially and inflation is described by exogenous shocks. For example in Smets and Wouters (1998) exogenous price markup shocks explain more than half of the variance in inflation during first years after the shock. This paper examines how firm turnover and financial friction help explaining inflation dynamics. The two factors enter the New-Keynesian

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Phillips curve directly and therefore can potentially help improving the empirical fit of the equation.

I augment a standard medium scale sticky price and sticky wage New Keynesian DSGE model such as Smets and Wouters (1998) with two additional features. First, the number of firms in the economy is variable. I assume that the creation of firms is labor intensive and allow the death rate of firms to be stochastic. The number of firms is determined by free entry condition and the number of firms determines the markup dynamics in the economy (see Bergin and Corsetti (2008), Bilbiie et al. (2007) and Bilbiie et al. (2012)). The law of motion for the number of firms is based on Bilbiie et al. (2007). Second I allow for a financial friction in the economy. Firms borrow resources from banks to pay for a share of production costs in advance. This way an interest rate change has a direct impact on the costs of production. The financial friction is based on the seminal work by Christiano et al. (1997) and Ravenna and Walsh (2003) and more recently employed by Rabanal (2006) and Uhlig (2007).

The model economy is described by the following 5 structural shocks: monetary policy, labor productivity, wage cost-push shocks, a shock to the fixed cost of starting a business, and a shock to the firm survival probability. I match the model with five U.S. data series: consumption, hours, inflation, the interest rate, and the creation of firms for the period 1983Q1-1998Q3. I estimate the parameters of the model with the Bayesian likelihood approach and use the variance decomposition at the business cycle frequency and the forecast error variance decomposition to discuss the main results.

The results show that firm dynamics play an important role in describing inflation. The shocks to the cost of firm creation explain two-thirds of the variance in inflation at the business cycle frequency. However increasing number of firms does not lead to immediate decrease in prices. As firm creation is labor intensive, a drop in the cost of entry leads to an increase in the demand in labor, resulting in an increase in marginal costs and inflation. As more firms are created and the number of firms is increasing the markup effect becomes stronger and inflation drops again.

Estimation results point towards a high level of financial friction: around 80% of the production costs are borrowed from the banks. However I find little evidence that the cost channel is important in explaining the volatility of inflation at the business cycle frequency. The results are in line with the findings of Ravenna and Walsh (2003) who find evidence for the cost channel. But compared to Rabanal (2006) my estimate for the financial friction is relatively high. He also estimates a DSGE model using Bayesian technique and finds that 15% of the costs are borrowed from the banks. Also Uhlig (2007) calibrates the share of costs borrowed from the banks to 10%. Similarly to these papers
I find that the financial friction has little to explain in inflation dynamics. Instead I find that financial friction is important in explaining the effects of monetary policy shock. Without financial friction the model would predict that the number of firms falls after a monetary expansion. This would be in sharp contrast with the empirical evidence from VAR literature stating that the number of firms increases with positive monetary shocks. In my model financial sector plays a big role in reproducing this stylized fact.

The model assigns very little importance to the wage cost-push shocks. This is in sharp contrast with the findings of Smets and Wouters (1998). Technology shocks explain 17% of the variance in inflation at over the business cycle. This is in accordance with the DSGE and VAR evidence where the role of technology shocks is around one-fifth (see Smets and Wouters (1998) for the DSGE and Altig et al. (2003) for the VAR literature). Finally, monetary shocks and firm survival shocks explain around six percent of the variance in inflation at the business cycle frequency.

The paper contributes to three strands of literature. First it shows that inclusion of the firm turnover can improve the empirical fit of the New-Keynesian Phillips curve and improve standard DSGE models. Second the results of the Bayesian full likelihood estimation demonstrate that DSGE models with firm turnover might need to be calibrated differently from the models without firm turnover. Thirdly the paper shows that although increasing number of firms may result in lower inflation, policies promoting firm creation that result in the higher number of firms, might be inflationary in the short run.

The rest of the paper is organized as follows. Second chapter introduces the model with financial frictions and firm turnover. Third chapter gives a short overview of the data and the estimation approach. Basic results are presented in chapter four and chapter five concludes.

2 The model

In the first section I present a New Keynesian dynamic stochastic general equilibrium model with financial friction and the creation and destruction of firms. There are five types of agents in the economy: final goods producers, intermediate goods producers, households, banks and a government.

Households maximize their utility from consumption and leisure, firms maximize profits. In the final goods sector, firms operate under full competition and aggregate inputs from the intermediate firms into consumption good. In the intermediate goods production sector firms operate under monopolistic competition structure. The firms
are subject to stochastic death shocks and the creation of firms is labor intensive. The number of firms in the intermediate goods sector is determined by the free entry condition.

The economy has a financial sector. It takes deposits from the households and receives monetary injections from the government. Banks give loans to the intermediate firms as the firms are assumed to borrow a share $\xi$ of their wage bill from the banks. Finally, monetary policy authority decides about the monetary injections to commercial banks by targeting the interest rate.

2.1 Household problem

The representative household maximizes discounted lifetime utility from consumption $c_t$ and dislikes time spent at work $n_t$.

$$U_t = E_t \left[ \sum_{t=0}^{\infty} \beta^t \left( \frac{(c_t - \chi c_{t-1})^{1-\frac{1}{\sigma}}}{1 - \frac{1}{\sigma}} - \frac{An_t^{1+\frac{1}{\kappa}}}{1 + \frac{1}{\kappa}} \right) \right]$$

where $\beta$ is the discount factor, $\chi$ is the consumption habit parameter, $\sigma$ is the intertemporal elasticity of substitution, $\kappa$ is the Frisch elasticity of labor supply, $A$ is scaling parameter, and $E_t$ is the conditional expectations operator.

Households need cash at hand to buy a fraction $\eta$ of the consumption ($C_t$). The cash in advance constraint is $H_{t,\text{res}} + \eta C_t = H_{t-1}$ where $H_{t,\text{res}}$ is the residual cash holding, which in equilibrium equals zero, and $H_{t-1}$ is cash at hand in period $t$. Divide the equation by $P_t$ to get the real budget constraint

$$h_{t,\text{res}} + \eta c_t = \frac{h_{t-1}}{\pi_t},$$

where $c_t = \frac{C_t}{P_t}$, $h_{t,\text{res}} = \frac{H_{t,\text{res}}}{P_t}$, and $h_{t-1} = \frac{H_{t-1}}{P_t}$.

Households face a sequence of budget constraints. The available funds in period $t$ consist of the income from working, deposits, bonds, profits, transfers and residual cash.

$$H_t + D_t + q_t B_t + (1 - \eta)C_t = W_t n_t + (1 + i_t)D_{t-1} + B_{t-1} + H_{t,\text{res}} + V_t + G_t$$

where $D_t$ is deposit with banks, $q_t$ is the discount price for the government bonds $B_t$, $1 + i_t$ is the gross return on deposits made the previous period, $G_t$ are the government transfers, and $V_t$ are the profits received from the household’s ownership of intermediate goods firms. The money is spent on non-cash consumption, or saved in bonds, and kept
in cash or deposits.

In real terms, the equation is given by

\[ h_t + d_t + q_t b_t + (1 - \eta) c_t = w_t u_t + (1 + i_t) \frac{d_{t-1}}{\pi_t} + \frac{b_{t-1}}{\pi_t} + h_{t, res} + v_t + g_t \]  \hspace{1cm} (4)

where \( d_t = \frac{D_t}{P_t} \), \( b_t = \frac{B_t}{P_t} \), \( w_t = \frac{W_t}{P_t} \), \( g_t = \frac{G_t}{P_t} \), \( v_t = \frac{V_t}{P_t} \), and \( \pi_t^C \) is consumer inflation defined specifically later.

Labor market is characterized by a sluggish adjustment of the nominal wage.

\[ w_t = (1 - \omega) w_{t-1} + \omega \Upsilon w^f_t \left(1 + u_{t,w} \right) \]  \hspace{1cm} (5)

Where \( w^f_t \) is the market clearing wage, \( \Upsilon \) shows bargaining power of households, and \( u_{t,w} \) is the wage cost-push shock following an ARMA(1,1), \( u_{t,w} = \rho u_{t-1,w} + \varepsilon_{t,w} \) and \( \varepsilon_{t,w} = \rho^m \varepsilon_{t-1,w} + \varepsilon_{t,w} \).

Households choose consumption, bonds, cash at hand, deposits, and work hours. The Lagrange multiplier on the cash in advance equation is \( \varpi_t \) and budget constraint \( \lambda_t \). The first order conditions are:

\[ \eta \varpi_t = -(1 - \eta) \lambda_t + (c_t - \chi c_t-1)^{\frac{1}{\beta}} - \beta \chi (c_t+1 - \chi c_t)^{\frac{1}{\beta}} \]  \hspace{1cm} (6)

\[ \lambda_t q_t = \beta E \left[ \frac{\lambda_{t+1}}{\pi_{t+1}} \right] \]  \hspace{1cm} (7)

\[ \lambda_t = \beta E \left[ \frac{\varpi_{t+1}}{\pi_{t+1}} \right] \]  \hspace{1cm} (8)

\[ \lambda_t = \beta E \left[ \frac{1 + i_{t+1}}{\pi_{t+1}} \right] \]  \hspace{1cm} (9)

\[ \lambda_t w^f_t = An \]  \hspace{1cm} (10)

The optimality condition for the labor-leisure choice gives the market clearing wage \( w^f_t \).

2.2 Final good firms

Final good firms maximize profits

\[ P_t y_t - \int_{0}^{F_t} p_{t,j} y_{t,j} d\bar{j} \]  \hspace{1cm} (11)
where \( y_t \) is the final output, \( F_t \) is the number of intermediate inputs indexed by \( j \) with prices \( p_{t,j} \) and quantities \( y_{t,j} \). Firms use a CES aggregator for production

\[
y_t = \left( \int_0^{F_t} \frac{1}{y_{t,j}} \right)^{1+\mu}
\]

where \( \mu = \frac{1}{\sigma - 1} \) and \( \sigma \) is the intertemporal elasticity of substitution between intermediate goods. After some algebra, the demand for the intermediate inputs is following:

\[
y_{t,j} = \left( \frac{P_t}{p_{t,j}} \right)^{\frac{1+\mu}{\mu}} y_t
\]

where the price index is given by \( P_t = \left( \int_0^{F_t} \frac{1}{p_{t,j}} \right)^{-\mu} \). The relative price is given by \( \rho_t = \frac{p_{t,j}}{P_t} = N^\mu \).

In the equilibrium all firms are the same so \( p_{t,j} = p_t \). Inflation \( \pi_t = \frac{p_t}{p_{t-1}} \) is described in terms of intermediate goods prices and therefore the consumer inflation index \( \pi_t^C \) is given by \( \frac{\pi_t^C}{\pi_t} = \frac{\rho_t}{\rho_{t-1}} = \left( \frac{F_t}{F_{t-1}} \right)^\mu \). A rise in the number if firms leads to a drop in the consumer inflation relative to the intermediate goods inflation rate. When \( \mu \) approaches zero, the elasticity of substitution approaches infinity, and the variety effect on consumer inflation disappears.

### 2.3 Intermediate good firms

Intermediate sector firms produce goods for the final goods sector. The market structure is monopolistic competition and the number of firms is determined by a free entry condition.

Intermediate firms use a production technology which is linear in labor.

\[
y_{t,j} = \gamma_t n_{t,j}
\]

where \( \gamma_t \) is a productivity shock that is assumed to follow an ARMA process \( \gamma_t = \rho_{\gamma} \gamma_{t-1} + \varepsilon_{t,\gamma} \) and \( \varepsilon_{t,\gamma} = \rho_{\varepsilon} \varepsilon_{t-1,\gamma} + \xi_{t,\gamma} \).

Firms have to pay part of the labor input in advance. They borrow funds for this purpose from commercial banks. This gives rise to the loan condition for the representative firm \( L_{t,j} = \xi W_{t} n_{t,j} \).

In order to change prices, firms face a price adjustment cost as in Rotemberg (1982) with the cost parameter \( \phi \). The profits are given by \( V_{t,j} = (p_{t,j} \gamma_t - (1 + \xi_t)MC_t)n_{t,j} - \)
\( \frac{P_t \phi}{2} \left( \frac{p_{t,j}}{P_{t-1,j}} - 1 \right)^2 \), and in real terms:

\[ v_{t,j} = \left( \frac{p_{t,j}}{P_t} - (1 + \xi_i) m_{c_t} \right) y_{t,j} - \frac{\phi}{2} \left( \frac{p_{t,j}}{p_{t-1,j}} - 1 \right)^2 \tag{15} \]

where the real variables are \( v_{t,j} = \frac{V_{t,j}}{P_t} \), and \( m_{c_t} = \frac{M_{c_t}}{P_t} \).

The firm \( j \) chooses labor \( n_{t,j} \) and price \( p_{t,j} \). The cost minimization problem gives marginal cost net of interest rate payments

\[ m_{c_t} = \frac{w_t}{\gamma_t}. \tag{16} \]

The net present value of the firm \( NPV \) today is defined as the discounted profits of all future periods. The net present value is defined at the time when production has already taken place, but firms do not yet know if they survive until the next period. In this way the net present value is the same for the incumbents and new firms. In nominal terms the net present value is defined as

\[ NPV_{t,j} = (1 - \delta) E_t \left[(1 + u_{t+1,\text{surv}}) V_{t+1,j} + NPV_{t+1,j} \right] \]

and in the real terms after dividing with the price level:

\[ npv_{t,j} = (1 - \delta) E_t \left[ \frac{\lambda_{t+1}}{\lambda_t} (v_{t+1,j} + npv_{t+1,j}) \right], \tag{17} \]

where the \( \frac{\lambda_{t+1}}{\lambda_t} \) is the stochastic discount factor of the consumer, \( \delta \) is the exogenous death probability of the firm, and \( u_{t,\text{surv}} \) is the exogenous survival shock of the firm. The shock follows an ARMA(1,1),

\[ u_{t,\text{surv}} = \rho_{\text{surv}} u_{t-1,\text{surv}} + \varepsilon_{t,\text{surv}} \]

and \( \varepsilon_{t,\text{surv}} = \rho_{\text{ma,\surv}} \varepsilon_{t-1,\text{surv}} + \varepsilon_{t,\text{surv}} \). Previously \( \text{Vilmi (2009)} \) has a model with a stochastic rate of firm survival. In this paper I the survival probability is modeled as an exogenous process for the reason of simplicity. However the survival probability could also be modeled as an endogenous factor in the model. In fact \( \text{Jacobson et al. (2008)} \) show that macroeconomic factors are important for the the firm bankruptcy rates.

In order to enter, firms have to pay a sunk entry cost in labor. The free entry condition is given in real terms:

\[ npv_{t,j} = \xi_{\text{ent}} \frac{w_t}{\gamma_t} (1 + \xi_i) (1 + u_{t,\text{ent}}), \tag{18} \]

where the entry cost shock \( u_{t,\text{ent}} \) is ARMA(1,1) process

\[ u_{t,\text{ent}} = \rho_{\text{ent}} u_{t-1,\text{ent}} + \varepsilon_{t,\text{ent}} \]

and

\[ \varepsilon_{t,\text{ent}} = \rho_{\text{ma,\ent}} \varepsilon_{t-1,\text{ent}} + \varepsilon_{t,\text{ent}} \]

New firms can only produce the following period and a fraction of firms dies at the
end of the period, so some of the new firms never produce. The law of motion of the firms is

\[ F_t = (1 - \delta)(1 + u_{t,\text{surv}})(F_{t-1} + F_{t-1}^E) \]  (19)

There are two issues writing the number of firms dynamics in this way. First, there is no guarantee that the number of firms created is not negative. However this problem is addressed by assuming that the variance of the entry shock is small. Secondly, there is nothing that stops from the number of firms to increase between two periods if the positive survival shock exceeds the natural death rate of firms, so that firms can be generated from nothing overnight. The interpretation of it would be that some of the firms split in two but they are not accounted among the entrants.

Because of the price adjustment cost, the model is characterized by a forward looking Phillips curve:

\[ \rho_{t,j} = \frac{p_{t,j}}{P_t} = m_{u_{t,j}}mc_t \]  (20)

where \( \rho_{t,j} = \frac{p_{t,j}}{P_t} \) is the relative price, and the markup \( (m_{u_{t,j}}) \) is given by following equation

\[
\left( -\frac{1}{\mu} - \frac{y_{t,j}}{\phi} \left( \frac{\pi_t}{\pi} - 1 \right) \frac{\pi_t}{\rho_t \pi} + \frac{\phi}{y_{t,j}} (1 - \delta)E_t \left[ (1 + u_{t+1,\text{surv}}^t) \frac{\lambda_{t+1}}{\lambda_t} \left( \frac{\pi_{t+1}}{\pi_t} - 1 \right) \frac{\pi_{t+1}}{\rho_t \pi} \right] \right)^{-1}
\]

As this is one the key equation that is changed compared to the standard model, I present here the log-linearized version.

\[ \hat{\pi}_t = \frac{y_{t,j}}{\phi \mu} \left( -\hat{\rho}_t + \frac{\xi}{1 + \xi} \hat{\gamma}_t + m_{c_t} \right) + \beta(1 - \delta)\hat{\pi}_{t+1} \]  (22)

where the variables without time subscript denote their steady-state levels, the variables with hats denote percentage change from the steady state with the exception of inflation and interest rate where it is percentage point change from the steady state, and the firm level subscript \( j \) are dropped as all firms are the same.

The equation states that the inflation rate today depends on the expected inflation and marginal cost as in the standard Phillips curve. However the two new elements, financial frictions and the firm turnover, uncouple marginal cost (the wage rate) from the inflation rate by making markups endogenous. In short, the financial friction
modifies the effect of marginal cost on inflation. Decreasing marginal cost leads to a drop in inflation. Decreasing inflation reduces the interest rate, and thus the cost of production, magnifying the effect on the inflation rate. Any shock that results in **an increase in the number of firms** pushes down markups and reduces inflation.

### 2.4 Banks

Banks lend money to the intermediate good sector firms, who pay share $\xi$ of the wages in advance. The banks can use funds deposited by the households households $d_{t-1}$ and money injections of the central bank $\psi_t$. By aggregating get the following condition:

$$\frac{d_{t-1}}{\pi_t} + \psi_t = \xi w_t n_t = l_t$$  \hspace{1cm} (23)

### 2.5 The Government and the Central Bank

Central bank uses money injections to the commercial banks

$$m_t = \frac{m_{t-1}}{\pi_t} + \nu \psi_t$$  \hspace{1cm} (24)

where $\psi_t$ is the money injection and $\nu$ determines what is the share of money taken out from the economy in the end of the period.

Monetary policy is described by an interest rate rule:

$$i_t = \bar{i} + \rho_i i_{t-1} + (1 - \rho_i) \left[ \zeta_{\pi} \left( \frac{\pi^C_t}{\pi^{C}_{\pi}} - 1 \right) + \zeta_{\pi} \left( \frac{m_{t-1}}{mc} - 1 \right) + \epsilon_{t,i} \right]$$  \hspace{1cm} (25)

where $\epsilon_{t,i}$ is an idiosyncratic shock to the interest rate.

The budget is balanced every period:

$$g_t = (\nu + i_t) \psi_t$$  \hspace{1cm} (26)

### 2.6 Aggregation and market clearing

Money in this model is the sum of cash ad hand and deposits

$$m_t = d_t + h_t$$  \hspace{1cm} (27)

The hours worked by the household are divided between creating new firms and
producing output.

\[ n_t = F_t n_{t,j} + F^E_t \frac{\xi_{ent}(1 + u^e_{t,ent})}{\gamma_t} \]  

(28)

Aggregate profits \( v_t \) include the individual profits of the firm minus the cost of starting new businesses.

\[ v_t = F_t v_{t,j} - F^E_t w_t \xi_{ent}(1 + \xi_{it})(1 + u^e_{t,ent}) \frac{(1 + u^e_{t,ent})}{\gamma_t} \]  

(29)

In the total consumption I take out the effect of the number of firms on the consumption in order to keep the productivity of the economy independent from the number of firms,

\[ c_t = F_t^{\nu-(1+\mu)} y_t, \]  

(30)

where \( \nu = 1 \), so the model departs from the standard Dixit-Stiglitz aggregator. The reason is that I focus on looking at the transmission through the Phillips curve. Without this transformation the increasing number of firms would lead to production technology that is not linear in labor. The issue should be dealt in a separate paper.

2.7 Equilibrium

The system is described by 33 variables, out of which 28 are endogenous, \( b_t, y_t, c_t, n_{t,j}, n_t, v_{t,j}, v_t, y_{t,j}, y_t, m_t, l_t, h_t, m_t, l_t, \psi_t, i_t, q_t, w_t, w^I_t, \pi_t, \pi^C_t, \text{NPV}_t, F_t, F^E_t, P_t, P_{t,j}, P_t, \rho_t \), and two Lagrange multipliers: \( \lambda_t, \lambda_t \).

There are 5 exogenous i.i.d shocks: \( \epsilon_{t,\gamma}, \epsilon_{t,w}, \epsilon_{t,ent}, \epsilon_{t,i}, \epsilon_{t,surv} \). I allow ARMA(1,1) structure for the processes of technology \( \gamma_t \), labor cost \( u_{t,w} \) and entry costs \( u_{t,ent} \) shocks. The equilibrium is symmetric, in which consumers maximize utility, firms and banks maximize profits, and all markets clear.

3 Data, Estimation and Priors

I estimate the model using quarterly US data for the sample period 1983Q1-1998Q3. This sample period reflects a compromise between availability of data and institutional features of the U.S. economy. Firm creation data is not available for the period after 1998Q3. In the year 1983 a major change in the bankruptcy law was launched. I use the following 5 series for the US economy:

- consumption - log of real non-durable consumption divided by 16 years and older civilian population, demeaned and detrended,
• hours - log of non-agricultural sector hours worked, divided by 16 years and older civilian population, demeaned and detrended,

• inflation, CPI inflation, demeaned,

• the Federal Funds Rate, demeaned,

• the number of new firms, log of firm creation, demeaned and detrended,

The data is presented in the Figure 1. There is a strong positive correlation between hours, consumption and the creation of firms. The inflation rate and the short-term interest rate are also strongly comoving. The contemporaneous correlation between hours and inflation is close to zero for the full sample. Consumption and hours have similar variances. The variance of firm creation clearly exceeds that of the hours.

Figure 1 here

The firm creation in the model and data are not calculated in the identical way. The model with endogenous entry and exogenous exit is a measure for net entry. However, in the data I prefer to use the number of new firms as a proxy for net entry because of problems with the available quarterly net entry measure. The main difficulty in getting a good series for net entry is to account for the closing firms (for a more detailed discussion see Uuskula (2008)).

Some of the parameters are know to be difficult to estimate, especially because of the short sample period and will instead be calibrated using results from previous studies for quarterly frequency in order to concentrate on the main parameters of interest relating to firm turnover. The calibrated parameters are presented in Table 1. The discount rate $\beta = .99$ is set to match a 4% annual real interest rate. The exogenous rate of firm death is set to $\delta = 0.025$ in order to match 10.7% annual firm closing rate in the U.S. The number of firms is set to 1 without the loss of generality and I solve for the steady state entry cost. Steady state markup is 25% ($\mu = .25$), which is higher than standard in the data, but lower than often calibrated in the entry literature (Bilbiie et al. (2007) assume steady state markup equal to 36%). The number of firms and the markup determine the entry cost to satisfy the free entry condition. Steady state inflation is 1.005 to match 2% annual inflation. In solving the model I assume that people work one third of their time $\hat{n} = \frac{1}{3}$ and I solve for the value of $A$ that satisfies this constraint.

Table 1 here
In addition I calibrate the parameters on consumption habit $\chi = .7$. Frisch elasticity of labor supply $\kappa = 1$, both often used in the DSGE literature. In addition there are a few parameters for which there was very little information in the current set of observables. The share of cash on hand goods and the share of government money left in the economy in the end of the period are both equal to $\eta = \nu = 0.5$ and the wage markup equal to 10% ($\Upsilon = 1.1$). Robustness analysis is carried out about the importance of the fixed parameters in the estimation.

I use the Bayesian likelihood approach to estimate the model using the Metropolis-Hastings sampler as described in Canova (2006). All calculations are done in Matlab, the model is log-linearized around the stochastic steady state and solved with the method of undetermined coefficient of Uhlig (1999). The priors of the parameters are selected so that they represent the theoretical restrictions and with very low information content (see Table 2). The autoregressive parameters are set to be between 0 and 1 with the mean 0.5 and variance 0.29². For the intertemporal elasticity of substitution and price stickiness I assume normal distributions. For the intertemporal elasticity of substitution I use the mean of 1 and for the Rotemberg price adjustment cost with the mean of 17 and variance equal to 16. The prior value for the price stickiness is taken from Ireland (2001) and adjusted for the value of calibrated markup and units of account in the price adjustment cost.

Table 2 here

I take 250000 draws in two chains. The initial values are chosen based on posterior maximization and only the last 50% of the draws are used in calculating the moments of the data to allow for a burn-in period. The convergence is difficult to achieve in some the parameters, such as the ARMA processes of the shocks. The confidence intervals for the impulse responses and variance decompositions are based on 1000 independent non-parametric draws from the posterior.

4 Results

Before explaining the main results I discuss some of the parameter estimates that are crucial for the dynamics of inflation. The posteriors of the model parameters are presented in Table 3

Table 3 here
First, the results show the importance of the financial friction in the model. The parameter estimate for the financial friction - the share of wages paid in advance - is 0.8 with a relatively wide confidence interval. The results support the findings of Ravenna and Walsh (2003) who use single equation approach in the estimation of the cost channel. The share of costs borrowed from the banks is much higher than the estimate of Rabanal (2006). He finds that only a small share (0.15) of costs are borrowed from the banks. Also Uhlig (2007) calibrates the parameter to a low value as 0.1.

Second, the price and wage stickiness parameters are lower compared to the previous estimates. The parameter estimate for the Rotemberg price adjustment cost is 11. The posterior is much lower than the prior value 17, the transformed value to make price adjustment cost comparable with the paper by Ireland (2001) as discussed in the section on priors. The price stickiness parameter value cannot be directly translated to the Calvo probability of re-setting prices since the Phillips curve contains financial friction and the relative price.

The parameter estimate for the wage flexibility is very close to one (wage rigidity is close to zero), leaving very little importance for the wage stickiness. The parameters for the nominal rigidities are well identified and do not depend very strongly on the prior distribution as previously found by Del Negro and Schorfheide (2008).

Third, the Taylor weight on inflation is around 1.05 and the weight on marginal costs is zero, implying that the central bank is fully inflation targeting. Interest rate smoothing parameter is 0.73 implying sluggishness in the interest rate to react to inflation.

The intertemporal elasticity of substitution is 0.7. The autoregressive parameters of the shocks are strongly different from one with one exception, the autoregressive parameter for the wage cost-push shocks is close to one. This probably reflects the high persistence of the hours series but also difficulties in identifying the ARMA process of the shock. Therefore in the estimated model, the wages are persistent because of the persistent wage costs. To all the other shocks, wages react immediately. The entry cost shock is also described by an ARMA process. This might indicate some positive externalities in creating firms which are not explicitly modeled. The technology shock is approximately described by an AR process and the survival shock has only some autocorrelation.

In order to answer the question: what explains inflation dynamics, I look at variance decompositions and impulse response functions of the structural shock. The variance decomposition at the business cycle frequency is based on the counterfactual data generated by including one shock at the time. I use the Hodrick-Prescott filter with the smoothing parameter $\lambda = 1600$ to remove long run trends, calculate variances and the
share of the respective variance from the sum of the individual variances of the data that
the five shocks produce. The results of the variance decomposition at the business cycle
frequency are presented on Table 4. I present the forecast error variance decomposition
(FEVD) results and the impulse response functions for the period of 20 quarters after the
shock together with the 90% confidence intervals. The line in the middle is calculated
at the medians of the parameter estimates.

Table 4 here

First column of Table 4 presents the benchmark results for the importance of the
estimated 5 shocks in explaining the 5 data series that are matched in the estimation
at the business cycle frequency. The shocks to the cost of entry explain around 67%
of the variance in inflation at the business cycle frequency. The importance of the
entry costs shocks in explaining inflation is also confirmed by the forecast error variance
decomposition analysis. Figure 2 presents the FEVD results for the entry cost shock.
Variations in the cost of entry explain more than half of the variance in inflation during
first five years after the shock.

Figure 2 here

The channel through which entry costs influence inflation is not trivial. A drop in the
entry cost, which makes creation of firms more efficient brings a hump-shaped increase
in the creation of firms and inflation. As it is good time to invest into creating new
firms, demand for labor increases (see Figure 3). In order to hire more people, firms
pay higher wages the workers. The increase in production costs results in inflation. The
central bank increases the interest rate, resulting the costs of production to increase even
more. As the number of firms is going up only gradually, therefore it takes time before
the increase in the creation of firms results in a higher number of firms in the economy.
So markup decreases with a relatively long lag. But as the number of firms stays up for
a period of time, the markups are low even when the hours worked and the creation of
firms have converged back to the initial levels.

Figure 3 here

In the reaction to the shock the substitution away from consumption into creating
new firms has only little effect, but consumption still drops after the initial shock. As
the number of firms increases due to increased entry, consumption reaches back its initial
level after 3 years. However this channel moderates the reaction of hours and wages, but does not undo the effect.

The firm survival shock explains around 6% of the variance of inflation at the business cycle frequency and 7-8% from the FEVDs (see Figure 1). A drop in the stochastic death rate increases the number of firms and lowers inflation. A 1% increase in the number of firms brings inflation down by 0.05pp. at the time of the impact. There are two channels which lead to a drop in inflation. First, higher number of firms decreases the markup in the economy and lowers inflation. Second, an increase in the number of firms lowers the need to create new firms and labor demand drops leads to a drop in wages.

The firm survival shock explains around 6% of the variance of inflation at the business cycle frequency and 7-8% from the FEVDs (see Figure 4). A drop in the stochastic death rate increases the number of firms and lowers inflation. A 1% increase in the number of firms brings inflation down by 0.05pp. at the time of the impact. There are two channels which lead to a drop in inflation. First, higher number of firms decreases the markup in the economy and lowers inflation. Second, an increase in the number of firms lowers the need to create new firms and labor demand drops leads to a drop in wages.

Figure 1 here

This effect of the number of firms to inflation can be compared the finding of Cecioni (2009). She looks at the effect of change in the number of firms on the inflation rate and concludes that the number of firms is an important factor determining inflation. She finds that a 10% increase in the number of firms brings inflation down by 1.4 pp. in the medium horizon. My results show that in case of costly creation of firms it is important to separate how the increase in the number of firms is achieved. If there are many new firms created, the increase in the number of firms can be even inflationary in the short run because of the increase in the costs of production.

Variations in the exogenous technology are the second most important shock in explaining inflation. The technology shocks explain around 18% of the variance in inflation at the business cycle frequency. Technology shock explain 15-20% of the volatility in inflation, with the impact increasing in time because of the persistence of the shock. The share of the technology in explaining inflation is higher than the estimates of Smets and Wouters (1998), who find that productivity can explain around 5% of the variance in inflation at all horizons. The estimated importance of the technology shock is much closer to the estimate of Altig et al. (2003) VAR evidence. Their estimated technology shocks explain around 16% of the variance at the business cycle frequency.

Cost-push shocks have little to say about inflation. In the FEVD the median effect reaches 10% five years after the shock (see Figure 5) and 2.5% at the business cycle frequency. This stands in contrasts with the findings of Smets and Wouters (1998), who’s results show that wage markup shocks explain 50% of the inflation 2.5 years after the shock. However similar to Smets and Wouters (1998) my results show that a higher share of variance explained in inflation by the cost-push shocks at lower frequencies.

Figure 5 here
Monetary shocks have only some effects on the inflation at the very short run (see Figure 6). In spite of the low levels of nominal rigidities and the strong cost-channel, inflation drops after a contractionary monetary shock. The small real effects of monetary policy are often found in the full likelihood estimation of the DSGE models. In this paper zero effect on hours is included in the posterior of the impulse responses. There results are consistent with the agnostic identification approach results of Uhlig (2005).

The second column in Table 4 presents the variance decomposition for an estimation of the model where the parameter on the financial friction is calibrated very close to zero $\xi = 0.01$. The differences for the variance decomposition of inflation are quite small. The share of the variance explained by the entry cost shock is now 68%, up by one percentage point. The survival shock gains some explanatory power, the share of the variance explained increases from 6 to 11%. The increase comes mainly from the technology shocks, which now explain around 13% of the variance. However the financial friction seems to matter for the relative importance of the real variables.

Entry cost and firm survival shocks explain now a much higher share in hours and consumption than before. In particular the financial friction is important in explaining the qualitative effects of monetary shocks that a monetary contraction decreases entry. In the benchmark model a drop in the interest rate leads to an increase in the creation of firms. This result is also supported by the VAR evidence (see for example Bergin and Corsetti (2005), Lewis and Poilly (2012) or Uuskula (2008)). However in the model where the financial friction is set to zero, the number of firms decreases after an expansionary monetary shock. This is a common finding in the papers without a financial friction such as Bilbiie et al. (2007)). Therefore the financial friction is important for the real variables and has only limited impact on the relative variances of inflation. This result also confirms the finding of Rabanal (2006) that the cost channel is not important for the inflation variance.

In order to understand the properties of the estimated model I have conducted a few robustness checks, mainly for the values of the calibrated parameters. One of the important parameters is the markup in the intermediate goods sector. Cecioni (2009) calibrates the value equal to around 6%, to a much lower value than in this paper. Differently Bilbiie et al. (2007) fix the value of markup at 35.71%, which is much higher compared to my benchmark results. When I fix the price markup to 10%, technology and wage cost-push shocks are less important and the stochastic rate of survival is more
important (see the last column in Table 4). When markup is equal to 35.71%, wage shocks have smaller and the entry costs shocks bigger role (third column in Table 4).

Following Uhlig (2007), I allow the shock to the interest rate $\epsilon_{t,i}$ to have an AR structure. The results however show that the value of autoregressive parameter is equal to zero. The posterior likelihood and variance decomposition results are not sensitive to the changes in the parameters on the share of cash goods, money left in the economy, and wage markup. A drop in the value of Frisch elasticity of labor supply to a level consistent with the microeconometric evidence (0.2) increases the importance of entry shocks on consumption and inflation and the magnifies the effect of wage cost-push shocks on hours.

5 Conclusions

In this paper I augment a medium scale sticky wage and sticky price macroeconomic model with financial frictions and firm turnover and estimate it for the U.S. economy. My results show that the shocks to the cost of entry are important in explaining the variance of inflation over the business cycle. When creating firms is labor intensive, then a drop in the cost of entry leads to increase in the labor demand as many new firms are created. Increase labor demand results in higher marginal costs and inflation. As number of firms increases markups decrease and inflation starts to decrease. In this model financial frictions play only a minor role in explaining the dynamics of inflation.
References


Figure 1: Data used in the estimation
Table 1: Calibrated parameters

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<tr>
<th>Name</th>
<th>Value</th>
<th>Notes</th>
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<td>$\beta$</td>
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</tr>
<tr>
<td>$\pi$</td>
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<td>Steady state inflation, yearly 2%</td>
</tr>
<tr>
<td>$\delta$</td>
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<td>Share of firms closed each period, 10% per year</td>
</tr>
<tr>
<td>$N$</td>
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<td>Number of firms, normalization</td>
</tr>
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</tr>
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</tr>
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<td>Mark-up</td>
</tr>
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</tr>
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<td>Wage markup</td>
</tr>
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Table 2: Prior distribution of the estimated parameters

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<td>16</td>
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<td>0.0841</td>
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Table 3: Posterior distribution of the estimated parameters

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22
Table 4: In sample variance decompositions

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Figure 2: Forecast error variance decomposition, Entry cost shock
Figure 3: Impulse response functions, Entry cost shock
Figure 4: Forecast error variance decomposition, Firm survival shock
Figure 5: Forecast error variance decomposition, Wage cost-push shock
Figure 6: Forecast error variance decomposition, Monetary shock