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Monetary Transmission Mechanism with Firm Turnover

Lenno Uusküla*

Abstract

An expansionary monetary policy shock increases the entry rate and the number of firms in the US. A pure sticky price model predicts that the number of firms in the economy should go down after a monetary expansion, but this prediction is at odds with the empirical findings. In marked contrast, the cost channel mechanism generates an increase in the number of firms that is consistent with the data. A key insight is that the greater price stickiness is, the stronger the cost channel needs to be to generate firm dynamics that are consistent with the data.

JEL classification: E32, C32

Keywords: monetary transmission, cost channel, sticky prices, firm turnover

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Non-technical summary

The recent financial that started in 2007 and was followed by an economic crisis demonstrated the importance of financial markets in shaping how the macroeconomic reacts to various shocks, including the monetary policy shock. The workhorse channel in monetary transmission models is still the sticky price mechanism. Although the mechanism has been shown to be effective in fitting some of the data, it also predicts that the number of firms should decrease after monetary easing. This paper shows that this prediction is at odds with the empirical findings and then demonstrates how a cost channel financial friction generates impulse responses that fit the data. The results demonstrate that the greater price stickiness is, the stronger the cost channel needs to be to generate firm dynamics that are consistent with the data.

The paper first shows that the number of new firms grows rapidly and strongly after an expansionary monetary shock in a post WWII US data. As the exit margin remains initially unchanged, the number of firms operating in the economy increases because of new firms coming to the market. At a later stage the number of failures drops, adding to the increase in the number of firms. The results are similar to previous literature for net entry, but in addition I employ new data on bankruptcy filings from the US Bankruptcy Courts together with the establishment death data of the BLS.

After establishing the stylised fact, the paper shows that a sticky price model that has been complemented by cost channel financial friction can fit the dynamics of the number of firms observed in the data and illustrates how financial frictions are important in the monetary transmission mechanism. The theoretical part builds a dynamic stochastic general equilibrium (DSGE) model with endogenous firm creation, with sunk cost in the labour used to establish a firm, and exogenous firm destruction following Bilbiie et al. (2007), Bergin and Corsetti (2008), Uhlig (2009) and Bilbiie et al. (2012). The financial friction has several names in the literature; in a seminal paper Christiano et al. (1997) called it the limited participation model, and it has later also been called working capital for firms or the cash-in-advance constraint for firms by many others and used my many including Christiano et al. (2005), Ravenna and Walsh (2006), Rabanal (2007) and Uhlig (2009).

In a sticky price model when labour is used for sunk cost of creating a firm, an interest rate cut leads to a drop in the number of firms. This is because the expansionary shock leads to an increase in demand for consumer goods and consequently to a higher demand for labour. Labour costs thus increase equally for producing goods and for creating firms. Lower profits per firm cut the creation of new firms and reduce labour demand to a level where the free entry condition is satisfied. The drop in the number of firms stands in contrast to the empirical results.

Inclusion of a sufficiently strong cost channel on top of price stickiness leads to an increase in the number of firms after a monetary expansion that is observed in the data. The main assumption in the mechanism is that firms borrow funds from financial intermediaries to produce output, in particular firms borrow funds for wages. In order to create an expansionary monetary policy shock, the central bank lends additional resources to financial intermediates to achieve a certain target for the interest rate. Financial intermediaries lend these additional resources to firms, which now get loans at lower interest rates. The cost channel cuts the cost of production and the cost of creating new firms. The stronger the cost channel is, the smaller the increase in the overall cost of production is, leading to stronger expansion in the economy, contributing to the increase in the net present value of a firm.

Moreover, potential entrants that borrow from banks to meet the entry costs benefit from lower interest rates. Increased labour demand from entry generates wage growth up to the point where the entry cost equals the net present value of firms. Clearly there are very low levels of the cost channel that are too weak to overturn the counterfactual reaction of firm creation from the sticky price mechanism, but the stronger the cost channel is given price stickiness, the smaller the drop in entry. At a certain level the cost channel becomes strong enough to flip the reaction of firm creation so that the entry of new firms becomes positive after an expansionary monetary shock. The importance of the cost channel does not mean that prices cannot be sticky and does not contradict the importance of the role of slow price adjustment. The paper calibrates the model to US data and shows that reasonable levels of the cost channel are sufficient to reverse the counterfactual prediction of the sticky price mechanism.

Contents

1 Introduction

The recent financial and economic crisis demonstrated the importance of financial markets in shaping macroeconomic dynamics, but the workhorse channel in monetary transmission models is still the sticky price mechanism. Although the mechanism has been shown to be effective in fitting some of the data, it also predicts that the number of firms should decrease after monetary easing. This paper shows that this is at odds with the empirical findings. It then asks whether the cost channel can help in explaining the effects of a monetary shock. The paper shows that a sticky price model that has been complemented by cost channel financial friction[1] can fit the dynamics of the number of firms observed in the data and illustrates how financial frictions are important in the monetary transmission mechanism. The results demonstrate that the greater price stickiness is, the stronger the cost channel needs to be to generate firm dynamics that are consistent with the data.

The paper first shows that the number of new firms grows rapidly and strongly after an expansionary monetary shock. As the exit margin remains initially unchanged, the number of firms operating in the economy increases because of new firms coming to the market. At a later stage the number of failures drops, adding to the increase in the number of firms. The paper uses data on firm creation and destruction, and on establishment births and deaths in the US for various periods after WWII. The empirical evidence is based on a small structural vector autoregressive (VAR) model for the US economy, which takes in real GDP, the GDP deflator inflation rate, the Federal Funds rate, and several measures of firm turnover which are included either one-by-one or in groups. I adopt the recursive approach with contemporaneous restrictions and put the firm turnover measure into the central bank information set so as to identify monetary shocks, but the results are very robust to various changes in the model.

The empirical findings use extensive new high quality data from various sources, and in this way they contribute to the literature on measuring the effects of monetary policy on the creation and destruction of firms and establishments. The paper demonstrates that a rapid increase in the number of firms and establishments comes from the entry margin and not the exit margin. Bergin and Corsetti (2008) use a small scale VAR of monthly data and impose short-run restrictions placing the entry variable outside the central bank information set in order to identify the monetary shock. They find an effect on the number of new firms only when they use non-borrowed reserves to identify the monetary shock, but not when they use the more standard Federal Funds Rate (FFR). The current paper finds strong effects on the entry of new firms by using quarterly data for the FFR to identify the shock. Lewis (2009) takes a sign restriction approach to estimate the effect of a monetary shock on net entry. She finds that net entry increases only with a significant lag after a monetary expansion and more recently Lewis and Poilly (2012) find a similar effect from a monetary shock on net entry using a VAR model with short-run restrictions. I find similar results in this paper for net entry, but in addition I employ new data on bankruptcy filings from the US Bankruptcy Courts together with the establishment death data of the BLS to demonstrate that the firm destruction margin remains initially unchanged and the exit rates decline later following the positive monetary shock.

[1] The mechanism has several names; in a seminal paper Christiano et al. (1997) called it the limited participation model, and it has later also been called working capital for firms or the cash-in-advance constraint for firms. The terms have the same meaning in this paper unless otherwise clearly stated.

The theoretical part builds a dynamic stochastic general equilibrium (DSGE) model with endogenous firm creation, with sunk cost in the labour used to establish a firm, and exogenous firm destruction following Bilbiie et al. (2007), Bergin and Corsetti (2008), Uhlig (2009) and Bilbiie et al. (2012). The model first replicates the finding in the literature that in a sticky price model without the cost channel, an interest rate cut leads to a drop in the number of firms. This is because the expansionary shock leads to an increase in demand for consumer goods and consequently to a higher demand for labour. Labour costs thus increase equally for producing goods and for creating firms. Lower profits per firm cut the creation of new firms and reduce labour demand to a level where the free entry condition is satisfied. This stands in contrast to the empirical results.

As a theoretical contribution the paper shows that including a sufficiently strong cost channel on top of price stickiness, as proposed by Christiano et al. (1997) and later employed by many others, including Christiano et al. (2005), Ravenna and Walsh (2006), Rabanal (2007) and Uhlig (2009), leads to an increase in the number of firms after a monetary expansion that is observed in the data. The main assumption in the mechanism is that firms borrow funds from financial intermediaries to produce output, in particular firms borrow funds for wages. In order to create an expansionary monetary policy shock, the central bank lends additional resources to financial intermediates to achieve a certain target for the interest rate. Financial intermediaries lend these additional resources to firms, which now get loans at lower interest rates. The cost channel cuts the cost of production and the cost of creating new firms. The stronger the cost channel is, the smaller the increase in the overall cost of production is, leading to stronger expansion in the economy, contributing to the increase in the net present value of a firm. Moreover, potential entrants that borrow from banks to meet the entry costs benefit from lower interest rates. Increased labour demand from entry generates wage growth up to the point where the entry cost equals the net present value of firms. Clearly there are very low levels of the cost channel that are too weak to overturn the counterfactual reaction of firm creation from the sticky price mechanism, but the stronger the cost channel is given price stickiness, the smaller the drop in entry. At a certain level the cost channel becomes strong enough to flip the reaction of firm creation so that the entry of new firms becomes positive after an expansionary monetary shock. The importance of the cost channel does not mean that prices cannot be sticky and does not contradict the importance of the role of slow price adjustment. However, the stickier prices are, the higher the level that the cost channel needs to be at for it to fit the effect of the monetary shock on firm turnover. The model is kept simple to show clearly the mechanism that affects firm turnover. The paper calibrates the model to US data and shows that reasonable levels of the cost channel are sufficient to reverse the counterfactual prediction of the sticky price mechanism. I calibrate the cost channel parameter to 1.276 as estimated by Ravenna and Walsh (2006) and use financial data on the US to show that the parameter is at the lower end on a scale of possible values.

Recently Lewis and Poilly (2012) have also included a cost channel on top of sticky prices and sticky wages in order to analyse the role that variable mark-ups play in inflation when the number of firms is variable. They restrict the parameter to between zero and one and reach an estimate for the cost channel between 0.5 and 0.9. Unlike in this paper, the cost channel in their paper is not sufficient to change the reaction of firm entry after a monetary shock. The current paper contributes to the growing literature on the importance of financing in firm dynamics and shows that a very simple framework is sufficient to match the data qualitatively. Bergin et al. (2014) show how access to finance is crucial for new firms empirically, while the Macnamara (2014) model of entry and exit includes a working capital channel but does not look at monetary shocks. Supporting the working capital mechanism in the paper, Robb and Robinson (2014) find empirical evidence that new firms do borrow a lot of resources, and in fact outside debt is on average the largest single category of funding for start-ups during their first year of operation. In addition, Gross and Verani (2013) find that better financing conditions make exporting easier. La Croce and Rossi (2015) introduce an elaborate financial sector on top of an endogenous entry framework. They also have a cost channel in production, but not in the creation of firms and they do not look at monetary policy shocks[2].

This paper also contributes to the discussion in the literature on the composition of entry costs. In order to overcome the counterfactual prediction of sticky prices on firm turnover, Bilbiie et al. (2007) and Bergin and Corsetti (2008) assume for the entry cost that new firms buy goods from existing firms, which sell at pre-set prices. Monetary expansion then increases the entry of firms because the real entry cost has fallen. However, an increase in the demand for output leads to a hike in wages and so to a fall in profits for existing firms. Lower profits should then lead to a drop in the number of entering firms and an increase in exits in the production sector[3]. Cavallari (2013) shows how a sufficiently high share of imports helps to explain the stylised facts of the international business cycle. All these models rely on the assumption that new firms can buy at pre-existing prices. Therefore, creating firms becomes cheap compared to flexible price equilibrium. However, the price stickiness literature stresses explicit and implicit contracts that keep prices fixed, but such contracts cannot be the main reason for new firms to be able to buy at the prices of incumbents. Moreover, the existing firms, in the sticky price set-up, have to sell at non-optimal prices in the current period and foresee that the prices can remain unchanged and non-optimal for a time. So with Calvo contracts (such as in Cavallari (2015)), firms that have prices further away from the optimal would like to exit, but by assumption this is not allowed. There are no such problems in the financial friction model.

I use a broad definition of entry costs, which includes the time that is needed for coming up with the idea for a new product or service, working out the business plan, making the plan work, hiring the right people, finding the right suppliers, and marketing, and for the general allocation of resources to acquire the technology to produce a good or service. The US Small Business Administration lists 10 steps to consider for people who intend to start a new company[4], and describes them with words like write, choose, determine, obtain and understand; most of the points require a substantial amount of consideration, care and time, and are not direct inputs from other firms. Even though Djankov et al. (2002) estimate the entry costs in terms of legal costs to be high in the US, they put the cost of the labour required to complete these legal steps 2.5 times higher than the legal costs themselves.

The paper is structured as follows. Section 2 sets up the VAR and describes the data and presents the empirical results. Section 3 explains the sticky price and financial friction model with firm turnover and calibrates the model. Section 4 discusses the properties of

[2]See also Bergin et al. (2014), Gross and Verani (2013), and Robb and Robinson (2014) for recent evidence of financial frictions in firm turnover.

[3]Elkhoury and Mancini-Griffoli (2006) assume that in order to create a firm, entrepreneurs have to buy goods from a specific sector in the economy that has to set its prices in advance, whereas all other businesses set the prices of their goods freely. In such a scenario, an expansionary monetary shock lowers the real cost of entry and consequently the creation of firms increases.

[4]See US Small Business Administration (Link, accessed 15.07.16).

the model and shows how the cost channel helps in explaining the effect of a monetary shock on the dynamics of the number of firms.

2 VAR evidence

In this section I show that in the US an expansionary monetary shock leads to an increase in firm creation and a drop in firm destruction, resulting in a higher number of firms. The section first presents the VAR model and the short-run restriction scheme to identify the shock. It further describes the data, discusses the main results and finishes with a check on the robustness of the empirical findings.

2.1 Method and data

I set up a VAR model in order to estimate the effects of the monetary policy shock on the firm turnover measures, and take the recursive approach to identify the monetary shock. The reduced form VAR is given by: $y_t = \sum_{i=1}^{p} b_i y_{t-i} + u_t$, where y_t is the vector of endogenous variables, b_i-s are matrices of coefficients, p is the number of lags in the model, and u_t is the error term.

In order to identify the monetary shock, I set up a structural VAR model:

$$A_0 y_t = B_0 + \sum_{i=1}^{p} B_i y_{t-i} + \epsilon_t \tag{1}$$

where B_i-s are matrices of the structural coefficients and are related to b_i-s so that $b_i = A_0^{-1} B_i$ and ϵ_t are the structural shocks, and the variance-covariance matrix $\Sigma_\epsilon = E(\epsilon_t' \epsilon_t)$ is assumed to be diagonal and related to the reduced form shock variance-covariance matrix $\Sigma_u = E(u_t' u_t)$ by the formula $\Sigma_u = A_0^{-1\prime} \Sigma_\epsilon A_0^{-1}$.

The benchmark VAR consists of: GDP level, GDP deflator inflation, firm turnover measure(s), and the federal funds rate. A central banker takes into account the contemporaneous values of the variables in the information set (Ω), then introduces the shock (ζ_t) by setting the interest rate (R_t): $R_t = F(\Omega) + \zeta_t$. The variables in the central bank information set are not allowed to change contemporaneously to the change in the policy rate. The recursive approach to identifying the monetary policy shocks that builds on a Taylor-rule type of argument is popular in the empirical literature, and is adopted in the papers by Altig et al. (2011) and Boivin et al. (2009). The main alternative is the non-recursive approach by Sims and Zha (2006), but this has been shown to result in very similar impulse responses to those of the recursive identification scheme.[5]

Data on real GDP, the GDP deflator inflation rate, and the Federal Funds rate are taken from the FRED database of the Federal Reserve bank of St. Louis, see Table 1 for a detailed description of data sources. The real GDP is divided by population for the real GDP per capita series, the Federal Funds rate is the value at the third month of

[5]Christiano et al. (1999) give an overview of the main results of the monetary shock and compare various short-run restriction identification approaches. Uhlig (2005) proposes an identification scheme in which sign restrictions are set on the impulse response functions. The sign restrictions approach challenges some of the empirical results obtained by the short-run restrictions.

the quarter. The FFR was at a zero lower bound after the start of the global financial and economic crisis and many unconventional policy measures were taken during that time. To take account of the unconventional measures, I use the shadow interest rate of Wu and Xia (2016) for the period from 2009Q1 to 2015Q3. GDP is given in log level and I take the difference of the log of the GDP deflator index to obtain the inflation rate, while the FFR is at an annualised rate and untransformed.

Table 1: Data description and sources.

Name	Description and source
Real GDP	Real Gross Domestic Product (GDP), Fred of St. Louis Fed., mnemonic GDPC1
Population	Total Civilian Noninstitutional Population over 16, Fred of St. Louis Fed., mnemonic CNP16OV
GDP deflator	GDP implicit price deflator, Fred of St. Louis Fed., mnemonic GDPDEF
FFR	Federal Funds Rate, Fred of St. Louis Fed., 1954M7 onwards, mnemonic FEDFUNDS
Shadow interest rate	From Wu and Xia (2016)
Number of new firms	Number of new business enterprises, 1948M1–1998M9, Dun & Bradstreet Inc., Economagic
Bankruptcy filings	Number of bankruptcy filings by companies, 1960Q3–2016Q1, U.S. Bankruptcy Court
Establ. birth rate	Birth rate of establishments, 1992Q3–2015Q3, BLS, Business Employment Dynamics
Establ. death rate	Death rate of establishments, 1993Q2–2014Q4, BLS, Business Employment Dynamics
Establ. birth number	Number of establishment births, 1992Q3–2015Q3, BLS, Business Employment Dynamics
Establ. death number	Number of establishment deaths, 1993Q2–2014Q4, BLS, Business Employment Dynamics
Net business formation	Net entry of business incorporations, 1948M1–1995M10, Dun & Bradstreet Inc., BEA
Number of failures	Number of business failures, 1953M1–1998M11, Dun & Bradstreet Inc., BEA
Failure rate	Number of failures per 10000 listed enterprises, 1957M1–1983M12, Dun & Bradstreet Inc., BEA

The availability of the enterprise turnover measures is restricted for the full post WWII sample. I use several measures for firm and establishment entry and exit from various sources. For the main results on the number of new firms, I use the number of new business incorporations, collected by Dun & Bradstreet Inc. and available for the period from 1948M1 up to 1998M9. The Dun & Bradstreet database covers around 90% of all enterprises with at least one employee and some without employees. The registration of a company in the database is voluntary and may happen after the actual start of the business, so the entry data do contain some noise, but because of the high coverage it can almost be interpreted as a population and not a survey based measure. The database covers the total number of stock corporations that have been issued charters under the general business corporation laws of the various States and the District of Columbia. The statistics include completely new businesses that have incorporated, existing businesses that have changed from the non-corporate to the corporate form of organisation, existing corporations that have been given certificates of authority to operate in another State as well, and existing corporations that have transferred to a new State[6]. For a measure of exiting firms, I use data from the US Court of Bankruptcy on the number of business bankruptcy filings. These data are administratively collected and cover all corporate bankruptcy filings in the US.

Establishment birth and death statistics come from the BLS database on Business Employment Dynamics. The data for the birth rate and the number of new establishments are available for the period from 1992Q3 to 2014Q4 and the death rate and the number are available for the period from 1993Q2 to 2015Q3. The difference between the birth and death rates is the net entry rate. The establishment survey data cover most private sector firms. An establishment is considered to be born when after no employment it has positive employment of at least one employee in the last month of the quarter for three quarters. The establishment is considered dead if after positive employment it has not had employment in the last month of the quarter for three quarters.

For additional evidence I use several other measures of firm turnover. Data for the number of business failures come from Dun & Bradstreet Inc. Failures are defined as concerns involved in court procedures or voluntary actions that will probably end in loss to creditors. These include, but are not limited to, discontinuances following assignment or attachment of goods, bankruptcy petitions, foreclosure, voluntary withdrawals with known loss to creditors, enterprises involved in court action such as receivership, and businesses making voluntary arrangements with creditors out of court that may or may not lead to discontinuance (see U.S. Department of Census (1975)). Coverage of sectors for business failures was extended in 1984, and the sectors added were banks, railroads, and real estate, insurance, holding, and financial companies, which meant the new data cannot be compared with the earlier data. Naples and Arifaj (1997) propose an adjustment which makes the post-1984 data comparable to the pre-1984 data, and their results show that the number of business failures increased on average by about 31% because of the increase in the coverage. For the period 1984–1996, I use the adjusted data.[7] Data for the failure rate per 10,000 listed enterprises is only available for the period from 1957M1 to 1983M12 and I use the average of the three months for quarterly data. The failure rate is obtained by dividing total failures by the total number of industrial and commercial enterprises listed in the Dun & Bradstreet Reference Book (see U.S. Department of Census (1975)).

The net business formation index, available for the period from 1948M1–1995M10, is calculated by Dun & Bradstreet using the number of new firms and the failure data, I use the value of the third month of each quarter. This series is compiled from monthly national data on the number of new business incorporations, the number of business failures and confidential data on telephones installed. These components are adjusted for seasonal variation and the number of trading days before being combined into the index

[6]Data for incorporations in the District of Columbia are included beginning from January 1963. (For further details see U.S. Department of Census (1975)). I use the sum of the three months to obtain quarterly data.

[7]There are no adjusted failure numbers available for 1997 and 1998. For these years I subtract 31% of firms to account for the average increase in the coverage. For quarterly values I use the average of the three months.

(see U.S. Department of Census (1975)). Armington (2004) discusses the quality of the data on the number of new firms and the net entry in more detail.

The creation of new firms, the net entry index, the number of business failures, the number of business bankruptcy filings, and the number of establishment births and deaths are used in log levels. The firm failure rate, and the establishment birth, death and net entry rates are used untransformed, in levels. The benchmark SVAR model has a constant term and assumes four lags.

2.2 VAR results

Figure 1 illustrates the dynamics of the firm turnover variables in response to an expansionary monetary policy shock. The drop in the interest rate of one standard deviation is about 1pp and it dies out six quarters after the shock. The point estimates shown with the solid line are presented together with the centred 95% confidence intervals using 5000 non-parametric bootstrap replications.

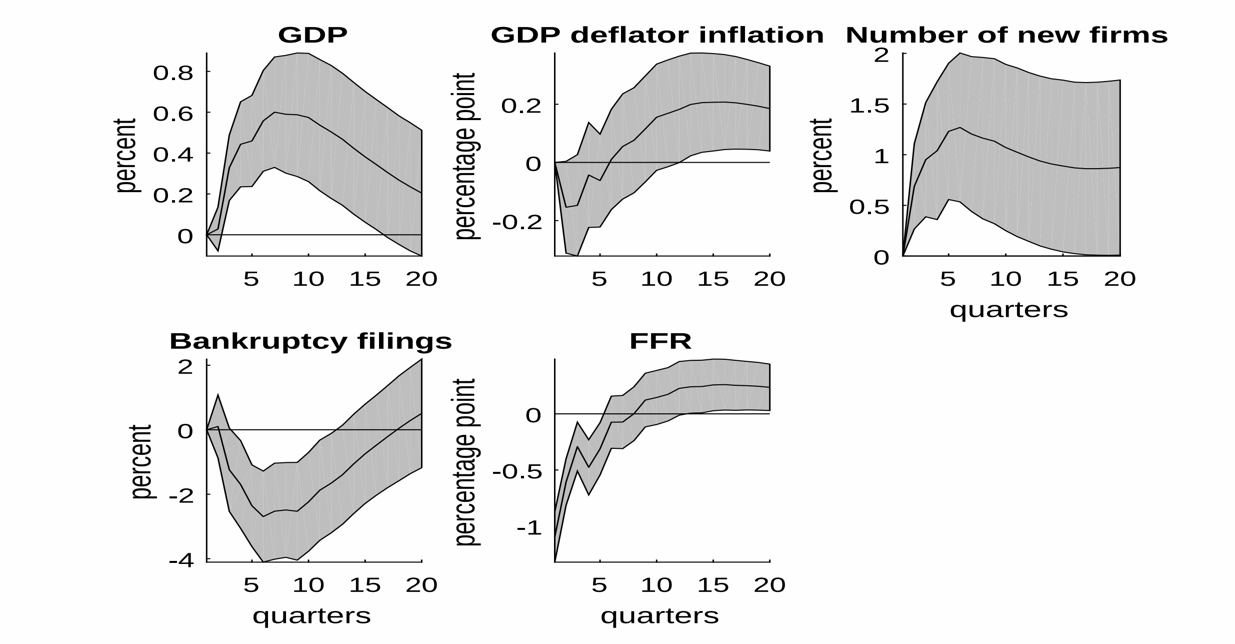

Figure 1: Impulse response functions to an expansionary monetary shock.
Notes: 95% centred confidence intervals around the point estimates, period 1960Q3–1998Q3

The number of new firms goes up by more than 1% within a few quarters, and the effect is statistically significant. For a steady state level of 2.5% of the number of firms created every quarter, the 1% increase in the number of new firms translates to an increase of about 0.025% in the number of firms. The reaction of the number of new firms is already strong one quarter after the shock, leading the reaction of GDP, which comes a quarter later. The number of business bankruptcy filings drops two quarters after the shock, bottoms out at 2.5% five quarters after it, and then climbs back. The results together mean that the number of firms increases. A further implication is that the failure rate goes down because a smaller number of firms fail from a higher total number of firms in the economy, as the entry of firms is higher and the number of failures is lower. The combination of reactions of entry and failures also ensures that net entry increases initially after an expansionary shock, but the effect later is inconclusive, as it can result in either a rise or a fall in the entry rate, depending on the level of new firm creation relative to the number of firms.

In addition, the expansionary monetary shock leads to a hump-shaped increase in output with a peak of 0.5 percent around seven quarters after the shock. The GDP deflator inflation rate decreases initially, but then turns, and remains positive for an extended period. The results for output and inflation are similar to those of several previously estimated VAR models, such as Altig et al. (2011), Christiano et al. (1999), and others, which confirm the identification of the monetary shock. The results for the number of new firms are similar to the estimates of Bergin and Corsetti (2008), but they use monthly data and non-borrowed reserves to identify the monetary shock. In contrast, they did not show any effect on new firms when they used the FFR to identify the monetary shock at monthly frequency and they excluded the number of new firms from the central bank information set.

Figure 2 presents impulse response functions using establishment birth and death measures from the Business Employment Dynamics database of the BLS. The estimation is done for the period from 1993Q2 to 2014Q4, as it is restricted by the common availability of the birth and death rate data. A standard deviation shock to monetary policy is about 30bp, and it lasts about 10 quarters, about twice as long as in the period starting from the 1950s. The shock brings an increase in the GDP level with a lag, with the GDP level rising by more than 0.3% at the maximum. Inflation too reacts more sluggishly, becoming statistically significantly different from zero after 10 quarters. This is a common finding in the literature for the recent period. Gertler and Karadi (2015) also find that industrial production reacts with a considerable lag to a monetary shock for the period since 1979.

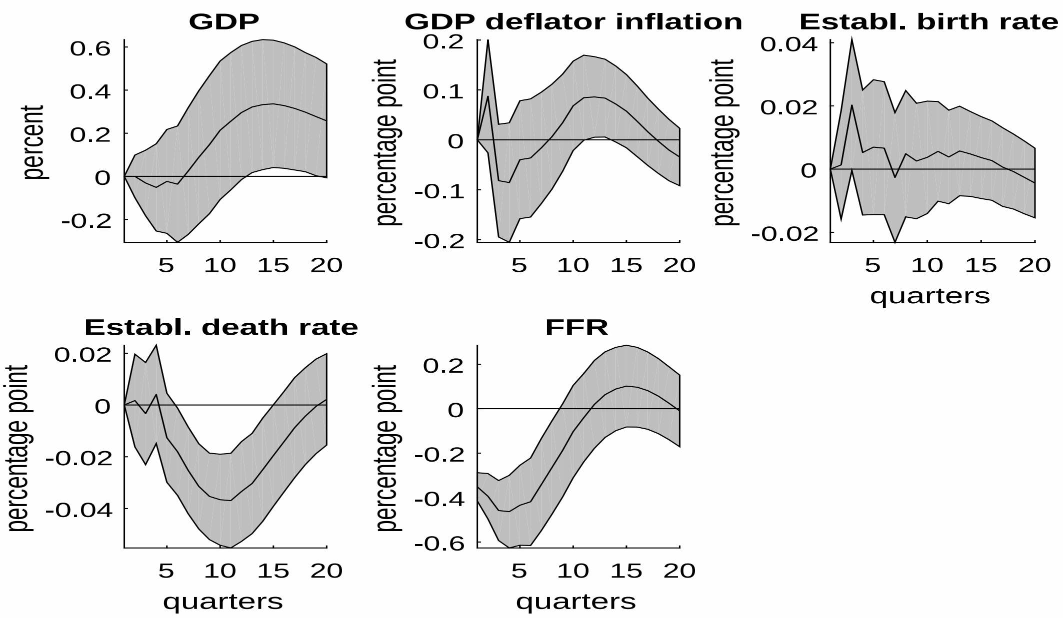

Figure 2: Impulse response functions to an expansionary monetary shock.

Notes: 95% centred confidence intervals around the point estimates, period 1993Q2–2014Q4.

The establishment birth rate jumps up rapidly for a short period and then after a period of time it rises again together with the GDP level. The reaction of the death rate is hump-shaped; it moves down as GDP goes through an expansionary phase. The results confirm the previous finding on the number of firms, as establishment entry also increases after a monetary expansion. There is no evidence that the number of new establishments would decline after a positive shock.

For robustness analysis I estimate the effects of a monetary shock on additional firm turnover data. The results are shown in Figure 3. The number of births and deaths of establishments are included together in a VAR, while other firm turnover variables are included one by one. The impulse responses of macroeconomic variables are not shown in the figure, but it should be noted that the firm turnover series are available for different time periods so that the VAR models are estimated for the restricted samples. The reactions of the macroeconomic variables used to identify the monetary shock in the models with net business formation, the number of failures and the failure rate are similar to those of Figure 1. The reaction of macroeconomic variables in the models with the number of establishment births and deaths and the net entry rate are similar to those in Figure 2.

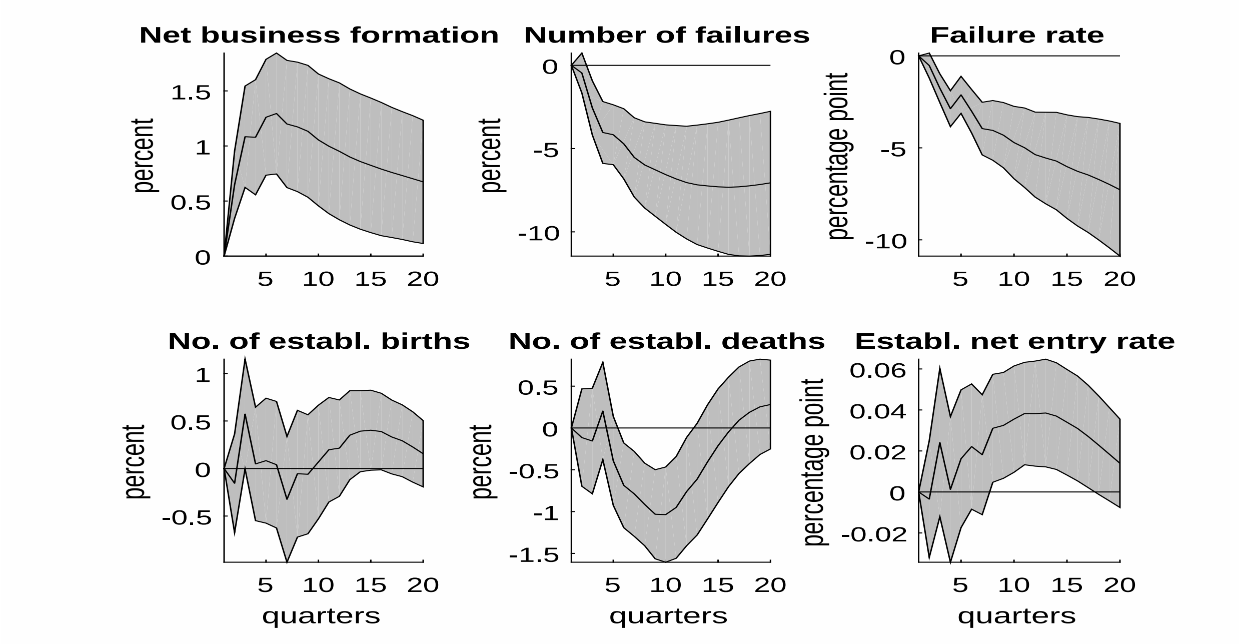

Figure 3: Impulse response functions to an expansionary monetary shock.
Notes: 95% centred confidence intervals around the point estimates. The net entry index of firms, period 1954Q3–1995Q3, the number of failures, period 1954Q4–1998Q3, the failure rate, period 1957Q1–1983Q4, and the net birth rate of establishments, period 1993Q2–2014Q4, are included one by one. Establishment birth and death numbers are in the VAR together, period 1993Q2–2014Q4.

The establishment net birth rate illustrates the dynamics in the birth rate net of the death rate in Figure 3 the bottom right plot. The dynamics indicate the initial increase that comes with the rapid reaction of the entry rate, although statistical significance is weaker because of the noise from the death rate. Later it increases in response to the decrease in the death rate of establishments. The reactions of the number of establishment births and deaths in Figure 3 bottom left and middle panels are relatively similar to the dynamics of the birth and death rates in the benchmark analysis. The number of establishment births reacts more strongly four years after the shock than the birth rate does, which is consistent with the higher number of firms prevailing in the economy so that the entry rate becomes lower. The number of failures and the failure rate (shown out of 100 firms) decline after a shock and the index of net business formation increases after the expansionary monetary shock. The results for net entry are close to the estimates of Lewis and Poilly (2012), Lewis (2009) and Bergin and Corsetti (2008).

Additional extensive robustness analysis confirms the qualitative results of firm and establishment turnover measures for monetary shocks. Using the actual FFR rate without the shadow rate leaves the establishment birth and exit impulse responses qualitatively unchanged. The inclusion of the real oil price in the VAR does not change the results qualitatively either. I also exclude the firm turnover variable from the information set of the central bank, placing it after the interest rate, as is done in Bergin and Corsetti (2008). The contemporaneous effect of the monetary shock on firm turnover measures is economically and statistically not different from zero. The shape of the impulse responses is similar, and the quantitative effects are of similar magnitude. In addition, I estimate the VAR on extended samples. For the number of new firms and the net business formation I use data starting from 1954Q3. I also estimate the failure rate for the full available period and the number of business failures up until 2015Q4. I detrend the bankruptcy filings, the number of business failures and the failure rate with quadratic trends as there were changes in the firm bankruptcy laws during the sample period that might have changed the trends. For the extended period the net business formation increase is stronger than the benchmark result. The number of new firms increases as in the main results, but the effect is less persistent.

All firm exit measures decrease strongly after monetary easing. The bankruptcy filings, the business failures and the failure rate all follow an inverted hump-shaped response. Additional robustness analysis of the results for the number of new firms, business failures and bankruptcies is presented in an early working paper (see Uusküla (2008)). For example in 1978, a new bankruptcy law eased the procedure for bankruptcy. The number of failures increased steadily and stabilised at a higher level in around 1983. In order to capture the change in the law, a dummy variable is added to the equation for business failures. The number of bankruptcy filings increases at the beginning and decreases at the end of the period, but the inclusion of dummies for different periods does not change the results given the confidence intervals of the estimated results. Moreover, the additional robustness analysis for firm turnover measures includes the results for a 12-dimensional VAR, and the identification of investment-specific and technology shocks in addition to the monetary shock, using non-borrowed reserves to total reserves instead of the interest rate to identify monetary shocks, taking different sub-periods and so forth.

To sum up, there is considerable evidence that the entry margin reacts positively and fast to an expansionary monetary shock. As the exit margin reacts with a lag, it is the entry margin that leads to an increase in the number of firms after the shock.

3 Theoretical model

This section presents a stylised model of firm turnover with sticky prices and the cost channel of monetary policy. The sector producing final goods aggregates inputs from intermediate firms. Firms in the intermediate goods sector operate under monopolistic competition, there is exogenous exit, a cost in labour in creating new firms, and a price adjustment cost, following the work by Bilbiie et al. (2007). Intermediate firms have to borrow a share of the wage bill from banks (as in Christiano et al. (1997) and

Ravenna and Walsh (2006)). In contrast to other firm turnover papers, all productivity and price effects from the varying number of firms are taken out so that the focus is on the basic mechanism. I calibrate the model to the US standard values and show how the price stickiness and financial frictions influence the dynamics of the number of new firms and the number of firms after a monetary shock.

3.1 Final goods firms

The final goods firms buy inputs from intermediate goods producers and make the goods for consumption. They produce their goods using a constant elasticity of substitution (CES) aggregator, but unlike in the standard approach the number of inputs is not restricted on a line from 0 to 1, but instead varies, going from 0 to the number of firms. The production function is given by:

$$c_t = N_t^{\iota-(1+\mu)} \left(\int_0^{N_t} y_{t,j}^{\frac{1}{1+\mu}} dj \right)^{1+\mu}, \tag{2}$$

where c_t is final consumption, N_t is the number of intermediate inputs indexed by j, and output per firm is $y_{t,j}$. Mark-up $\mu = \frac{1}{\theta-1}$ where θ is the elasticity of substitution between intermediate goods as in Bergin and Corsetti (2008). I take out the effect of the number of firms on consumption in order to keep the productivity of the economy independent of the number of firms and set the love for variety parameter $\iota = 1$. This way the production function is the same as the standard linear aggregation, where total output depends linearly on the number of intermediate firms and the monetary shock has no productivity effects.

The profit maximisation function for the final goods firms is standard:

$$P_t c_t - \int_0^{N_t} p_{t,j} y_{t,j} dj, \tag{3}$$

where the price of the individual input is $p_{t,j}$. Cost minimisation gives the demand for the intermediate good j and the corresponding price index that is given by $P_t = \frac{1}{N^{\iota-(1+\mu)}} \left(\int_0^{N_t} p_{t,j}^{-\frac{1}{\mu}} dj \right)^{-\mu}$. All final and intermediate goods firms in the economy are identical, so in equilibrium they set the same price $p_{t,j} = p_t$. Inflation of the intermediate goods is measured as the change in the average price of the individual goods $\pi_t = \frac{p_t}{p_{t-1}}$. Given the simplifications, there is only one inflation rate in the economy, so there is no need to keep track of the consumer welfare adjusted inflation as in Bilbiie et al. (2007).

3.2 Intermediate goods firms

Each intermediate firm produces one input good for the final goods producing sector. Intermediate goods firms operate under monopolistic competition, there is a labour cost in creating firms, and the free entry condition determines the number of firms as in Bilbiie et al. (2007). Firms use linear production technology in labour $y_{t,j} = L_{t,j}$, where $L_{t,j}$ is the labour input of individual firms. There is no capital in the production function. Christiano et al. (2005) show that capital itself does not play a very important role in matching consumption and inflation reactions, so the model builds on a simple three-equation monetary model of consumption, inflation and the interest rate as in Galí (2015).

Firms borrow funds for the labour cost from commercial banks, forming a working capital condition for the firms. This is the key parameter of the model as it describes the extent of the financial friction. The higher the parameter is, the stronger the effect of an interest rate cut is on lowering the cost of production.

Price setting is subject to a price adjustment cost ϕ like in Rotemberg (1982). Real profits are given by:

$$v_{t,j} = \left(\frac{p_{t,j}}{P_t} - (1 + \xi i_t) mc_t \right) y_{t,j} - \frac{\phi}{2} \left(\frac{p_{t,j}}{p_{t-1,j}\pi} - 1 \right)^2 , \tag{4}$$

where the real profits per firm are $v_{t,j}$, real marginal costs are mc_t and i_t is the nominal interest rate paid to the commercial banks. Compared to Calvo type price rigidity, the Rotemberg price adjustment cost simplifies the model as all firms are symmetric and the distribution of prices collapses to one single price. The Rotemberg set-up follows the paper by Bilbiie et al. (2007). The intermediate firm j chooses labour $L_{t,j}$ and price $p_{t,j}$. The cost minimisation problem gives the marginal cost net of interest rate payments: $mc_t = w_t$. The interest rate cost on top of the marginal costs follows the papers by Ravenna and Walsh (2006) and Uhlig (2009) that do not have firm turnover in the model.

The net present value npv_t of the firm consists of the discounted profits of all future periods and is measured after the firm has produced goods but while it is unknown whether the firm will survive. Under this definition the net present value is identical for incumbents and new firms. In real terms the net present value is given by:

$$npv_{t,j} = (1 - \delta) E_t \left[\frac{\lambda_{t+1}}{\lambda_t} (v_{t+1,j} + npv_{t+1,j}) \right] , \tag{5}$$

where δ is the exogenous death probability of the firm so that a fraction $(1 - \delta)$ survive, E_t is the conditional expectations operator, and the $\frac{\lambda_{t+1}}{\lambda_t}$ is the stochastic discount factor of the consumer. The equation is the value function notation, which is analogue to the expression for the real value of the firm in Bilbiie et al. (2007)[8].

There are many potential entrants. To enter the market, potential firms face a sunk cost in labour and need to borrow a share of wage costs from the banks. The quasi free entry condition is given by:

$$npv_{t,j} = \frac{1}{\Psi} \xi^{ent} w_t (1 + \xi i_t), \tag{6}$$

where ξ^{ent} is the labour needed to create a firm. This follows the literature such as Judd (1985) and Romer (1990). I define a parameter $0 < \Psi \leq 1$ that measures the share of the net present value spent on entry costs from the net present value. When $\Psi = 1$ then firms have zero expected profits at the time of entry, and the condition corresponds to the 'completely' free entry condition. When $\Psi < 1$ there are some profits left to the firm and

[8]There is also evidence that the exit margin reacts significantly at a later stage, an aspect that has recently been discussed by Khan et al. (2014) and Bergin et al. (2014) who show how incumbents react to shocks. Cost channel transmission should be consistent with the exit evidence, at a lower interest rate more firms can survive as their net present value remains higher than without the cost channel.

the net present value is higher than the entry costs, so there are some entry restrictions that do not allow the net present value before entry to approach zero. A standard reason for having monopolistic competition in a sticky price model with no entry costs is to keep the net present value of firms positive, so that even if they do not set their optimal price they are willing to continue production. The parameter also measures the share of labour used in creating new firms.

I assume that the sunk entry cost is in labour units for two reasons. The first argument is that the true costs that are sunk in creating a firm, the costs that have been incurred and cannot be recovered, are related to labour inputs. The equipment bought can be much more easily resold and is more likely to have a market value. The second argument for not using output as a sunk cost comes from evidence that price stickiness is mainly driven by customer relationships with either explicit or implicit contracts (see evidence in Fabiani et al. (2006) for the euro area), so new firms would not be in a position to buy inputs under prevailing existing contracts. If this were not true and new firms had to pay the market price instead of the prevailing price, the effects on entry would disappear and the model with output as a sunk entry cost could not match the actual number of firms increasing after a positive monetary policy shock.

New firms only start producing one period after being created and a fraction of all firms are closed at the end of each period, so some new firms never produce anything. The law of motion of the number of firms is given by:

$$N_t = (1-\delta)(N_{t-1} + N^E_{t-1}), \tag{7}$$

where N^E_{t-1} is the number of new firms created. Some of the new firms never produce, and wages and loan interest rates for these firms are paid from the total profits of the production sector before those profits are distributed to households, which means that there is a mutual fund that operates the firms on behalf of households. There are no bankruptcy related costs.

The free entry condition determines the number of firms in the model, as new firms are created until the expected profits, conditional on frictions, are equal to the entry cost. The shocks are assumed to be small enough for the death rate to remain at a level where the number of firms created never goes to zero or negative. As a result, the free entry condition is satisfied in every period, and the number of firms consistently illustrates the turnover of firms after a monetary shock and allows the model to contrast the data. Therefore the qualitative dynamics of the number of firms in the model are of most interest in the analysis of impulse responses and in the comparison with the data.[9]

The first order condition of the net present value with respect to prices gives the forward looking Phillips curve:

$$\frac{p_{t,j}}{P_t} = mu_{t,j} mc_t, \tag{8}$$

[9]The match of entry in the model and in the data is not straightforward as the number of new firms in the model also captures the possible state contingent dynamics in the exit of firms. The firm creation margin of a model is similar to a net entry measure in the data. When failures drop with increasing entry, which is true in the reaction of failures to a positive monetary policy shock in the data, the entry margin of the model overstates the importance of entry as the increase in the total number of firms would partially come through decreasing failures.

where the markup $mu_{t,j}$ is given by the following equation:

$$mu_{t,j} = \frac{(1+\mu)}{\mu(1+\xi i_t)} \left(-\frac{1}{\mu} - \frac{\phi}{y_{t,j}} \left(\frac{\pi_t}{\pi} - 1 \right) \frac{\pi_t}{\pi} + \frac{\phi(1-\delta)}{y_{t,j}} E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_{t+1}}{\pi} - 1 \right) \frac{\pi_{t+1}}{\pi} \right] \right)^{-1}. \tag{9}$$

The inflation rate today depends on expected inflation and the marginal cost as in the standard Phillips curve. However, the working capital assumption adds the interest rate cost on top of the marginal cost. The financial friction channel magnifies the effect of the marginal cost on inflation. Any shock that lowers the marginal cost leads to lower inflation. By the Taylor rule, lower inflation pushes down the interest rate, making the effect of the initial shock on inflation stronger. The variety effect on productivity and inflation is assumed away, so unlike in standard models with entry, the relative price of a good does not enter the equation, meaning the number of firms does not affect inflation directly.

3.3 The household problem

The representative household likes consumption c_t and dislikes work L_t and maximises discounted lifetime utility given by:

$$U_t = E_t \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \frac{A L_t^{1+\frac{1}{\kappa}}}{1+\frac{1}{\kappa}} \right) \right], \tag{10}$$

where U_t is lifetime utility at time t, β is the discount factor, σ is the intertemporal elasticity of substitution, κ is the Frisch elasticity of labour supply and A is a scaling parameter for steady state hours worked as in Bilbiie et al. (2007) but I allow for the intertemporal elasticity of substitution to be different from one. The Frisch elasticity of labour supply can also play a role as a congestive externality, as increasing labour demand from increased entry pushes up wages and reduces the number of firms created.

Households face a sequence of budget constraints. The available funds in period t consist of the income from working, deposits, bonds, profits and transfers. Resources are spent on consumption goods or government bonds, or are kept in deposits. In real terms, the budget constraint is given by:

$$d_t + q_t b_t + (1-\eta) c_t = w_t L_t + (1+i_t)\frac{d_{t-1}}{\pi_t} + \frac{b_{t-1}}{\pi_t} + v_t + g_t, \tag{11}$$

where d_t is the deposit at banks, q_t is the discount price for the government bonds b_t, g_t are government lump sum taxes or transfers, w_t is the wage rate and v_t is the profits received from the household's ownership of intermediate goods firms.

Households choose consumption, bonds, deposits, and working hours. The Lagrange multiplier on the budget constraint is λ_t. The first order optimality conditions set equal to zero are given by:

$$\lambda_t = (c_t)^{-\frac{1}{\sigma}}, \tag{12}$$

$$\lambda_t q_t = \beta E_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}} \right], \tag{13}$$

$$\lambda_t = \beta E_t \left[\lambda_{t+1} \frac{1 + i_{t+1}}{\pi_{t+1}} \right], \tag{14}$$

$$\lambda_t w_t = A L_t^{\frac{1}{\kappa}}, \tag{15}$$

where 12 and 13 give the Euler equation, and equation 14 describes the rule for deposits. Equations 13 and 14 set the bond and deposit interest rates to be equal. Finally, the optimality condition for the labour-leisure choice gives the market clearing wage in equation 15.

3.4 Closing the model

Banks lend working capital k_t to firms in the intermediate goods sector and ξ measures the strength of the cost channel. The banks can use funds deposited by households d_{t-1} and money injections ψ_t from the central bank. The aggregate loan condition is given by:

$$\frac{d_{t-1}}{\pi_t} + \psi_t = \xi w_t L_t = k_t. \tag{16}$$

The banks operate only as intermediaries of funds from the central bank and households to firms and the loans are paid back within the period. Closing firms always pay back their debts, and loans to the new firms that never produce are paid back from aggregate profits before the remaining profits are distributed to households. The commercial banks lend all their resources to firms, there is no credit rationing, and banks always make zero profits.

Central bank monetary policy is described by an inflation targeting Taylor rule:

$$i_t = \bar{i} + \rho_i i_{t-1} + (1 - \rho_i) \left[\zeta_\pi \left(\frac{\pi_t}{\bar{\pi}} - 1 \right) + \epsilon_{t,i} \right], \tag{17}$$

where $\bar{\pi}$ is the inflation target, ρ_i is the interest rate smoothing parameter, ζ_{pi} is the Taylor weight on inflation and $\epsilon_{t,i}$ is an idiosyncratic shock to the interest rate. The interest rate reacts more than one-to-one to the changes in inflation.

The policy interest rate is controlled through monetary operations. To determine the interest rate the central bank injects money into commercial banks that use available resources to give out loans:

$$m_t = \frac{m_{t-1}}{\pi_t} + \nu \psi_t, \tag{18}$$

where m_t is the aggregate money and ν determines what share of the money is injected into the economy by the central bank at the end of the period.

The government uses lump-sum transfers or taxes g_t to balance the budget every period:

$$q_t b_t = \frac{b_{t-1}}{\pi_t} - g_t + (\nu + i_t)\psi_t g_t = (\nu + i_t)\psi_t. \tag{19}$$

Money in this model is the amount of deposits $m_t = d_t$. The government budget constraint and the central bank's role in giving out loans to the commercial banks closely follow the papers by Uhlig (2009) and Christiano et al. (1997).

The aggregate hours of households are divided between creating new firms and producing output:

$$L_t = N_t L_{t,j} + N_t^E \xi^{ent}. \tag{20}$$

This concludes the model. The model is solved for the competitive equilibrium where consumers maximise lifetime utility, firms maximise profits and markets clear. The next section discusses the calibration of the model and presents the results for the importance of the cost channel.

4 Calibration and results

4.1 Calibration

I calibrate the model at quarterly frequency using traditional parameter values (see Table 2) for the US economy. The probability of the death of a firm is calibrated at 2.5%, as is standard in the literature and in line with the literature starting from Bilbiie et al. (2007). The 2.5% quarterly rate gives a 10.7% annual exit rate, which is very close to the 10.8% average death rate of firms from the BLS Longitudinal Business database for the period 1977-2013 and the 12.3% death rate of establishments during the period 1993Q2 to 2014Q4 calculated from the BLS Business Employment Dynamics data for the US. The discount factor reflects a real interest rate of 4% per year, and the steady state yearly inflation is 2%. The constant in front of the disutility of labour A only determines the steady state share of hours worked, which is set at $\frac{1}{3}$ and does not affect the impulse response function.

The mark-up is set at 36%, which is standard in the firm turnover literature (see for example Bilbiie et al. (2007)). The share of entry costs in the net present value $\Psi = 0.1$ is set so that the share of labour in the creation of new firms is around 2%. This lies between the 5.5% share of job creation by new firms in total employment between 1993 and 2013 given in the BLS Longitudinal Business Database, which also includes production, and the estimate of Djankov et al. (2002) that starting a firm in 1999 took about 1.69% of GDP per capita, meaning the 450,000 firms started in 1999 would add up to below 1% of GDP.[10] My benchmark calibration of entry share in labour is below the calibration of Lewis and Poilly (2012), who assume that the share of labour in startup activities in 1954 was 20%. I set the intertemporal elasticity substitution parameter $\sigma = 1$. The share of the central bank money left in the economy is set at 0.5. The interest rate smoothing parameter is 0.8, in line with the Smets and Wouters (2007) estimated mode of 0.81, well within the interval of the 90% credible set ranging from 0.77 to 0.85. The Taylor rule parameter of the interest rate response to inflation is equal to 2, close to the Smets and Wouters (2007) mode of 2.03 and the 90% credible set between 1.74 and 2.33. I calibrate the Frisch elasticity of labour supply to $\kappa = 5$. Rogerson and Wallenius (2009) show that the values in the macroeconomic models are very weakly related to the

[10] Barseghyan and DiCecio (2011) estimate from a panel of countries that the entry costs of a firm are 32% of GDP per worker.

Table 2: Calibrated parameter values.

Not.	Value	Robustness	Notes
β	0.99		Discount factor, yearly interest rate of 4%
π	1.005		Steady state inflation, yearly 2%
δ	0.025		Share of firms closed, 10.7% per year
N	1		Number of firms, normalisation
ξ^{ent}			Implied by the model
A			Matching $\bar{L} = \frac{1}{3}$
ρ_i	0.8		Interest rate smoothing
ν	0.5	[0.1, .9]	Share of money left in the economy
μ	0.36	[0.05, 0.5]	Mark-up
Ψ	0.1	[0.05, 1]	Entry cost share in net present value
σ	1	[0.2, 2]	Intertemporal elasticity of substitution
κ	5	[.2, 10]	Frisch elast. of labour supply
ζ_π	2	[1.5, 2.5]	Taylor weight on inflation
ψ	(1.8, 5.5, 14)		Price stickiness (2, 3 and 4.2 q. spells)
ξ	(0, 1.276, 1.915)		Cost channel, Ravenna and Walsh (2006)

Note: Robustness analysis is carried out by drawing uniformly from the values displayed in square brackets. Parameter values in round brackets are used to discuss the importance of sticky prices and the financial friction.

values estimated from micro data and higher values much higher than unity are realistic. Christiano et al. (2010) claim that the parameter should not be interpreted as the Frisch elasticity and calibrate the parameter to infinity. I log-linearise the model around the steady state and solve it computationally by using the method of undetermined coefficients proposed by Uhlig (1999)[11].

In calibrating the level of the cost channel I follow the estimates of Ravenna and Walsh (2006). They estimate the cost channel parameter to be 1.276 in their benchmark results, and I use this for my main analysis. For a high value of the cost channel I use the value of 1.915 from Ravenna and Walsh (2006), but this value is much lower than the alternative estimate of 11.831. Taking the confidence intervals into account, most of the support of the financial friction parameter is above one. Very similarly, Chowdhury et al. (2006) estimate the cost channel for the US to be about 1.3 using a single equation based method and Castelnuovo (2012) estimate it to 1.18 with the 90% confidence intervals ranging from 0.6 to 1.75 in Bayesian full likelihood analysis. Tillmann (2009b) estimates the time-varying cost channel and finds evidence for values much higher than one for most of the post WWII US sample, and in another paper Tillmann (2009a) uses the Ravenna and Walsh (2006) values for the cost channel in a theoretical setup. These estimates are close to the Barth and Ramey (2002) corrected calculations in Barth and Ramey (2011) that the gross cost channel parameter is equal to 5.7 months of sales and the net cost channel is equal to 3.7 months of sales for the period from 1959 to 2000. Their calculations only take into account inventories and trade receivables and payables. The share of inventories plus trade receivables is about 3.8 months of sales and net of trade payables it is about

[11] The model where the cost channel is set to zero cannot be solved directly because the monetary injection becomes undetermined, so the model with pure sticky prices is solved without the banking sector. The result of the pure sticky prices can be equally well approximated by fixing the cost channel parameter to 0.01.

2.3 months of sales for the period from 1993Q2 to 2014Q4. The share of inventories plus trade receivables is about 9.9 months of the private wage bill and the measure net of trade payables is about 6 months of the private wage bill. The debt to GDP and debt to wage cost of the private industries give much higher values for the parameter. The aggregate borrowing by non-financial corporations was 63.2% of annual GDP, which is around 2.5 times the quarterly GDP for the period from 1993Q2 to 2014Q4, the period for which the establishment data are available. The share of non-financial corporate debt to compensation of employees by private industries sets the parameter as high as 6.8 quarters of the total private compensation bill.

Part of the literature sets the parameter equal to unity or estimates the value to be between zero and one[12]. However, the evidence for the importance of financial markets is robust. There is a body of evidence showing that new firms borrow a lot, even if they have access to capital markets in the US. Moreover, the firms continue to rely on debt financing even after the first years of their existence, giving support to the cost channel hypothesis for existing firms too. For further empirical evidence see for example Robb and Robinson (2014). For some combination of the parameters and changes in the model, values below one are also sufficient to flip the counterfactual effect of the monetary policy shocks on firm turnover if there are price rigidities. For the pure sticky price model, I set the parameter equal to zero for the case of no cost channel.

I use three values of price adjustment cost to demonstrate how the cost channel works. For the benchmark value of the Rotemberg adjustment cost I set $\psi = 5.5$, which corresponds to an average price spell of three quarters and a Calvo parameter of 0.66, corresponding to the mean estimate of the price adjustment frequency of Smets and Wouters (2007). The low value of price stickiness is set at a two quarter price spell or a Calvo parameter of 0.49, $\psi = 1.8$, and the high value of the price adjustment cost $\psi = 14$ is very close to the Smets and Wouters (2007) upper bound estimate of four quarters and Calvo of 0.74.

4.2 Main results

Figure 4 presents the impulse response functions for a monetary expansion when the price stickiness parameter is set at 5.5, which corresponds to an average price spell of three quarters and a Calvo parameter of 0.66. The three impulse responses in the figure show the model with a high level of financial friction ($\xi = 1.915$) on the line with stars, with benchmark medium financial friction ($\xi = 1.276$) on the dotted line, and finally for comparison without financial friction ($\xi = 0$)[13] on the solid line. The monetary shock is scaled at one percentage point decrease in the annualised interest rate.

As expected, the pure sticky price model shows that an expansionary monetary policy shock leads to a drop in the creation of new firms and to a lower number of firms in the economy. As a result of an interest rate cut firms would like to increase prices and lower

[12]See for example Christiano et al. (1997) set it to unity and Lewis and Poilly (2012) estimate the parameter for the US data to be between 0.5 and 0.9. On the lower side the estimate by Rabanal (2007) for the cost channel is between 0 and 0.5 and Uhlig (2009) sets the value for existing firms at 0.1 for the US.

[13]By setting the parameter to zero the amount of loans is equal to zero. To solve the model I delete the equations related to the amount of loans. Alternatively one can set the parameter very close to zero such as $\xi = 0.01$.

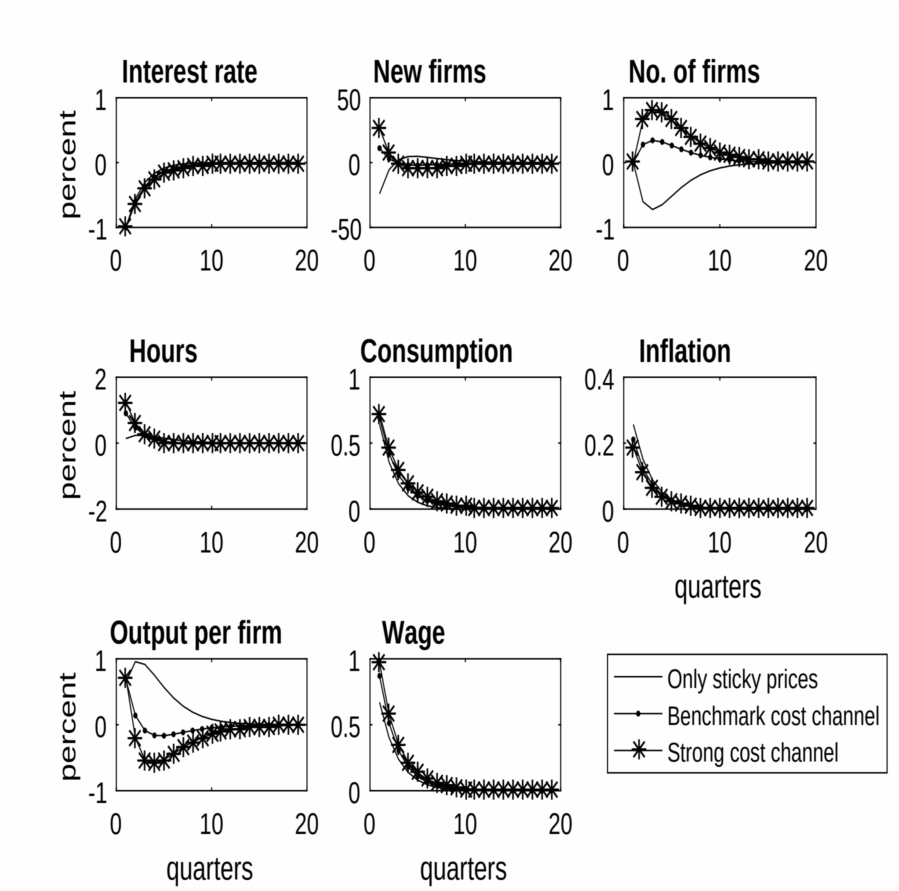

Figure 4: Impulse response functions to an expansionary monetary shock with benchmark (medium) price stickiness ($\phi = 5.5$, average price spell of 3 quarters, or Calvo parameter of 0.66).

the level of production, but the cost of price adjustment means that they are unable to increase their prices to the desired level immediately, so they must produce more than they want to. The temporarily low mark-up reduces the net present value of the firms at the time when wages are high, so the number of new firms decreases in order to equalise the cost of entry and the net present value of the firms. These results from the sticky price model are documented in several papers including Bilbiie et al. (2007).

The model with sticky prices and a high level of financial friction produces an increase in the number of firms after monetary easing. The shock leads to a drop in the funds which the financial intermediary can lend to the intermediate goods producers, and this results in higher wages and hours. However, an accompanying decrease in the interest rate cuts the costs of production, and as output increases, so do profits per firm. The higher value of the firms leads to an increase in the entry of firms in order to keep the free entry condition satisfied. The key difference from the pure sticky price model is that the cost of production and the cost of creating firms increase much less with the cost channel, which allows more firms to be created. The effect can even be so strong that the average size of the firm in terms of output drops. The number of new firms pushes up demand for labour until wages are so high that the entry cost equalises with the net present value of the firm.

The prediction of the model with the cost channel is qualitatively in line with the empirical results for the dynamics of the creation of firms. The estimated effect on the number of new firms was more persistent, but the VAR evidence on the establishment birth rate also indicated a short and sharp increase in the number of new firms after the shock, and much more persistent effects on output.

The medium benchmark value of the cost channel brings a weaker increase in the number of new firms, and so the positive effect on the number of firms is weaker, and the number of firms increases for two quarters after the shock. At even lower values of financial friction, the increase in the number of firms disappears and the number of firms drops, like in a pure sticky price case.

The inclusion of entry changes the dynamics of the hours worked. In the model with financial friction the number of new firms increases and this pushes up hours worked as well, whereas hours worked in the sticky price model also increase with demand, but the increase in hours is muted as fewer firms are created. The positive reaction of wages is largely independent of the strength of the financial friction and is consistent with the pro-cyclicality of the wages of new hires (see Pissarides (2009)).

Next, Figure 5 shows the impulse responses for the three levels of financial friction at a low level of price stickiness ($\phi = 1.8$, average price spell of two quarters, or Calvo parameter of 0.49) and illustrates how the financial friction and price stickiness interact. At a low level of price stickiness, a much lower level for the cost channel is needed for the number of firms to increase.

First the model with a low level of price stickiness and no financial friction shows how the price stickiness still leads to a decrease in the overall number of firms, though the drop in entry is smaller than with the medium level of price stickiness. The two models with benchmark and high levels of the cost channel result in qualitatively similar dynamics for the number of firms. The drop in the interest rate leads to a rapid increase in the number of new firms.

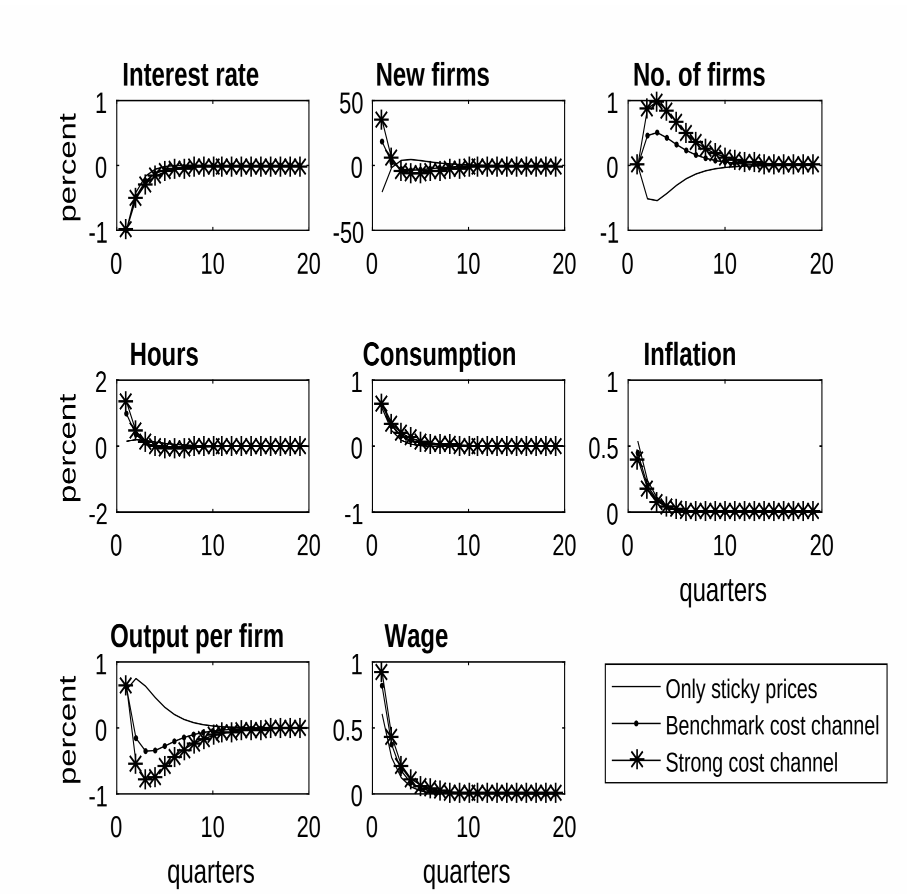

Figure 5: Impulse response functions to an expansionary monetary shock with low price stickiness ($\phi = 1.8$, average price spell of two quarters, or Calvo parameter of 0.49).

Finally, Figure 6 makes it explicit that a higher level of price stickiness requires a higher level of financial friction in order for dynamics for the number of firms to be generated that are consistent with the empirical facts. At a high level of price stickiness parameters ($\phi = 14$, Calvo parameter of 0.76, and average price spell of 4.2 quarters), the middle level of the cost channel parameter is not sufficient to bring a sizeable increase in the number of new firms.

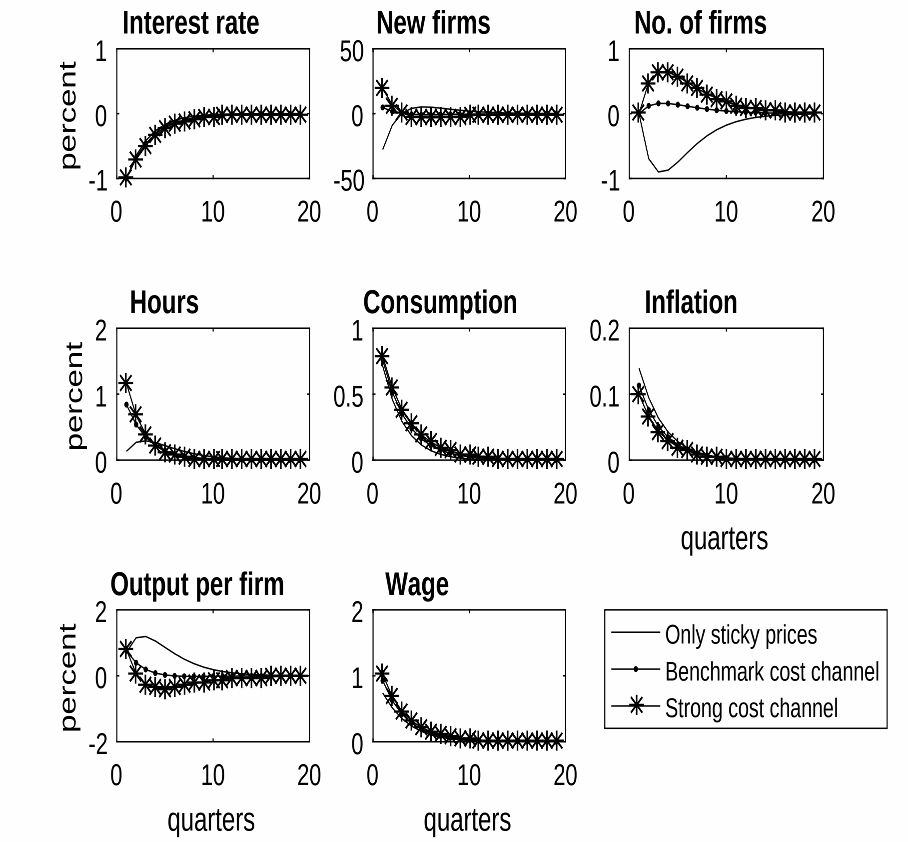

Figure 6: Impulse response functions to an expansionary monetary shock with high price stickiness ($\phi = 14$, average price spell of 4.2 quarters, or Calvo parameter of 0.76).

The financial friction could potentially dampen the reaction of the inflation rate after a monetary shock and make the impulse response smoother (see for example Rabanal (2007) and Christiano et al. (2005)). In the model, higher financial friction does make the initial reaction of the inflation rate smaller, but the effect is not quantitatively big. The key in understanding inflation in this model lies in the reaction of wages and hours. The model with endogenous entry leads to an additional increase in the labour demand to generate new firms after a monetary expansion, and this also puts pressure on hours and wages so that inflation reactions are similar. The assumption of sticky wages would dampen the effect of the shock on wages and inflation in the short run. That the cost channel has a small effect on inflation is consistent with the results in Rabanal (2007), who shows that the cost channel is not enough to generate the price puzzle that is often found in the SVAR papers. At the same time the cost channel strengthens the reactions of consumption and output, helping the model to magnify the real effects and decrease the need to rely on strong price stickiness.

The evidence for the dynamics of the number of firms supports recent findings that emphasise the role of finances in the creation of new firms (see Robb and Robinson (2014)). La Croce and Rossi (2015) assume that banks cannot insure against firms not paying back their debt and therefore are subject to idiosyncratic loss. This mechanism leads to higher volatility and more persistent effects of shocks on output. Although their framework does not include sticky prices and monetary shocks, it is likely that their mechanism in the context of this paper would enforce the cost channel mechanism of the monetary shock and make the reaction of real variables and firm turnover stronger and more persistent. In contrast, Bergin et al. (2014) allow new firms to use either debt or equity to finance the entry cost and show that a fall in the number of firms after an adverse financial shock helps to reduce the effect on output as the remaining firms become financially more sound and push up collateral value. Adding collateral constraints to the current model would also weaken the output response of the monetary shock by allowing the number of firms to drop and the value of the firm to increase.

4.3 Discussion and robustness

The results are robust to many parameterisations of the model. In order to study the sensitivity, I assume that the parameters can take values in a fixed interval and draw 1000 independent combinations of realisation from the uniformly distributed parameter space and calculate the impulse response functions. Table 2 column robustness gives an overview of the parameter ranges discussed. I assume the following intervals for the parameters: mark-up between 5 and 50 percent $\mu = [0.05, 0.5]$; the intertemporal elasticity of substitution below and above unity $\sigma = [0.2, 2]$; entry cost share in net present value $\Psi = [0.05, 1]$; changes to the share of labour working in creating new firms; the Taylor weight of inflation $\zeta_\pi = [1.5, 2.5]$ to cover the credible set region estimated by Smets and Wouters (2007); and the share of money taken out from the economy $\nu = [0.1, .9]$. I keep the price stickiness parameter $\phi = 1.8$ and show the two extreme cases of financial friction. Frisch elasticity of labour supply κ is allowed to have values between 0.2 and 10, incorporating both the microeconomic estimates and the macroeconomic values of the parameter.

Figure 7 presents the impulse responses for the range of parameterisations of the model with the Frisch elasticity above 5 and below 10. The grey area in the figure presents the full region of impulse response realisations with the strong cost channel ($\xi = 1.915$), and the area between the lines with asterisks presents the impulse responses for no financial friction ($\xi = 0$). All parameterisations of the model with strong financial friction lead to a higher number of new firms and a higher overall number of firms after monetary expansion. All models without financial friction but still with a low level of price stickiness see a decrease in the number of firms in the economy.

An important parameter in the transmission of the shock is the Frisch elasticity of labour supply κ, where the lower the elasticity is, the stronger the cost channel friction needs to be to overturn sticky prices. When the parameter value is between 0.2 and 5, there are parameter combinations, that include certain values for the labour share in creating firms and the intertemporal elasticity of substitution, at which the cost channel of 1.915 is not sufficient to overcome the counterfactual prediction of the sticky prices and generate positive entry. There are several possible extensions of the model, such as a cash-in-advance constraint for households or sticky wages, that allow the model to generate positive entry even at very low values of Frisch elasticity.

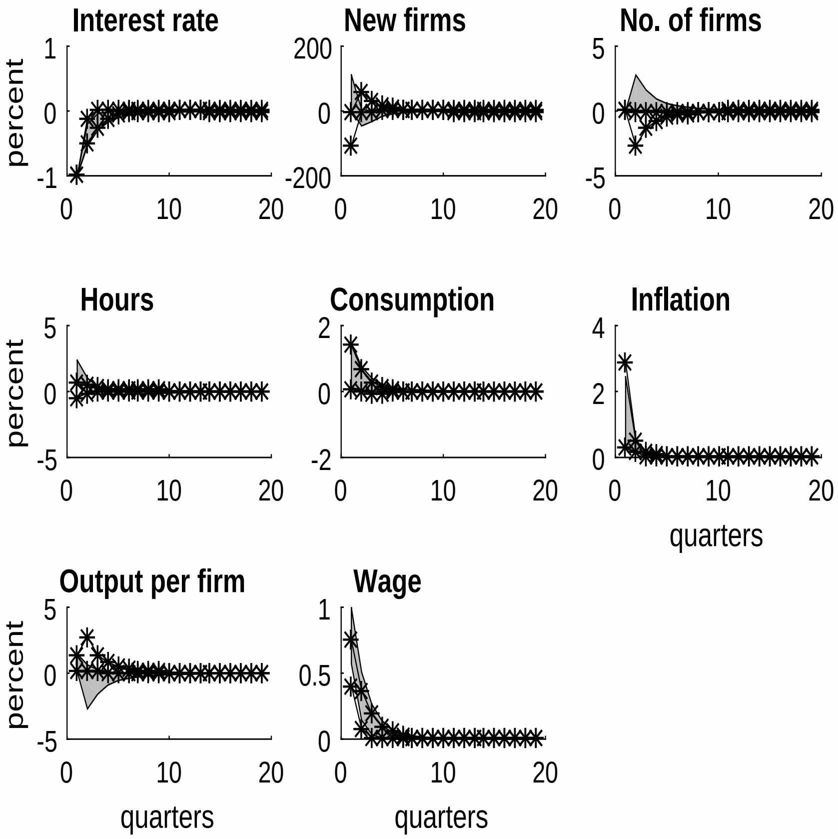

Figure 7: Robustness analysis of impulse response functions to an expansionary monetary shock.

Notes: The grey area presents the models with a strong cost channel ($\xi = 1.915$) and the area between the lines with asterisks shows the models with no cost channel ($\xi = 0$). The price adjustment cost is small $\phi = 1.8$. The intervals cover all the impulse responses generated from 1000 draws from the uniformly distributed parameter intervals discussed in the main text.

The mechanisms at work in the model are very simple and are stylised so as to make the mechanism that drives the results clear. The simplicity also makes it possible to discuss certain extensions intuitively. The results also hold for the sticky information type of transmission. The sticky price model where only the firms with low mark-ups change their prices can help to reduce the counterintuitive results of the sticky price approach and lead to monetary shocks having no effect on firm turnover, but cannot deliver any reversal of the impact. If very high menu costs for changing prices are assumed, firms could file for bankruptcy instead of increasing prices after an expansionary monetary shock, but then menu costs should also lead to more bankruptcies after expansionary monetary shocks. Therefore, the mechanism that causes the dynamics of firm turnover must be stronger to overcome the prediction of price stickiness.

Bergin and Corsetti (2008) use inputs for other firms that can be bought at pre-set prices to create new firms. Cavallari (2013) shows that a non-negligible share of imported goods helps to generate stylised facts for the international business cycle. Also in this model the inclusion of production in the entry cost helps to overcome the counterfactual prediction of sticky prices. When new firms can buy their inputs from other firms at lower prices than flexible price equilibrium after an expansionary monetary shock, it generates an incentive to create more firms now rather than in the future as it is cheap to create firms now rather than in the coming period when prices increase. The higher the share of inputs from other firms, the lower the level of financial friction that is needed to flip the reaction of the number of firms.

The original paper by Christiano et al. (1997) on the cost channel and the Uhlig (2009) paper have a cash-in-advance (CIA) constraint for households. I have assumed it away in the benchmark analysis, in order to show the pure effect of the cost channel on entry. However, the inclusion of the CIA constraint for households can help to bring the dynamics of firm creation in the model closer to the data with a smaller cost channel. I assume that for a fraction of goods η the household needs cash in hand. The constraint in real terms is $h_{t,res} + \eta c_t = \frac{h_{t-1}}{\pi_t}$, where h_{t-1} is the cash at hand from the last period that can be used to buy goods, parameter η is the share of cash in advance goods, and $h_{t,res}$ is the residual cash holding, which in equilibrium equals zero. The CIA constraint reduces real consumption after a monetary expansion as nominal cash is fixed but prices increase. The relative drop in consumption to a version without a CIA constraint for households frees up resources to create more firms in the period of the shock, and the number of new firms increases after an expansionary monetary shock even at very low levels of financial friction, reversing fast and strongly in the next quarter. The inclusion of the CIA constraint lowers the value of the cost channel needed to generate a sustained increase in the number of firms. The basic mechanism of the financial friction of the number of new firms remains unchanged, so the stronger the cost channel is, the smaller the decrease in the number of new firms is, or the stronger the increase in the number of new firms.

Wage rigidity helps to produce the dynamics for the number of firms observed in the data in this model, as was documented by Lewis and Poilly (2012). Real wage rigidity however leads to a situation where there is a lot of crowding of entry in the quarter of the shock. Wage rigidity brings expectations of wage increases in the future, making firm creation relatively cheap compared to what it is in subsequent quarters, so that the positive effect is reversed in the next quarter. Lewis and Poilly (2012) introduce a specific congestive friction on the cost of entry that helps to avoid a strong drop in the creation of firms after the initial quarter. The mechanism of sticky wages works through the mark-up in a similar way to the cost channel. In an extreme case of flexible prices and sticky wages the mark-up increases after a monetary expansion as prices increase but wages remain unchanged, leading to pro-cyclical mark-ups.

The qualitative results stay unchanged when prices are set one period in advance or when the model is rewritten to follow exactly the original paper on limited participation by Christiano et al. (1997). Both these models are discussed in a working paper version (see Uusküla (2008)).

The mechanism of the cost channel to generate positive entry relies on the new firms borrowing. In the benchmark calibration I have kept the cost channel parameter the same for entry and operating costs. If new firms borrow more funds than existing firms do, the required level of the cost channel for operating firms is much lower to flip the counterfactual effects of the sticky price mechanism.

5 Conclusions

This paper shows that the inclusion of firm turnover in a DSGE model helps in understanding the monetary transmission mechanism. First the paper offers empirical evidence that an expansionary monetary policy shock increases firm creation and the number of firms. Second, I demonstrate that in a DSGE model of firm turnover, sticky prices lead to a drop in the number of firms after a monetary expansion. The inclusion of a sufficiently strong cost channel reverses the sign of the reaction and offers a qualitative match with the empirical evidence. The greater price stickiness is, the stronger the cost channel needs to be to get the number of firms to go up after a positive monetary shock.

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