The Extensive Margin and Monetary Policy[1]

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Abstract

The creation of new firms, referred to as the extensive margin, is a significant but overlooked dimension of monetary policy. A monetary VAR documents that monetary policy has significant effects on firm creation. An analytically tractable model combining sticky prices and firm entry shows that entry alters the transmission of monetary policy innovations, acting much like a type of investment in more standard models. Monetary policy rules that offset the uncertainty of productivity shocks can raise the mean level of entry and thereby welfare, suggesting a new motivation for stabilization policy.

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1 Introduction

Business cycles are characterized by sizeable investment dynamics of firm entry and exit. Just as real and monetary shocks may lead firms to adjust the scale of production, they also create opportunities to introduce new goods in the market, as lower costs or higher demand raise the profitability of new product lines. The first type of adjustment is commonly referred to as the intensive margin, whereas the second type of adjustment is referred to as an extensive margin. A small but dynamic strand of literature has studied how the extensive margin of firm entry and product variety can contribute to our understanding of the business cycle in closed and open economies, e.g. Kim (2004), Ghironi and Melitz (2005), Bilbiie et al. (2005), Jaimovich (2006, 2007). These aim to provide a more complete model of imperfectly competitive markets in manufacturing where entry drives profits to zero.[1] The question this paper investigates is their monetary policy dimension.

There is a clear need for studies on this subject, given that the tendency for firms to fail is among the most recognizable features of recession, and that new startup firms are likely to be among the most sensitive to interest rate changes by policy makers. This paper argues that the extensive margin is a dimension of monetary policy that has been under-appreciated. Firstly, studying the dynamics of firm entry and exit may be a good place for economists to look for mechanisms of monetary policy transmission. It has been estimated that 25% of annual gross job destruction can be attributed to establishment deaths and 20% of annual gross job creation to new establishment births, as estimated by Davis and Haltiwanger (1990) on the basis of U.S. manufacturing data 1972-1986. Secondly, the extensive margin has welfare implications working through variety effects that are entirely distinct

[1] Recent open macro literature has explored the role of firm entry in the international business cycle, and analyzed international spillovers from policy and productivity shocks. (See Ghironi and Melitz, 2005; Corsetti, Martin, and Pesenti, 2005, among others.) Some contributions have also reconsidered issues of the welfare effects of product varieties – with potentially relevant implications for the design of international and domestic price indexes. (See the above contribution and Broda and Weinstein, 2004). Our model builds on a macroeconomic literature on firm entry, which focused on issues of indeterminacy of equilibria and increasing returns. (See Chatterjee et al., 1993; Devereux et al., 1996; and Kim, 2004). The flexible price case of our model will have several similar implications to these earlier papers. For an empirical study relating entry to exchange rate fluctuations see Campbell and Lapham (2004).

from the intensive margin. As a result, studying the extensive margin dimension of monetary policy may augment the welfare implications that motivate monetary policy.

A first novel contribution of this paper is to document empirically in U.S. data a correlation of extensive margin entry with monetary policy. The paper augments standard monetary VAR models with measures of new firm incorporations and net business formation. These measures of entry are found to respond significantly to monetary policy innovations.

The theoretical contribution of the paper is to formulate an analytically tractable model that combines price stickiness and firm entry decisions, as a means for studying the transmission and welfare implications of the extensive margin of monetary policy. In this model, firms must prepay a fixed cost in the period prior to production, which is the cost of an exogenously given quantity of intermediate inputs that are necessary to start up production. This startup fixed cost must be paid each period, and can be interpreted as investment expenditure under the simplifying assumption of complete depreciation of capital within one period. Firms cover such cost with their profits derived from monopolistic pricing. As demand and cost are affected by shocks, the number of firms that find it profitable to enter the market will vary over time. Firms enter the market by producing new differentiated products, thus enlarging the set of goods available to consumers and other firms. The preference specification allows for love of variety, so that enlarging the set of goods may have positive effects on household utility. Price stickiness takes the form of prices that are set one period in advance.

The first theoretical finding is that the dynamics of entry can be understood through their similarity to the more familiar dynamics of investment in production capacity at the intensive margin. For a given entry cost, a fall in the real interest rate raises the expected discounted profits from creating a new firm, thus encouraging new entrants. Depending on the degree to which consumers and firms' managers benefit from the increased variety of goods and intermediate inputs, the presence of the extensive margin amplifies the real effects of monetary policy.

The second finding goes beyond fluctuations in firm entry to study its unconditional expectation. Full nonlinear solution of the model indicates that the mean number of firms is a negative function of the variance of productivity shocks. Previous sticky price models have shown that monopolistic firms respond to uncertainty by raising prices, thus exacerbating monopolistic distortions. This paper finds that uncertainty additionally has a similar effect in terms of reducing the number of firms active in a market. This finding is far from obvious, since the higher prices set by firms in response to uncertainty will also raise expected profits, which in turn could potentially encourage entry. We provide a proof that the first effect must dominate the second in our model.

The paper then studies the role of stabilization policy. The negative effect of productivity uncertainty on entry noted above can be offset if monetary policy follows a countercyclical policy, expanding in response to positive productivity shocks as to stabilize marginal costs. This implies a new motivation for stabilization policy, which could be viewed as an extensive margin of the output gap. There is a very new but growing literature studying monetary policy in environments with nominal rigidities and firm entry. Bilbiie, Ghironi and Melitz (2007) study a rich environment with sunk entry costs in terms of labor units and Rotemberg costs of price adjustment. Their findings include a motivation for price stabilization distinct from ours, in that the costs of price adjustment lower firm profits and distort entry decisions. Lewis (2006, 2008) documents in a model with sticky wages that monetary shocks stimulate entry by raising demand, and investigates policy implications. This differs from the mechanism in our paper, whereby monetary expansion lowers the real interest rate, encouraging firms to make the investment in entry necessary for future production. This distinction applies also with Elkhoury and Mancini Griffoli (2006), where entry costs are modeled as legal fees with sticky prices. Finally, Uusküla (2008) compares entry dynamics in sticky price models and limited participation models, using VAR evidence to discriminate between the two.[2]

[2] Since we focus on stabilization policy, we abstract from the growth dimension stressed by other macroeconomic models with entry, namely, the link between the creation of new firms and technological change when progress is embodied in new capital (e.g. Campbell 1998). Nonetheless, we observe that our model shares two standard predictions with this literature. First, current productivity shocks lead to entry — in this sense, entry is procyclical. Second, future productivity shocks leads to exit. The reason is however different from the obsolescence of current capital.

This paper is organized as follows. The next section motivates the theoretical work to follow with some original empirical results. Section 3 introduces the model. The next two sections analyze monetary transmission and policy rules. Finally, the model is extended to include physical capital in the variable cost of production. The online appendix includes analytical details of the derivations.

2 A look at the evidence

As empirical motivation for our inquiry, Figure 1 plots two metrics of entry, the U.S. index of net business formation and the number of new incorporations. The comovements with GDP are obvious, with correlations as high as 0.73 and 0.53, respectively. While the comovement with output has been noted in earlier research (see e.g. Devereux et al., 1996; Jaimovich, 2006, 2007; Bilbiie, Ghironi and Melitz, 2005), we go on here to document a relationship with monetary policy. To this goal, simple unconditional correlations are not appropriate. Indeed, if one uses the increase in nonborrowed reserves ratio to total reserves as an indicator of an expansionary monetary policy stance, its unconditional correlations with the above measures of entry are negative (-0.28 and -0.18), rather than positive as one might expect. Similarly, the correlation with the federal funds rate has different sign (-0.04 and 0.06) depending on the measure of entry, whereas one may instead expect an unambiguously negative correlation with this indicator of monetary contraction. A likely problem is that monetary policy is adjusted counter to business cycle fluctuations, so the unconditional correlations are likely conflating endogenous monetary contractions with the booms in GDP that may have given rise to them.

Using even a simple vector autoregression to separate these effects gives a dramatically different and much clearer picture. First, we follow Eichenbaum and Evans (1995) in specifying a VAR ordering the nonborrowed reserves ratio after industrial production and consumer prices. In addition, we follow Christiano, Eichenbaum and Evans (1999) by including sensitive commodity prices to control the price puzzle. In this system we insert in turn each of our measures of entry, where the full list of

Rather, exit is due to the anticipation of a fall in prices and sales revenue due to productivity gains in a (monopolistic) competitive environment.

variables in order are: industrial production, CPI, commodity prices, non-borrowed reserves ratio, and net business formation (or new incorporations). The first two and the final series are in logs. Data is monthly, running from 1959:1 to 1996:9 when incorporations are used and to 1994:12 for net business formation. The entry series have been discontinued at these respective dates, with net business formation obtained from Economagic, and incorporations from the Survey of Current Business. Identification is by Cholesky decomposition, where monetary policy can respond contemporaneously to production, CPI, and commodity prices. Figure 2a shows that now there is a statistically significant positive effect of nonborrowed reserves on net business formation. Figure 2b shows a similar effect on incorporations, with statistical significance beginning in the eighth month.

Next, as in Eichenbaum and Evans (1995), we also include the federal funds rate in the system as an alternative measure of monetary policy stance.[3] As seen in figures 2c and 2d, the direction of the effect once again conforms with our intuition: a rise in the interest rate discourages entry, with significance in the case of net business formation.[4]

One can draw a number of lessons from these impulse responses. Firstly, monetary innovations appear to have no discernible immediate impact on entry. In all four cases represented in the figures, the effect on entry in the initial period of the monetary innovation is very small in magnitude and not statistically significant. However, there is a delayed response of entry to monetary policy. In three of the four cases, the entry response is statistically significant and peaks at about one year after the monetary policy innovation. This delayed response may be regarded as a useful stylized fact, perhaps reflecting the lags inherent in setting up a new enterprise, and we construct our theoretical model with this feature in mind. Finally, regarding persistence, of the three figures where the entry response achieved signifi-

[3] The variable list now consists of: industrial production, CPI, commodity price, federal funds rate, nonborrowed reserves ratio, and an entry measure.

[4] We also considered VARs with long-run restrictions, and found results broadly consistent with those above. Uusküla (2008) provides VAR evidence that bankruptcy filings and failures rise in response to monetary innovations. We verified that this conclusion holds also in our 5 and 6-variable VAR settings. This indicates that future theoretical work might want to consider models that study more explicitly the role of firm exit as separate from entry.

cance at the one-year mark, in two of these three cases this response fails to remain significant around the two-year mark. We conclude that there is mixed evidence in the VAR results for longer-term persistence in the entry response conditional on monetary shocks.

Computing variance decompositions indicates that in the initial period of the shock, virtually no share of the forecast error variance of either of the entry measures is attributable to either measure of monetary policy innovation. But after one year, 33% of forecast error in entry measured as net business formation, and 10% of that measured as new incorporations, can be attributed to innovations in non-borrowed reserves. The values are somewhat smaller for innovations in terms of the federal funds rate, at 9% and 1% respectively. Taken as a whole, the results provide further support for the idea that monetary shocks are important for understanding fluctuations in entry.

Note that we cannot decompose the share of aggregate output fluctuations into intensive and extensive components, since our measures of entry do not indicate the size of new entrants. As new entrants tend to be smaller in size compared to incumbent firms, the extensive margin share of changes in aggregate output may be smaller than that for the number of firms. On the other hand, there are also reasons to suspect that our measure of entry understates the importance of the extensive margin for aggregate output. In addition to the introduction of new firms, one should also consider the effects of new product lines introduced by existing firms. In studying plant-level data from the U.S. Census of Manufactures from 1963-1982, Dunne, et al. (1988) find that new firms are far more numerous than existing firms diversifying their product mix or production facilities, but adjusting for size, both groups account for about half of the impact of the extensive margin on output. The theoretical model to follow can be interpreted to describe both of these types of extensive margin adjustment, and the theoretical lessons it contributes to the literature can apply equally to new products created by new firms or existing firms. But given the lack of aggregate data series on new product development, our VAR analysis above was limited to demonstrating the presence and significance of monetary policy impacts on new firms.

Our conclusion from these various VAR exercises is that there appears to be a relationship between monetary policy changes and the tendency for firms to enter or go out of business. While such a connection is quite natural and may seem obvious, to our knowledge, this is the first paper to document this finding. The main message we take from this brief empirical exercise is that it invites and motivates the theoretical work to follow, which explores how entry might operate as part of the monetary policy transmission process and how it can affect optimal policy design.

3 The model

Consider a closed economy where a representative household consumes a basket of differentiated goods, demanding positive quantities of all the goods available in the market. The household supplies labor to firms and owns claims on firms' profits.

The number of goods varieties produced by firms is endogenously determined in the model. Firms and goods varieties are defined over a continuum of mass n_t and indexed by $h \in [0, n_t]$. To start production of a particular good variety, firms sustain fixed costs consisting of a bundle of intermediate inputs required to set up a firm's capital. Once the fixed costs are paid, firms start producing with a period lag. Interpreting one period as a year, this feature is intended to reflect the finding from the VARs above, that entry does not appear to respond contemporaneously to innovations, but the response reaches its maximum after one year. As in Kim (2004) and Devereux et al. (1996), we assume for simplicity that this fixed cost needs to be repaid each year. In addition to being necessary for analytical solution, this assumption is consistent with the VAR results above, where evidence of a significant entry response disappears after the second year of the shock. This specification may also be understood as analogous to the common simplifying assumption that physical capital fully depreciates after one period. Firms operate under conditions of monopolistic competition: in equilibrium firms will choose to produce one specific variety only. Hence, an increase in n_t corresponds to both the introduction of new varieties, and the creation of new firms.

The government is assumed to set monetary policy, collect seigniorage, and rebate any surplus to households in a lump-sum function.

3.1 Households

The utility of the representative national household is a positive function of consumption C_t and money holding M_t/P_t and a negative function of labor effort ℓ_t – whereas P_t is the welfare based consumption price index (defined below) and M_t is the stock of money that the representative household chooses to hold during the period. As household preferences are defined over a very large set of goods, utility is a well-defined (and non-decreasing) function of all goods available in the market.

The representative household maximizes $E_0 \sum_{t=0}^{\infty} \beta^t U(C_t)$, whereas utility in period t is:

$$U_t = \log C_t - \kappa \ell_t + \chi \ln \frac{M_t}{P_t}. \tag{1}$$

In the above expression C_t is a composite good that includes all varieties:

$$C_t = A_t \left[\int_0^{n_t} C_t(h)^{1-\frac{1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

where

$$A_t \equiv (n_t)^{\gamma - \frac{\sigma}{\sigma-1}}. \tag{3}$$

As in Benassy (1996) and the working paper version of Dixit and Stiglitz (1974), in our specification of preferences the parameter σ denotes the elasticity of intratemporal (i.e., across varieties) substitution, with $\sigma \geq 1$, and the parameter γ measures the degree of consumers' love for variety: $\gamma - 1$ represents the marginal utility gain from spreading a given amount of consumption on a basket that includes one additional good variety in a symmetric equilibrium (see also Corsetti, et al. 2005). In what follows, the analysis will conveniently restrict the value of the γ to be close to $\frac{\sigma}{\sigma-1}$, so that our specification of consumption is close to the standard Dixit-Stiglitz case.[5]

In each period, households buy $s_t(h)$ shares in the firm h (which start operating in the following period) at the price $q_t(h)$. At the same time, they receive dividend payments from their previous period investment. The budget constraint for the

[5] By assuming log preferences, we restrict our attention to economies with a well defined balanced growth path. However, we also abstract from potentially interesting wealth effects on labor supply (see Corsetti, et al. 2005).

representative household is therefore:

$$\int_0^{n_t} p_t(h) C_t(h) dh + \int_0^{n_{t+1}} s_t(h) q_t(h) dh + B_t + M_t \tag{4}$$
$$\leq w_t \ell_t + \int_0^{n_t} s_{t-1}(h) \Pi_t(h) dh - T_t + (1 + i_t) B_{t-1} + M_{t-1}$$

where $p_t(h)$ denotes the price of variety h; $s_t(h)$ is the share of firm h purchased in period t; w_t is the nominal wage rate; $\Pi_t(h)$ is firm h's total dividend paid in period t; T are lump-sum net taxes, B_t is the household's holding of a nominal bond (in zero net supply), and i is the nominal interest rate. Note that consumption falls on n_t goods, financial investment on n_{t+1} shares.

3.2 Firms and the government

The representative firm producing a specific variety h has access to the following production function:

$$Y_t(h) = \alpha_t \ell_t(h) \tag{5}$$

where $Y(h)$ is the output of variety h, $\ell(h)$ is labor used in its production, and α_t is a country-specific labor productivity innovation that is common to all firms.

To start the production of a variety h at time $t+1$, at time t a firm needs to install K_t units of capital. The latter consists of a basket of intermediate inputs/goods:

$$K_t = A_{K,t} \left[\int_0^{n_t} K_t(h)^{1-\frac{1}{\sigma}} dh \right]^{\frac{\sigma}{\sigma-1}}$$

Here, $A_{K,t}$ is an indicator of efficiency of investment defined as:

$$A_{K,t} \equiv (n_t)^{\gamma_K - \frac{\sigma}{\sigma-1}} \tag{6}$$

which is a direct analog to the love of variety in consumption. For a given requirement K_t, a higher efficiency index $A_{K,t}$ implies a smaller demand of goods $\int_0^{n_t} K(h) dh$.

Let $p_t(h)$ denote the price of variety h. From cost minimization, one can derive the investment demand for the good h

$$K_t(h) = A_{K,t}^{\sigma-1} \left(\frac{p_t(h)}{P_{K,t}} \right)^{-\sigma} K_t \tag{7}$$

where P_K is the price index of a unit of K:

$$P_{K,t} = \frac{1}{A_{K,t}} \left[\int_0^{n_t} p_t\left(h\right)^{1-\sigma} dh \right]^{\frac{1}{1-\sigma}}. \tag{8}$$

Observe that in a symmetric equilibrium the demand for the good h is $K(h) = K_t/n^{\gamma_k}$. The entry costs thus faced by each firm in equilibrium are symmetric and equal to $P_{K,t}K_t$.

Now, as households purchase equities at the price $q_t(h)$, this will finance investment in new firms as long as this price covers the cost of setting up a new firm. Because of free entry, then, this process will continue until, in equilibrium, the market value of a firm is equal to the cost of entry:

$$q_t(h) = P_{K,t}K_t. \tag{9}$$

To facilitate analytical solution, the following analysis will assume 100 percent depreciation: after paying the fixed cost, a firm can produce variety h in period $t+1$ only. Additionally, variation in the efficiency of investment ($A_{K,t}$) likewise introduces serial dependence in investment which precludes analytical solution. Numerical results at the end of section 4 and in section 6 will be used to study the implications of variable investment efficiency for model dynamics; all other sections of the paper will abstract from this feature (setting $\gamma_k = 1$).

Since it is assumed that households will demand any number of varieties supplied in the market, from the vantage point of a new firm it will never be profitable to produce a particular variety already produced by other firms, rather than introducing a new one. Hence in equilibrium firms are monopolistic suppliers of one good only. The resource constraint for variety h is:

$$Y_t(h) \geq C_t\left(h\right) + n_{t+1}K_t\left(h\right) \tag{10}$$

where $C_t\left(h\right)$ is consumption of good h by the representative household, while the second term on the right hand side is the demand for investment goods by all the firms that will be producing in $t+1$.

Households and firms will be symmetric in equilibrium. Hence one can write the h firm's operating profits as:

$$\Pi_t\left(h\right) \equiv p_t\left(h\right)C_t\left(h\right) + p_t\left(h\right)n_{t+1}K_t\left(h\right) - w_t\ell_t\left(h\right). \tag{11}$$

We posit that firms are atomistic, so that they ignore the effect of their pricing decision on the price level.

Households provide labor to firms for both start-up and production activities. Hence the resource constraint in the labor market is:

$$\ell_t \geq \int_0^{n_t} \frac{Y_t(h)}{\alpha_t} dh. \tag{12}$$

The model abstracts from public consumption expenditure. The government uses seigniorage revenues and taxes to finance transfers. The public budget constraint is simply:

$$M_t - M_{t-1} + \int_0^{L_t} T_t(j)dj = M_t - M_{t-1} + T_t = 0 \tag{13}$$

and in equilibrium money supply equals demand, or $M_t = \int_0^{L_t} M_t(j)dj$. Finally, the bond is in zero net supply:

$$\int_0^1 B_t(j)dj = 0. \tag{14}$$

so that $B_t = 0$ in aggregate terms. The analysis will consider two sources of uncertainty. Labor productivity, α_t, and investment requirement for entry K_t are random variables.

3.3 Equilibrium allocation

The representative household maximizes (1) with respect to $C_t(h)$, ℓ_t, B_t, $s_t(h)$ and M_t subject to (4). The first order conditions are:

$$C_t(h) = A_t^{\sigma-1} \left(\frac{p_t(h)}{P_t} \right)^{-\sigma} C_t \tag{15}$$

$$w_t = \kappa P_t C_t \tag{16}$$

$$\frac{1}{P_t C_t} = \beta (1 + i_t) E_t \frac{1}{P_{t+1} C_{t+1}} \tag{17}$$

$$\frac{q(h)}{P_t C_t} = E_t \left[\beta \frac{\Pi_{t+1}(h)}{P_{t+1} C_{t+1}} \right] \tag{18}$$

$$\frac{M_t}{P_t} = \chi \frac{1 + i_t}{i_t} \tag{19}$$

where P_t is the utility-based consumer price index:

$$P_t = \frac{1}{A_t} \left[\int_0^{n_t} p_t(h)^{1-\sigma} dh \right]^{\frac{1}{1-\sigma}}. \tag{20}$$

Equation (15) characterizes the allocation of consumption demand over varieties. Equation (16) characterizes labor supply decisions, and (17) intertemporal allocation decisions. Equation (18) characterizes the investment decision for entry, and (15) is money demand.

As already stated above, households will finance new firms as long as the present discounted value of expected profits will be above the cost of entry

$$P_{K,t}K_t \leq q_t(h) = E_t\left[\frac{\beta U'(C_{t+1})}{U'(C_t)}\frac{P_t}{P_{t+1}}\Pi_{t+1}(h)\right].$$

In other words, there will be entry as long as the setup costs are below the market value of new firms. With competitive markets and free entry, the number of firms will adjust until the above holds with an equality sign. Following Corsetti and Pesenti [2005a] it is convenient to define two new variables as follows

$$\begin{aligned} \mu_t &= P_t C_t \\ Q_{t,t+1} &= \beta\frac{P_t C_t}{P_{t+1}C_{t+1}} = \beta\frac{\mu_t}{\mu_{t+1}}. \end{aligned} \tag{21}$$

The first is a measure of monetary stance. The second is the stochastic discount factor.

Nominal rigidities are introduced by assuming that firms preset the price of their products before shocks are realized (i.e. simultaneously to the decision to enter), and stand ready to meet demand at the ongoing price. Hence, the entry decision coincides with the optimal choice of this price for the period of production. Firms choose their price maximizing the expected discounted value of their profits

$$Max_{p(h)}\ E_t\left[Q_{t,t+1}\Pi_{t+1}(h)\right] \equiv$$
$$Max_{p(h)}\ E_t\left\{Q_{t,t+1}\left[L_{t+1}p_{t+1}(h)\,C_{t+1}(h) + n_{t+2}p_{t+1}(h)\,K_{t+1}(h) - w_{t+1}\ell_{t+1}(h)\right]\right\}.$$

Using the first order conditions of the representative household, the price indices, and the definition of μ one can also rewrite the firm's problem as

$$Max_{p(h)}\ E_t\left[Q_{t,t+1}\Pi_{t+1}(h)\right] = E_t\left\{\frac{\beta\mu_t}{\mu_{t+1}}\left[p_{t+1}(h) - \frac{k\mu_{t+1}}{\alpha_{t+1}}\right]\left[\frac{L_{t+1}}{n_{t+1}^{\gamma}}\frac{\mu_{t+1}}{P_{t+1}} + \frac{n_{t+2}K_{t+1}}{n_{t+1}^{\gamma_K}}\right]\right\}.$$

The optimal preset price satisfies[6]

$$p_{t+1}(h) = \frac{\sigma}{\sigma-1} \frac{E_t \dfrac{\kappa}{\alpha_{t+1}} \left[\dfrac{L_{t+1}}{n_{t+1}^{\gamma}} \dfrac{\mu_{t+1}}{P_{t+1}} + \dfrac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma_K}} \right]}{E_t \dfrac{1}{\mu_{t+1}} \left[\dfrac{L_{t+1}}{n_{t+1}^{\gamma}} \dfrac{\mu_{t+1}}{P_{t+1}} + \dfrac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma_K}} \right]}. \tag{22}$$

It is easy to verify that, with flexible prices, the optimal price set at time will take the well-known form

$$p_{t+1} = [\text{mark up}] \cdot MC_t = \frac{\sigma\kappa}{\sigma-1} \frac{\mu_{t+1}}{\alpha_{t+1}} \tag{23}$$

where MC stands for marginal costs.

Recall from above that free entry in a competitive market implies $q_t(h) = E_t \left[\beta Q_{t,t+1} \Pi_{t+1}(h) \right]$. Substituting the first order conditions of the representative household's problem and using our definitions above, one can write

$$P_{K,t} K_t = E_t \left\{ \frac{\beta \mu_t}{\mu_{t+1}} \left[p_{t+1}(h) - \frac{\kappa \mu_{t+1}}{\alpha_{t+1}} \right] \left[\frac{L_{t+1}}{n_{t+1}^{\gamma}} \frac{\mu_{t+1}}{P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma_K}} \right] \right\}. \tag{24}$$

This expression and equation (22) summarize the macroeconomic process in our economy.

3.4 Aggregation

Assuming symmetry over varieties, h, the aggregate price index from equation (20) may be computed as

$$P_t = p_t(h) n_t^{1-\gamma}. \tag{25}$$

This price index falls with a rise in the number of firms if there is love for variety, $\gamma > 1$, since greater variety then makes it easier to achieve one unit of the consumption index.

If aggregate real GDP (Y) is deflated by the aggregate price level, it too is affected by entry:

$$Y_t = \frac{p_t(h)}{P_t} y_t(h) n_t = y_t(h) n_t^{\gamma}. \tag{26}$$

[6] We note here that, with preset prices, large negative shocks may make ex post operating profits negative – raising an issue of whether firms will voluntarily accept to produce even if they are loosing money. For simplicity, we rule this possibility out by restricting the support of the shock (as discussed in Corsetti and Pesenti, 2001).

An increase in the number of varieties raises the effective level of GDP, an effect that past research has referred to as the "returns to variety" or "returns to specialization."[7] Note that these utility-consistent definitions of aggregate price and output are not in general appropriate for comparing the model to data, as the variety effect is overlooked by statisticians; however, these are the concepts appropriate for the welfare analysis conducted here. The size of these variety effects depend on the size of the love for variety parameter, γ, which is free to be calibrated based on what is thought to be reasonable. Recall that standard Dixit-Stiglitz preferences imply $\gamma = \frac{\sigma}{\sigma-1}$.

4 Nominal rigidities and the transmission of monetary and real shocks

This section traces how price stickiness shapes the transmission of shocks, both monetary and productivity. This analysis provides lessons regarding the role of entry in monetary transmission, and also will provide a basis for monetary policy to improve the ability of the economy to respond to productivity shocks.

With nominal rigidities, the macroeconomic process in a symmetric equilibrium is described by the following two equilibrium conditions:

$$p_{t+1}(h) = \frac{\sigma}{\sigma-1} \frac{E_t \frac{\kappa}{\alpha_{t+1}} \left[\frac{L_{t+1}}{n_{t+1}} \mu_{t+1} + \frac{n_{t+2} K_{t+1}}{n_{t+1}} p_{t+1}(h) \right]}{E_t \frac{1}{\mu_{t+1}} \left[\frac{L_{t+1}}{n_{t+1}} \mu_{t+1} + \frac{n_{t+2} K_{t+1}}{n_{t+1}} p_{t+1}(h) \right]} \tag{27}$$

$$p_t(h) K_t = \mu_t \cdot E_t \left\{ \frac{\beta}{\mu_{t+1}} \left[p_{t+1}(h) - \frac{k \mu_{t+1}}{\alpha_{t+1}} \right] \left[\frac{L_{t+1}}{n_{t+1}} \frac{\mu_{t+1}}{p_{t+1}(h)} + \frac{n_{t+2} K_{t+1}}{n_{t+1}} \right] \right\}. \tag{28}$$

The first is optimal pricing; the second ensures that the value of new firms are equal to entry costs.

First, consider *i.i.d.* labor productivity shocks. As prices are preset during the period, productivity shocks changing α_t for only one period are seen in the equations above to have no impact on entry. If prices cannot fall, productivity gains fail to lower the cost of entry in the way they would in a flexible price model. (See the online appendix for a derivation and discussion of the flexible price case.) Further,

[7] See Devereux et al. (1996) and Kim (2004) for elaboration of this point.

the effects on consumption and output from a flexible price case are not observed here: as prices do not fall, there is no rise in demand from consumers, and output remains unchanged. Instead, employment falls temporarily, as higher productivity implies fewer workers are needed to satisfy an unchanged aggregate demand.

Next, the two equations above indicate clearly that in the sticky price model money is not neutral. Consider a once-and-for-all unanticipated temporary shock to μ at time t (i.e., money stocks go back to their initial value from $t+1$ on). From the RHS of the equation (28) above, one sees that a monetary shock μ_t that lowers real interest rates translates into a higher discount factor, therefore boosting expected discounted profits, that is, the market value of firms.[8] With preset goods prices, however, the overall entry cost does not change with monetary conditions. Hence, by reducing the real interest rate a temporary monetary shock raises firms' value relative to setup costs, leading to entry.[9] Observe nonetheless that, while at time $t+1$ there will be a higher number of firms and goods, the number of firms is predetermined and cannot rise in the same period in which the shock occurs. Hence the rise in demand (for both investment and consumption) driven by a monetary shock is met by a rise in output per firm solely at the intensive margin — the extensive margin takes effect only after one period. We stress the analogy in the monetary transmission channel between this model with entry and standard models without entry but with investment in physical capital. The effect of expansionary monetary shocks on the effective real interest rate induces a rise in consumption demand and investment (the latter via a raise in expected discounted profits), which translates into higher real output.

For illustrative purposes, Figure 3 graphs the effects of a monetary shock using

[8] In Bilbiie et al. (2007), this transmission mechanism is analyzed by appealing to the no-arbitrage condition linking the real demand on bonds to the real return on equity. In their approach, a temporary interest rate cut reduces the real return on bonds, inducing the expected return on equity to fall today. For this to be possible, the price of equity (our q_t) must increase today relative to tomorrow. Indeed, combining the Euler equations for bonds and equities, this corresponds to a fall in the discount rate of future profits.

[9] Observe that, if entry costs consist of labor paid at the current economy wide wage rate, by (16) and (21) money innovations would be neutral in our model. This is because any change in the value of the firm due to the effect of monetary policy on equilibrium discounting of future profits, is exactly offset by a rise in the cost of entry.

a linearized version of the model.[10] The solid lines report the case where love for variety in consumption is taken into consideration when computing the price index and deflating variables; in contrast, the long-dashed lines pertain to the case where variety effects are not taken into consideration. The figure suggests two lessons regarding macroeconomic dynamics with entry. First, with entry the inflationary implications of monetary expansion are reduced. Once new firms begin production in the second period of the shock, the added variety implies an adjustment in the price index, as indicated in (25). This effect reflects the lower cost of obtaining one unit of the consumption under a love for variety.

A second lesson is that entry in response to monetary shocks amplifies and gives some persistence to the effective impact on output. The downward adjustment in the effective price index due to variety effects above likewise implies a corresponding upward adjustment in computing the real value of output. The solid line depicts output adjusted for the effects of "variety on C": it shows that in the period after the shock, output remains above its long-run level due to the increased number of varieties. In contrast, the long-dashed line depicts output without adjustment for variety effects: this shows that, by its conventional measure, output would return to its long-run level already in the period after the shock.

Dynamics of course remain limited here, due to the restrictions imposed above to eliminate serial dependence in entry and thereby permit analytical solution. But consider briefly the dynamics of a case where the key restriction $\gamma_k = 1$ is relaxed. Suppose the Dixit-Stiglitz aggregator that is used for consumption were applied also to investment, by setting $\gamma_k = \gamma$. Variety effects then apply also to investment. This case is represented in Figure 3 by the line with short dashes, labeled "with variety in C and I." In this case, when new firms begin operation in the year after the shock, the price index for investment falls due to variety effects. This lowers the effective cost of entry one year after the shock, inducing an additional round of new entry, albeit smaller than in the previous year. In turn, when these firms begin operation

[10] To replicate a 20% markup in pricing, we calibrate the elasticity of substitution at $\sigma = 6$. Maintaining the degree of love for variety implied by Dixit-Stiglitz then requires $\gamma = \frac{\sigma}{\sigma-1} = 1.2$. We set $\beta = 1$ for simplicity. The size of the fixed cost of entry is immaterial to these results, but we set it at a value of $K = 0.012$, which implies an entry level to $n = 6$.

in the second year after the shock, this lowers the cost of investment and encourages entry again in the next year. Thus, love for variety in investment can be seen in the figure to be one mechanism by which more complex dynamics in entry can arise. Another promising mechanism for generating richer dynamics, which is left to other research not concerned with analytical solutions for welfare, may also be found by modeling the cost of entry as a sunk cost lasting multiple periods.[11]

5 Monetary policy rules

This section turns to stabilization policy, focusing on the effects of monetary rules, where we express our indicator of monetary stance μ as a function of exogenous shocks to productivity.

5.1 Monetary rules supporting a flex-price allocation

A first question regards the conditions (if any) under which there exist monetary rules that support a flex-price and flex-wage allocation. The answer is positive: in our economy there exists a class of policy rules that equalize the allocation across market equilibria with and without nominal rigidities. Such a class is identical to the one studied by Corsetti and Pesenti (2005a,b) for a simpler economy without entry.[12] Suppose that monetary authorities pursue policy rules such that

$$\mu_t = \Upsilon_t \alpha_t$$

at all times, where Υ_t is a possibly time-varying variable anchoring the level of nominal prices. As is well understood, policies satisfying the above conditions follow the conventional prescription of 'leaning against the wind' of excess demand above the natural (or flexible-price) level of output. To see this, consider a positive productivity shock raising natural output above current demand: policy makers react to such a shock with an expansion, bringing aggregate demand up to the new enhanced productive capacity of the economy. Conversely, consider the anticipation of a positive productivity innovation one period in the future. As agents anticipate higher

[11] See Bilbiie et al. (2005) for a useful method for modeling multi-period entry.

[12] See section 4 of Bergin and Corsetti, 2005, for a derivation of the flexible price equilibrium and Pareto optimal allocation in this model.

income, at current interest rate they would optimally raise consumption, bringing demand above the current natural rate of output, which is unchanged. Policy makers react to the shock by raising interest rates, as to cause consumers to postpone their spending plans.

Setting $\Upsilon_t = 1$, it is easy to verify that marginal costs are identically equal to κ, and preset prices are constant

$$p_{t+1}(h) = \frac{\sigma\kappa}{\sigma - 1}. \tag{29}$$

In other words, marginal costs are completely stabilized. Using this price expression in the free entry condition, the resulting expression for entry is the same as one finds for a flex price allocation. Observe that randomness in K_t per se does not create any policy trade-off for policy makers, as (independently of price stickiness) entry fluctuates endogenously and optimally in response to it.

In an economy with the above rule in place, the individual good prices p are constant, but the welfare-based CPI comoves negatively with entry. For exactly this reason, the goal of (welfare-based) CPI stability may not be a good target for policy makers. To the extent that it is desirable to support a flex price allocation, monetary authorities should stabilize firms' marginal costs and product prices, not the CPI. The price level should instead move freely with entry, providing information about fluctuation in consumption utils which — given prices — households enjoy.

Pursuing policy rules that ensure $\mu_t = \alpha_t$ will not be sufficient to ensure a Pareto optimal allocation. This is because monopoly pricing distorts consumptions and labor, and the supply of varieties may be too large or too small. Welfare can be improved by complementing the above monetary stabilization rule with appropriate taxes and subsidies (see e.g. Bilbiie, Ghironi and Melitz 2005).

5.2 Incomplete stabilization

Suppose that monetary authorities do not react to shocks at all, and money evolves along some deterministic path. This would be the case if the central bank let money grow at some rate that may vary over time, but it is not contingent on current economic shocks. What are the consequences of incomplete stabilization?

When productivity is i.i.d., n_{t+2} will be independent of n_{t+1} in equilibrium. Hence one can write the optimal preset price as

$$p_{t+1}(h) = \frac{\kappa\sigma}{\sigma - 1} E_t \frac{1}{\alpha_{t+1}}, \tag{30}$$

where without loss of generality we have assumed a constant μ targeting $\Upsilon_t = \Upsilon = 1$. As marginal cost is a convex function, the above expression is increasing in the variance of α: the higher the uncertainty about future productivity, the higher the preset price. Note that with i.i.d. shocks, goods price will be constant.

Comparing optimal prices in the case of complete stabilization and no stabilization of productivity shocks yields a conclusion consistent with the analysis in Corsetti and Pesenti (2005a,b): prices are higher in the absence of stabilization.[13] Marginal cost uncertainty exacerbates monopolistic distortions in the economy, creating a production inefficiency. In the model with a fixed number of varieties, lack of stabilization implies that, because of nominal rigidities, a firm's employment falls suboptimally when productivity is high, while it rises suboptimally when productivity is low. As optimal pricing by firms ensures that employment is on average equal to its natural rate, this implies that a firm's output (and the corresponding consumption of the good variety it produces) will be below the average level in a flex price equilibrium. This is also true in our framework, following from (30). To generalize such a result from the individual firm output, to the aggregate level of output, however, we need to establish what happens to the number of firms and goods varieties in an equilibrium without stabilization.

With sticky prices, i.i.d. shocks to α do not translate into any fluctuation in entry: given goods prices (30), random fluctuations in productivity only affect employment and output, not investment or consumption. The number of firms n_{t+1} will only vary with K. Using (30) in (28), one can write for the no-stabilization

[13] If a fraction of firms can re-optimize their prices within the period, then lack of stabilization would also translate into inflation variability, as some prices would rise or fall with marginal costs.

case

$$\frac{\kappa\sigma}{\sigma-1}E_{t-1}\left[\frac{1}{\alpha_t}\right]K_t \tag{31}$$
$$= E_t\left\{\beta\left[\frac{\sigma}{\sigma-1}\kappa E_t\left[\frac{1}{\alpha_{t+1}}\right]-\frac{\kappa}{\alpha_{t+1}}\right]\left[\frac{L}{n^{ns}_{t+1}}\frac{1}{\frac{\kappa\sigma}{\sigma-1}E_t\left[\frac{1}{\alpha_{t+1}}\right]}+\frac{n^{ns}_{t+2}K_{t+1}}{n^{ns}_{t+1}}\right]\right\}.$$

where the superscript ns stands for 'no stabilization'. As shown in the online appendix, this expression can be further simplified as follows:

$$E_{t-1}\left[n^{ns}_{t+1}K_t\right]=\left(\frac{\sigma-1}{\sigma-\beta}\right)\frac{\beta}{\sigma}\frac{1}{\kappa}L\frac{1}{E_{t-1}\left[\frac{1}{\alpha_t}\right]}. \tag{32}$$

Conversely, in a flex-price equilibrium, or in an equilibrium with complete stabilization, investment fluctuates with the state of the economy: the number of firms rises when productivity is high and/or investment requirement is low. Using (30) in (28) setting $\mu_t=\alpha_t$, one can derive (details in the online appendix):

$$E_{t-1}\left[n^{s}_{t+1}K_t\right]=\left(\frac{\sigma-1}{\sigma-\beta}\right)\frac{\beta}{\sigma}\frac{1}{\kappa}L\frac{1}{E_{t-1}\left[\frac{1}{\alpha_t}\right]}-\frac{cov_{t-1}\left[\frac{1}{\alpha_t},n^{s}_{t+1}K_t\right]}{E_{t-1}\left[\frac{1}{\alpha_t}\right]}. \tag{33}$$

where the superscript s stands for 'stabilization'.

Comparing (32) and (33), the difference between the number of entrants under the two policies can be written as:

$$E_{t-1}\left[n^{s}_{t+1}K_t\right]-E_{t-1}\left[n^{ns}K_t\right]=\frac{-cov_{t-1}\left[\frac{1}{\alpha_t},n^{s}_{t+1}K_t\right]}{E_{t-1}\left[\frac{1}{\alpha_t}\right]}>0. \tag{34}$$

The covariance on the right-hand-side must be negative, since a rise in productivity in period t (α_t) leads to expansionary monetary policy under the stabilization rule (μ_t), which lowers the interest rate and increases entry. It follows that on average, for any given path of K, there are more varieties and firms in a fully stabilized economy.

An interesting conclusion from the above analysis is that higher preset prices due to lack of stabilization (our first result above) do not encourage entry (the opposite of our second result). To see why, observe that fluctuations in the future demand for investment goods make future profits and sales uncertain. Demand uncertainty clearly matters for entry because, by starting production with a preset price, every firm commits to satisfy any demand prevailing in the future at a given price. However, in the model above, these fluctuations reflect countercyclical stabilization policy, which guarantees that investment demand will be highest during periods of positive productivity shocks, when it is most efficient for the firm to produce; demand will be lowest when it is not efficient for the firm to produce. These fluctuations in future demand are clearly beneficial. Conversely, all fluctuations in future investment demand are completely eliminated under the no-stabilization policy case (since entry is constant with i.i.d. shocks): firms suboptimally supply the same quantity of goods for all levels of marginal costs. The covariance term in the expression above can thus be read as a negative risk premium, making precommitment to entry more appealing under the case of stabilization policy. The percentage gap in entry between the two cases can be written even more simply in terms of the variance of the productivity shock (written here for the case K_t constant at 1).

$$E_0\left(\ln n_t^s - \ln n_t^{ns}\right) = 0.5var_{t-1}\left(\ln \alpha_t\right).$$

A final observation is that in our distorted economy with no stabilization, employment inefficiently fluctuates with productivity shocks, falling when these are high and vice-versa. These shocks open output gaps that are not (but should be) counteracted by stabilization policy. In our framework, the gap between output with flexible prices $\alpha_t L\ell^{flex}$, and output with nominal rigidities but no stabilization policy $\alpha_t L\ell^{ns}$ will simply be proportional to the productivity shock:

$$\frac{\alpha_t L\ell^{ns}}{\alpha_t L\ell^{flex}} = \left(\frac{1}{\alpha_t}\right)/E_t\left(\frac{1}{\alpha_{t+1}}\right).$$

Yet, with i.i.d. shocks expected employment in an economy with sticky price but no stabilization is still constant at its flex-price (natural) level:

$$E_{t-1}\ell^{ns} = \ell^{flex}$$

i.e. it is identical to expected labor supply in a fully stabilized economy. Hence, ex ante, lack of stabilization does not impinge on expected disutility from labor.

5.3 Welfare

The previous subsection showed that a lack of monetary policy means that prices are high and entry is low, and on average consumption and output are below their level in a fully stabilized economy. It follows that, when love of variety conforms to Dixit-Stiglitz with $\gamma = \sigma/(\sigma-1)$, lack of stabilization is surely detrimental to welfare. Monopolistic distortions are exacerbated, and the number of varieties falls relative to an already suboptimal (average) level. However, can one be sure that incomplete stabilization reducing entry is detrimental in general, also when the number of varieties in a market allocation is too high from a welfare perspective?

To address this question, first derive an analytically tractable expression for the expected utility of the representative households. Since expected employment is constant at its flex price level, expected utility only varies with the expected (log of) consumption (see the online appendix). Thus, in a stationary economy:

$$E_0 U_t = E_0 \ln C_t + \text{constant} = E_0 \left[\ln(\mu_t) - \ln P_t\right] + \text{constant}.$$

With symmetry among firms, the price level varies inversely with entry: $P_t = n^{1-\gamma} p$. Abstracting from constant terms (independent of stabilization policies) expected utility can then be written:

$$E_0 U_t = E_0 \left[\ln(\mu_t) + (\gamma - 1)\ln n_t - \ln p_t\right].$$

Recall that, with no stabilization, $\mu = 1$, and $p = \frac{\kappa\sigma}{\sigma-1} E_{t-1}\left(\frac{1}{\alpha_t}\right)$; with full stabilization, $\mu = \alpha$, $p = \frac{\kappa\sigma}{\sigma-1}$. The difference in expected utility in the two cases simplifies to

$$\begin{aligned} & E_0 U_t^s - E_0 U_t^{ns} = \\ & \quad = E_0\left[\ln(\alpha_t) + (\gamma-1)\ln n_t^s\right] - E_0\left[(\gamma-1)\ln n_t^{ns} - \ln E_{t-1}\left(\frac{1}{\alpha_t}\right)\right] = \\ & \quad \simeq \{0.5 var \ln \alpha_t) + (\gamma-1)E_0\left(\ln n_t^s - \ln n_t^{ns}\right)\} > 0 \end{aligned}$$

which (provided the marginal benefit of variety is nonnegative $\gamma - 1 \geq 0$) is unambiguously positive. Intuitively, even when the market supply of product diversification is excessive from a welfare perspective, it is not a good idea to give up macroeconomic stabilization on the ground that this would, on average, lower the number of varieties. This is because, as shown above, lack of stabilization also raise prices, therefore exacerbating (welfare-reducing) monopolistic distortions in the economy, and depressing consumption and average output. We also note that the welfare wedge that can be attributed to failure to stabilize marginal costs is rising in productivity uncertainty, as captured by the first term on the right hand side of the above expression.

Since under $K = 1$, $E_0 \left(\ln n_t^s - \ln n_t^{ns}\right) = 0.5var_{t-1}\left(\ln \alpha_t\right)$, the earlier expression can be simplified as:

$$\begin{aligned} E_0 U_t^s - E_0 U_t^{ns} &= 0.5var\left(\ln \alpha_t\right) + (\gamma - 1)\left[0.5var_{t-1}\left(\ln \alpha_t\right)\right] \\ &= \frac{\gamma}{2} var_{t-1}\left(\ln \alpha_t\right) > 0. \end{aligned} \tag{35}$$

That is, the utility gap opened by insufficient stabilization becomes proportional to the variability of productivity shocks. Note that in our set up, such a gap is already expressed in terms of equivalent units of consumption, that equate welfare in an economy with full stabilization and in an economy without stabilization. To wit:

$$\begin{aligned} E_0 U^{ns}\left((1+x)C_t, \ell_t\right) &= E_0 U_t^s \\ E_0 \ln\left(C^{ns}\right) + \ln\left(1+x\right) &= E_0 \ln\left(C^s\right) \\ x &\simeq E_0 \ln\left(C^s\right) - E_0 \ln\left(C^{ns}\right) = \frac{\gamma}{2} var(\ln \alpha_t). \end{aligned}$$

To the extent that stabilization raises average entry, preferences for product variety add another dimension to the costs of lack of stabilization. The size of the welfare gain is proportional to the degree of love for variety assumed in preferences, γ. In particular, for the love of variety implied by the standard Dixit-Stiglitz specification, $\gamma = \frac{\sigma}{\sigma-1}$, the welfare cost of business cycle fluctuations is amplified by this same value, $\frac{\sigma}{\sigma-1}$, which one may recall also turns out to be the equilibrium price markup charged by optimizing firms over marginal costs.

6 Quantitative Exploration

In this section we further explore the quantitative properties of the model by enriching it with physical capital as a factor of production. Because the model already characterizes the fixed entry cost as a type of capital, we will refer to the more conventional type of capital as variable cost capital, denoted K_t^V.

The production function for variety h (5) is replaced by:

$$Y_t(h) = \alpha_t \left(K_{t-1}^V(h)\right)^{\theta} \left(\ell_t(h)\right)^{1-\theta}, \tag{36}$$

where θ is the capital share in production, and $K_t^V(h)$ is the capital input in the production of variety h. This capital input is an aggregate over varieties of goods, analogous to that used to define fixed cost capital earlier in the paper:

$$K_t^V(h) = A_{K,t}\left[\int_0^{n_t} K_t^V(h,i)^{1-\frac{1}{\sigma}}\,di\right]^{\frac{\sigma}{\sigma-1}} = n_t^{\gamma_k} K_t^V(h,i)\,.$$

So the price index and allocation of demand over varieties for variable-cost capital mirrors that for fixed-cost capital defined in (8) and (7). Overall aggregate variable-cost capital in the economy can be computed by summing over firms: $K_t^V = n_t K_t^V(h)$. Firms rent this capital from households at real rental rate r_t, implying a factor demand:

$$K_{t-1}^v(h) = \frac{1}{\alpha_t}\left(\left(\frac{\theta}{1-\theta}\right)\frac{w_t}{r_t P_t}\right)^{1-\theta}. \tag{37}$$

Households make the capital accumulation decision, subject to a constant depreciation rate δ, and a quadratic adjustment cost scaled by the parameter ψ. The household budget constraint becomes

$$\begin{aligned}&\int_0^{n_t} p_t(h)\,C_t(h)\,dh + \int_0^{n_{t+1}} s_t(h) q_t(h)\,dh + B_t + M_t\\&+P_t\left[K_t^V-(1-\delta)K_{t-1}^V\right]+\frac{\psi}{2}\frac{P_t\left(K_t^V-K_{t-1}^V\right)^2}{K_{t-1}^V}\\ \leq& w_t\ell_t + \int_0^{n_t} s_{t-1}(h)\Pi_t(h)\,dh - T_t + (1+i_t)B_{t-1} + M_{t-1} + r_t K_{t-1}^V,\end{aligned} \tag{38}$$

implying a capital accumulation condition:

$$1+\frac{\psi\left(K_t^V-K_{t-1}^V\right)}{K_{t-1}^V} = \beta E_t\left[\frac{C_{t+1}}{C_t}\left(r_t+(1-\delta)+\frac{\psi}{2}\frac{\left(\left(K_{t+1}^V\right)^2-\left(K_t^V\right)^2\right)}{\left(K_t^V\right)^2}\right)\right]. \tag{39}$$

Investment demand for variable-cost capital can be defined $I_t^V = K_t^V - (1-\delta)K_{t-1}^V$.

Marginal costs of production now include rental payments:

$$MC_t = \frac{(r_t P_t)^\theta (k\mu_t)^{1-\theta}}{\alpha_t \theta^\theta (1-\theta)^{1-\theta}}.$$

So price setting by firms (22) is replaced by

$$p_{t+1}(h) = \frac{\sigma}{\sigma-1}\frac{E_t\left\{\frac{1}{\mu_{t+1}}D_{t+1}(h)\,MC_{t+1}\right\}}{E_t\left\{\frac{1}{\mu_{t+1}}D_{t+1}(h)\right\}} \tag{40}$$

where demand for variety h for its various uses is defined:

$$D_{t+1}(h) = \frac{L_{t+1}}{n_{t+1}^{\gamma}} \frac{\mu_{t+1}}{P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma_K}} + \frac{I_t^V}{n_t^{\gamma_K}}.$$

The entry condition (24) likewise becomes:

$$P_{K,t} K_t = E_t \left\{ \frac{\beta \mu_t}{\mu_{t+1}} \left[p_{t+1}(h) - MC_{t+1} \right] D_{t+1}(h) \right\}. \tag{41}$$

Regarding calibration, the capital share $\theta = 0.36$ is taken from Chari et al. (2002), $\beta = 0.96$ is chosen to reflect a period equal to one year, and the deprecation rate is set at $\delta = 0.10$. The adjustment cost parameter is set so that the share of investment expenditure going to adjustment costs in response to a one standard deviation money shock is 0.19% (as was the case in Chari et al. (2002)), implying for our model a calibration of $\psi_I = 2.7$.[14] The calibration implies that 20% of GDP goes to total investment expenditure, including that on fixed cost and variable cost capital. The money supply shock process is also generalized to

$$\left(\mu_t - \mu_{t-1}\right) = \rho_\mu \left(\mu_{t-1} - \mu_{t-2}\right) + \varepsilon_t$$

where the calibration $\rho_\mu = 0.68$ and the standard deviation of μ is 2.3% as in Chari et al. (2002).We calibrate the love for variety parameter at the value most accepted in the literature, $\gamma = \frac{\sigma}{\sigma - 1}$, which is the value implied by Dixit-Stiglitz.[15]

Figure 4 shows the impulse response of the number of firms to a one standard deviation expansionary monetary shock. Note that the shape of the response in Figure 4 looks very similar to that for the simpler model reported in Figure 3a, although the magnitude of the response is scaled up by the new calibration of the shock. This is not surprising, since the new specification does not change the sunk

[14] We continue to calibrate the mean of the fixed cost, K, at 0.12, but this parameter has no effect on our results. This parameter enters the model equations only jointly as a product with the number of firms, n. In order to calibrate this product, we can note that the model equations in steady state imply the share of industry sales spent on fixed costs is $nK = \beta/\sigma$. Our calibrations above imply this share is 0.16, which is within the range estimated by Domowitz et al. (1988, table 5) for major U.S. industries.

[15] We found one paper to date trying to estimate a parameterized love for variety. Ardelean (2007) estimates the elasticity of imports with respect to the extensive margin of new varieties, and finds the degree of love for variety is 44% lower than that implied by Dixit-Stiglitz. Note that scaling down this parameter would also scale down our welfare gains derived in the previous section.

set up cost pinning down ex ante the scale of firm production via the free entry condition. Capital accumulation does not fundamentally alter these firm dynamics.

In comparing the theoretical response of our model — in its different specifications — to the empirical impulse responses estimated from the VAR on U.S. data in figures 2a,b, the theory succeeds in capturing some features of the data better than others. Clearly, it captures the fact that there is a significant response in entry over time — in our specification, we allow for a period of investment in new firms preceding production. What is more difficult to account for is a persistent response in entry. In figure 2a the confidence band for entry remains in positive territory for over three years; in figure 2b it intersects the zero line after about two years. While efficiency gains in investment (γ_k) succeed in generating some persistence in the effect of monetary policy, the model apparently falls short of fitting the magnitude of the response. If the theoretical model is to generate more persistent dynamics in the number of firms, it likely needs to be generalized further, such as including multi-period sunk costs.

7 Conclusion

This paper explores some basic monetary policy issues in a model with firm entry. We use a stylized model in which firms use monopoly profits to pay a fixed cost of entry prior to each period of production, and in which prices are preset one period. In this context entry has implications for the transmission of monetary and technology shocks, with features similar to investment dynamics in standard models without entry. However, entry matters in terms of its implications for welfare working through love of variety in preferences.

The paper analyzes reasons why stabilization policy has a role to play in promoting entry. Previous literature has shown that, absent stabilization policy, uncertainty about productivity induces firms to raise their markups and thereby lower welfare relative to their level in the flex-price allocation. In this paper we replicate this result in an economy with entry. In addition, we show that, on average, uncertainty also lowers entry relative to a flex-price allocation. Since the amount of entry can affect welfare in the ways noted above, stabilization policy has an additional role in regulating the optimal number of entrants, as well as the optimal level of production per firm.

References

[1] Ardelean, A., 2007. How strong is the love of variety? Mimeo.

[2] Benassy, J.P., 1996. Taste for variety and optimum production patterns in monopolistic competition. Economics Letters 52, 41-47.

[3] Bergin, P. and G. Corsetti, 2005. Towards a theory of firm entry and stabilization policy. NBER Working Paper No. 11821.

[4] Bilbiie, F., F. Ghironi, and M. Melitz, 2005. Business cycles and firm dynamics. Mimeo.

[5] Bilbiie, F., F. Ghironi, and M. Melitz, 2007. Monetary policy and business cycles with endogenous entry and product variety. Forthcoming in NBER Macroeconomics Annual, MIT Press.

[6] Broda, C. and D. Weinstein, 2004. Globalization and the gains from variety. NBER Working Paper No. 10314.

[7] Campbell, J., 1998. Entry, exit, embodied technology, and business cycles. Review of Economic Dynamics 1, 371-408.

[8] Campbell, J. and B. Lapham, 2004. Real exchange rate fluctuations and the dynamics of retail trade industries in the U.S.-Canada border. American Economic Review 94, 1194-1206.

[9] Chari, V.V., P.J. Kehoe, and E.R. McGrattan, 2002. Can sticky price models generate volatile and persistent real exchange rates? Review of Economic Studies 69, 533-563.

[10] Chatterjee, S., R. Cooper, and B. Ravikumar, 1993. Strategic complementarity in business formation: aggregate fluctuations and sunspot equilibria. The Review of Economic Studies 60, 795-811.

[11] Christiano, L, Eichenbaum, M., and C. L. Evans, 1999. Monetary policy shocks: what have we learned and to what end? In: J. Taylor and M. Woodford (Eds.), Handbook of Macroeconomics, pp. 65-148.

[12] Corsetti, G., P. Martin and P. Pesenti, 2005. Productivity spillovers, terms of trade and the 'home market effect.' CEPR DP 4964.

[13] Corsetti, G. and P. Pesenti, 2001. Welfare and macroeconomic interdependence. Quarterly Journal of Economics 116, 421-445.

[14] Corsetti, G. and P. Pesenti, 2005a. International dimensions of optimal monetary policy. Journal of Monetary Economics 52, 281-305.

[15] Corsetti, G. and P. Pesenti, 2005b. The simple geometry of transmission and stabilization in closed and open economy. NBER Working Paper No. 11341.

[16] Davis, S. and J. Haltiwanger, 1990. Gross job creation and destruction: microeconomic evidence and macroeconomic implications. In: O.J. Blanchard and S. Fischer (Eds.), NBER Macroeconomics Annual, pp. 126-168.

[17] Devereux, M., A. Head and B. Lapham, 1996. Aggregate fluctuations with increasing returns to specialization and scale. Journal of Economic Dynamics and Control 20, 627-657.

[18] Dixit, A.K. and J. Stiglitz, 1974. Monopolistic competition and optimum product diversity, working paper version. In: S. Brakman and B.J. Heijdra (Eds.), The Monopolistic Competition Revolution in Retrospect, Cambridge University Press, pp. 70-88.

[19] Domowitz, I.R., G. Hubbard, and B.C. Petersen, 1988. Market structure and cyclical fluctuations in U.S. manufacturing. Review of Economics and Statistics 70, 55-66.

[20] Dunne, T., M.J. Roberts and L. Samuelson, 1988. Patterns of firm entry and exit in U.S. manufacturing industries. The RAND Journal of Economics 19, 495-515.

[21] Eichenbaum, M., and C.L. Evans, 1995. Some empirical evidence on the effects of shocks to monetary policy on exchange rates. Quarterly Journal of Economics 110, 975-1009.

[22] Elkhoury, M. and T. Mancini Griffoli, 2006. Monetary policy with firm entry. Mimeo.

[23] Ghironi, F. and M. Melitz, 2005. International trade and macroeconomic dynamics with heterogenous firms. Quarterly Journal of Economics 120, 865-915.

[24] Jaimovich, N. 2006. Firm dynamics, markup variations, and the business cycle. Mimeo.

[25] _________, 2007. Firm dynamics and markup variations: implications for sunspot equilibria and endogenous economic fluctuations. Journal of Economic Theory 137, 300-325.

[26] Kim, J., 2004. What determines aggregate returns to scale? Journal of Economic Dynamics and Control 28, 1577-1594.

[27] Lewis, V., 2006. Macroeconomic fluctuations and firm entry: theory and evidence. National Bank of Belgium, Working Paper Research 103.

[28] _________, 2008. Optimal monetary policy responses to firm entry. Mimeo.

[29] Uuksüla, L, 2008. Limited participation or sticky prices? new evidence from firm entry and failures, Mimeo, European University Institute.

Fig. 1a
Comovement of net business formation with U.S output

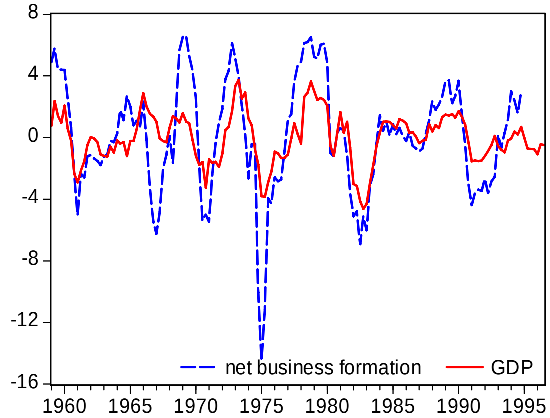


Fig. 1b
Comovement of new incorporations with U.S output

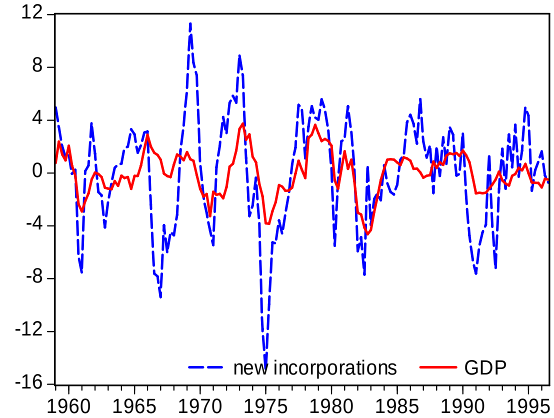


Fig. 2a
Response of net business formation to innovation in nonborrowed reserves

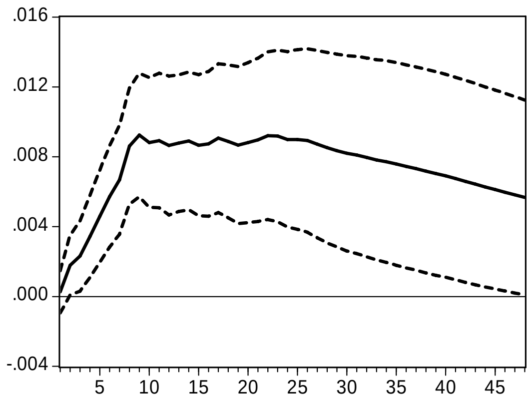


Fig. 2b
Response of new incorporations to innovation in nonborrowed reserves

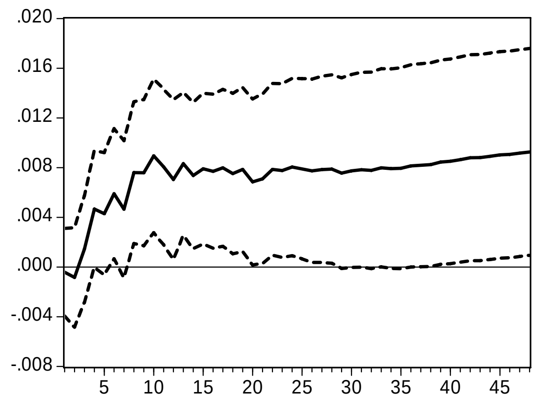


Fig. 2c
Response of net business formation to innovation in federal funds rate

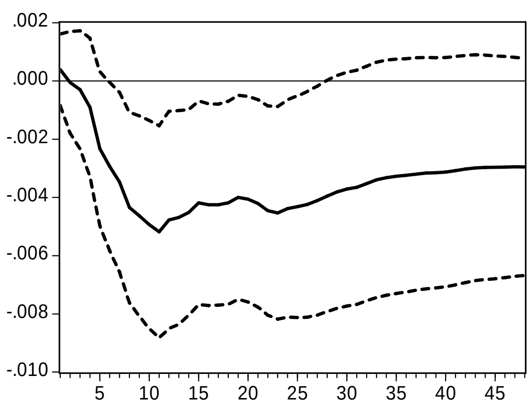


Fig. 2d
Response of new incorporations to innovation in federal funds rate

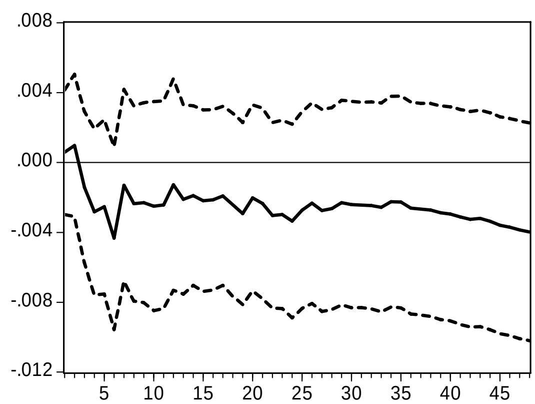
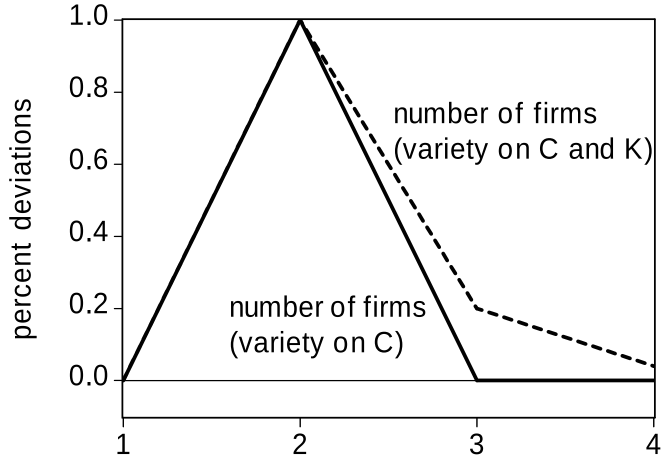
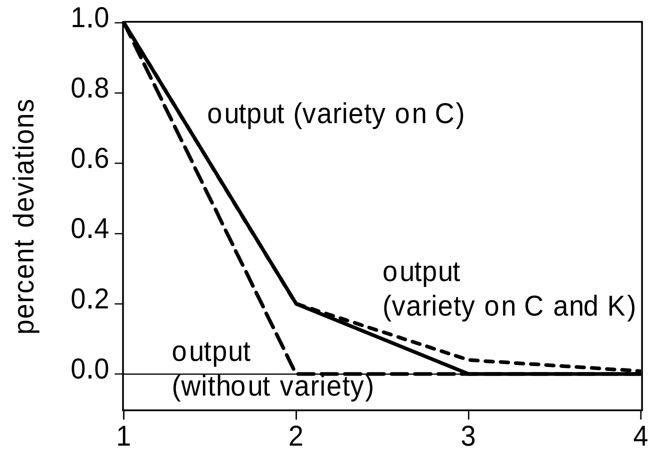


Fig 3. Model simulations: Monetary shock (permanent rise in μ by 1%) under sticky prices

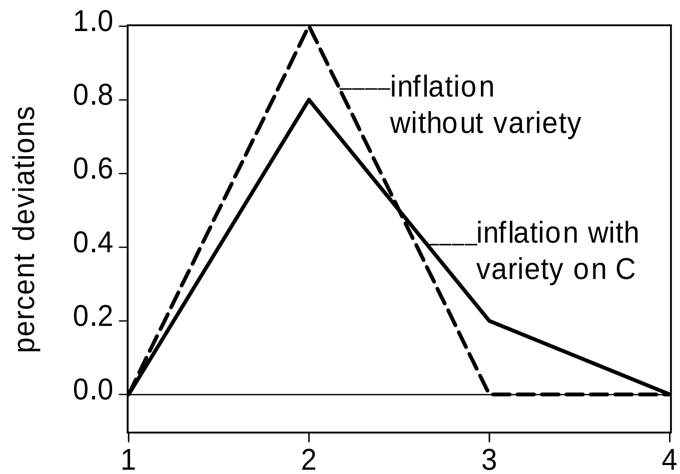
a. Entry



b. Output



c. Inflation



calibration: $\sigma = 6$, $\gamma = \sigma/(\sigma - 1) = 1.2$, $\beta = 1$, K=0.012, $\kappa = 1$

Fig 4. Model simulation: Monetary shock (permanent rise in μ by 1 standard deviation) under sticky prices, and variable cost capital