

EUI WORKING PAPERS

ECO No. 2005/24



Towards a theory of firm entry
and stabilization policy

PAUL BERGIN
AND GIANCARLO CORSETTI



EUROPEAN UNIVERSITY INSTITUTE

Department of Economics
Pierre Werner Chair on European Monetary Union

EUROPEAN UNIVERSITY INSTITUTE
DEPARTMENT OF ECONOMICS

Towards a theory of firm entry and stabilization policy

PAUL BERGIN AND GIANCARLO CORSETTI

EUI Working Paper **ECO** No. 2005/24

This text may be downloaded freely only for personal academic purposes. Any reproductions, whether in hard copies or electronically, require the consent of the author. If cited or quoted, reference should be made to the full name of the author(s), editor(s), the title, the working paper, or other series, the year and the publisher.

ISSN 1725-6704

© 2005 Paul Bergin and Giancarlo Corsetti
Printed in Italy
European University Institute
Badia Fiesolana
I – 50016 San Domenico di Fiesole (FI)
Italy

<http://www.iue.it/>
<http://cadmus.iue.it/dspace/index.jsp>

Towards a theory of firm entry and stabilization policy*

Paul Bergin

University of California at Davis and NBER

Giancarlo Corsetti

European University Institute, University of Rome III, and CEPR

This draft: October 2005

Abstract

This paper studies the role of stabilization policy in a model where firm entry responds to shocks and uncertainty. We evaluate stabilization policy in the context of a simple analytically solvable sticky price model, where firms have to prepay a fixed cost of entry. The presence of endogenous entry can alter the dynamic response to shocks, leading to greater persistence in the effects of monetary and real shocks. Entry affects welfare, depending on the love of variety in consumption and investment, as well as its implications for market competitiveness. In this context, monetary policy has an additional role in regulating the optimal number of entrants, as well as the optimal level of production at each firm. We find that the same monetary policy rule optimal for regulating the scale of production in familiar sticky price models without entry, also generates the amount of (endogenous) entry corresponding to a flex-price equilibrium.

JEL classification: E22, E52, L16

Keywords: productivity, monetary policy, market dynamics.

*Comments by Jeff Campbell, Pedro Teles and seminar participants at the Universidade Catolica Portuguesa are gratefully acknowledged. This work is part of the Pierre Werner Chair Programme on Monetary Union, at the Robert Schuman Centre of the European University Institute. Financial support from the programme is gratefully acknowledged.

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. A small but dynamic strand of literature has recently reconsidered different dimensions in which models with firm entry and product variety can contribute to our understanding of the business cycle in closed and open economies (e.g. Ghironi and Melitz, 2005; Jaimovich, 2004). These aim to provide a more realistic model of imperfectly competitive markets in manufacturing, where entry drives profits to zero and generate plausible market dynamics; in some versions, they also shed light on the role of research and development in generating economic fluctuations.¹ The question we investigate in this paper is their monetary policy dimension.

One can list several reasons why business cycle researchers should be interested in firm entry. Firstly, we see strong empirical evidence that entry dynamics comove with the business cycle, a stylized fact that will be discussed below. Secondly, entry has the potential to serve as an amplification and propagation mechanism for real shocks, and to affect the transmission mechanism for monetary policy. Thirdly entry may have notable welfare effects, to the degree that households derive utility from greater variety, or to the degree that the entry of new firms raises competition in a market. By way of example, under a standard Dixit-Stiglitz specification with a substitution elasticity implying a 20% markup, a one percent decrease in consumption expenditure lowers the total consumption index by 20% more if it corresponds to 1 percent reduction in the number of varieties bought by the consumers, rather than a proportional fall in the consumption of each variety.² This example illustrates that the extensive margin of consumption and output fluctuations, in the form of changes in the number of firms and varieties, can have distinct implications from the intensive margin, the average size of firms. Thus, as a final point, in light of its effect on welfare we expect entry to affect the design of optimal monetary policy, as output gap stabilization may now

¹Recent 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). Some traits of these models are in common with a related literature on firm entry focusing on issues of indeterminacy of equilibria and increasing returns. (See Chatterjee et al., 1993; Devereux et al., 1996; and Kim, 2004).

²This can be easily seen by considering the Dixit-Stiglitz consumption aggregator over symmetric varieties: $C = \left(\int_0^n c(h)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} = n^{\frac{\sigma}{\sigma-1}} c(h)$. Writing this in percent changes: $\tilde{C} = \frac{\sigma}{\sigma-1} \tilde{n} + \tilde{c}(h)$. For a typical case of $\sigma = 6$, a percentage rise in the number of varieties n affects total C by 1.2 times as much as an equal percentage rise in average size $c(h)$.

have an extensive as well as an intensive margin.

In this paper, we first briefly document the correlation of entry with monetary shocks, augmenting standard VAR models with measures of new firm incorporations and net business formation. Second, we build a stylized sticky price model of monetary policy when firm entry is endogenous. Firms must prepay a (possibly time-varying) 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 — it could be interpreted as investment expenditure under the simplifying assumption of complete depreciation of capital within the 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. Different from the standard specification, firms enter the market by producing new differentiated products, thus enlarging the set of goods available to consumers and other firms. We allow for love for variety in preferences, 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.

We find that entry affects the transmission of technology shocks as well as monetary policy transmission. With endogenous entry, the effect of productivity shocks on output is magnified by the increase in investment demand driven by new firms. With free entry, most of the output effect can be attributed to the creation of new firms and products, i.e. to the extensive margins. Monetary shocks also induce entry much as investment responds in a standard model: for a given entry (investment) cost, a fall in the real interest rate raises the expected discounted profits from creating a new firm. Different from the standard model, however, firms investing in new capital stock do not raise the scale of production of a given set of products (i.e. to exploit intensive margins) — facing a fall in their equilibrium prices. Product differentiation (i.e. exploiting extensive margins) allow them to operate with limited or no deterioration of their prices. As with productivity shocks, endogenous entry tends to generate some endogenous persistence in response to monetary shocks, though these particular effects are not large in the calibrated version of the model.

Our stylized model allows us to evaluate analytically monetary policy. We first show that there exists a simple class of policy rules such that the market allocation with nominal rigidities coincides with a market allocation where all prices are flexible. This class of policy is isomorphic to the one studied in Corsetti and Pesenti (2005a,b), in the context of a model without firm entry and investment. In an economy with these rules in place, the individual good prices p are constant, but the welfare-based CPI fluctuates 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 producers' prices. The price index may then freely fluctuate with entry, providing information about fluctuation in consumption utils — given prices — that households enjoy. The reason for this is similar to the reason underlying a well known result on optimal policy in open economy, whereas price stability call for stabilizing the domestic GDP deflator, and let the CPI move as to accommodate for equilibrium fluctuations in the relative price of imports (e.g. see Corsetti and Pesenti 2005a).

However, the allocation in a flexible price equilibrium will not be in general Pareto optimal. There are three distortions in our economy: monopoly power in production, under or oversupply of varieties, and nominal rigidities. Correcting the first two distortions requires an appropriate set of taxes and subsidies. Only if these are in place, can monetary policy be effective in targeting the efficient allocation.

We study two important macroeconomic consequences of lack of macroeconomic stabilization in our distorted economy. First, as in Corsetti and Pesenti (2005a,b), the lack of monetary stabilization translates into higher product prices. As a result, insufficient stabilization lowers the average scale of activity of all firms in existence. Second — this is a specific contribution of our paper — we show that the lack of stabilization lowers the average number of firms relative to a flex price allocation. This result is not obvious, since higher prices set by firms against increasing uncertainty tend to rise profits in equilibrium, hence creating an incentive to enter. Our analytical welfare analysis finds that unconditional expected welfare is unambiguously lower under a lack of stabilization, for all parameterizations of love for variety. But the welfare gains of stabilization policy rise with greater love for variety, potentially by a notable percentage — of the same order of magnitude as average markup.

We conclude our analysis by augmenting our model to explore the effects of firm entry on market competitiveness. We adapt a translog preference specification: new entry of firms raises the density of market competition and the elasticity of substitution between varieties. This forces firms to lower their markups and thereby reduces the monopolistic distortion in the economy. We show that this reallocates adjustment between extensive and intensive margins, and it offers an additional motivation for stabilization policy as a means of raising welfare.³

³Since 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

A related paper in the recent literature is by Bilbiie, Ghironi and Melitz (2005), which studies the dynamics of entry along the business cycle. In addition to differences in the model specification, while their focus is on cyclical properties of the macroeconomic process with firm entry, we concentrate on stabilization policy issues.

This paper is organized as follows. Section 2 introduces our model. Section 3 characterizes the flexible price equilibrium and compares it to the Pareto optimal allocation. The next two sections analyze monetary transmission and policy rules. Section 6 concludes.

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. Bilbiie, Ghironi and Melitz, 2005; Jaimovich, 2004; Devereux et al., 1996), 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. Clearly, 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 VAR 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.⁴

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

⁴The full list of 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, 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 1a shows that now there is a statistically significant positive effect of nonborrowed reserves on net business formation; figure 1b shows a similar effect on incorporations, with significance starting in the eight month after the shock. Then, as in Eichenbaum and Evans (1995), we also include the federal funds rate in the system as an alternative measure of monetary policy stance.⁵ As seen in figures 2a and 2b, the direction of the effect once again conforms with our intuition: a rise in the interest rate discourages entry, with significance in the net business formation case. Our conclusion from this exercise is that there appears to be a relationship between monetary policy and entry. This invites theoretical exploration of how entry might operate as part of the monetary policy transmission process and how it might affect optimal policy design.

3 The model

We consider a closed economy where households consume a basket of differentiated tradable goods, demanding positive quantities of all the goods available in the market. They supply labor to firms and own claims on firms' profits. We scale the economy such that there are L_t households in the economy.

The number of goods varieties produced by firms is endogenously determined in the model. To start production of a particular good variety, firms sustain entry costs consisting of the costs of intermediate inputs required to set up a firm's capital. Once the entry costs are paid, firms start producing with a period lag. They 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. For simplicity, we assume that, at the end of this period the capital invested in the creation of a specific variety fully depreciates and the production process starts again with new entry of firms. Firms and goods varieties are defined over a continuum of mass n_t and indexed by $h \in [0, n_t]$.

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

⁵The variable list now consists of: industrial production, CPI, commodity price, federal funds rate, nonborrowed reserves ratio, and an entry measure.

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

$$U_t = \log C_t - \kappa \ell_t + \chi \ln \frac{M_t}{P_t} \quad (1)$$

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

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

where

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

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 (see Corsetti Martin and Pesenti, 2005). In what follows, we 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.⁶

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 representative Home household is therefore:

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

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 denominated in Home currency, 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.

⁶By 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, Martin and Pesenti, 2005).

3.2 Firms and the government

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

$$Y_t(h) = \alpha_t \ell_t(h) \quad (5)$$

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 Home 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:

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

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, we can derive the investment demand for the good h

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

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

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

Observe that in a symmetric equilibrium the demand for the good h is $K(h) = K_t/n^{\gamma_K}$. The entry costs $q(h)$ faced by a firm are thus equal to:

$$q_t(h) = P_{K,t} K_t \quad (7)$$

For simplicity, in what follows we assume 100 percent depreciation: after paying the fixed cost, a firm can produce variety h in period $t + 1$ only.

Since we assume 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:

$$Y_t(h) \geq L_t C_t(h) + n_{t+1} K_t(h) \quad (8)$$

where $C_t(h)$ is consumption of good h by the representative Household, while the second term on the RHS 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 we can write the h firm's operating profits as:

$$\Pi_t(h) \equiv p_t(h) L_t C_t(h) + p_t(h) n_{t+1} K_t(h) - w_t \ell_t(h) \quad (9)$$

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

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

$$L_t \ell_t \geq \int_0^{n_t} \frac{Y_t(h)}{\alpha_t} dh. \quad (10)$$

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

$$M_t - M_{t-1} + \int_0^{L_t} T_t(j) dj = M_t - M_{t-1} + L_t T_t = 0 \quad (11)$$

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:

$$\int_0^1 B_t(j) dj = 0. \quad (12)$$

so that $B_t = 0$ in aggregate terms. Throughout our analysis we 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 Home 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:

$$C_t(h) = A_t^{\sigma-1} \left(\frac{p_t(h)}{P_t} \right)^{-\sigma} C_t \quad (13)$$

$$w_t = \kappa P_t C_t \quad (14)$$

$$\frac{1}{P_t C_t} = \beta (1 + i_t) E_t \frac{1}{P_{t+1} C_{t+1}} \quad (15)$$

$$\frac{q(h)}{P_t C_t} = E_t \left[\beta \frac{\Pi_{t+1}(h)}{P_{t+1} C_{t+1}} \right] \quad (16)$$

$$\frac{M_t}{P_t} = \chi \frac{1 + i_t}{i_t} \quad (17)$$

where P_t is the utility-based consumer price index:

$$P_t = \frac{1}{A_t} \left[\int_0^{n_t} p_t(h)^{1-\sigma} dh \right]^{\frac{1}{1-\sigma}} \quad (18)$$

Note that households will finance new firms as long as the present discounted value of expected profits will be above the cost of entry

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

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

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

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

We introduce nominal rigidities 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

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

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

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

The optimal preset price satisfies⁷

$$p_{t+1}(h) = \frac{\sigma}{\sigma - 1} \frac{E_t \frac{\kappa}{\alpha_{t+1}} \left[\frac{L_{t+1} \mu_{t+1}}{n_{t+1}^\gamma P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma \kappa}} \right]}{E_t \frac{1}{\mu_{t+1}} \left[\frac{L_{t+1} \mu_{t+1}}{n_{t+1}^\gamma P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma \kappa}} \right]} \quad (19)$$

⁷We 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).

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

$$p_{t+1} = [\text{mark up}] \cdot MC_t = \frac{\sigma \kappa}{\sigma - 1} \frac{\mu_{t+1}}{\alpha_{t+1}} \quad (20)$$

where MC stands for marginal costs.

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

$$P_{K,t} K_t = E_t \left\{ \frac{\beta \mu_t}{\mu_{t+1}} \left[p_{t+1}(h) - \frac{\kappa \mu_{t+1}}{\alpha_{t+1}} \right] \left[\frac{L_{t+1} \mu_{t+1}}{n_{t+1}^\gamma P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}^{\gamma_K}} \right] \right\} \quad (21)$$

This expression and equation (19) summarize the macroeconomic process in our economy.

4 Flex-price equilibrium and welfare with monopolistic distortions

In this section, we analyze the flexible price equilibrium allocation and its welfare properties relative to a Pareto-optimal allocation, with the goal of providing useful positive and normative benchmarks for the analysis to follow. Using (19) and (20), the dynamics of an economy with flexible prices is captured by the difference equation below:

$$\frac{\sigma}{\sigma - 1} \frac{K_t}{\alpha_t} \frac{1}{n_t^{\gamma_K - 1}} = E_t \left\{ \beta \frac{1}{\alpha_{t+1}} \frac{1}{\sigma - 1} \left[\frac{L_{t+1}}{n_{t+1}^{flex}} \frac{\alpha_{t+1}}{\kappa \sigma} + \frac{n_{t+2}^{flex} K_{t+1}}{(n_{t+1}^{flex})^{\gamma_K}} \right] \right\} \quad (22)$$

where the superscript 'flex' stands for flexible-price equilibrium, and without loss of generality we have set $\mu_s = 1$ for all s . Clearly, money is neutral. Investment in entry however responds to productivity shocks.

4.1 Real shocks and economic dynamics

From (22), the entry cost q_t (on the left hand side of the expression) falls with positive innovations to investment efficiency (corresponding to a fall in K_t) and/or with positive shocks to α_t (in a flex price equilibrium, productivity gains reduce current goods prices, decreasing the costs of investment). Entry in turn reduces expected profits, restoring equilibrium. Observe that entry reduces profits from both consumption sales (first term in the squared brackets of (22)) and investment sales (second term).

These effects are illustrated by Figure 3, which plots the effect of a persistent rise in productivity in a linearized and calibrated version of the model.⁸ Relative to the standard

⁸Calibrated values are: $\sigma = 6$, $\gamma = \frac{\sigma}{\sigma - 1} = 1.2$, $\gamma_K = 1$, $\beta = 1$, serial correlation in shock $\rho_\alpha = 0.9$, $K = 0.012$, $L = 1$.

model without entry, the effect of the shock on output is larger, as it includes the demand for investment. Since in our calibrated economy investment is 16% of output in steady state, output is approximately 16% larger.⁹ Observe also that once firms have a chance to enter, the rise in output generated by the shock operates at the extensive margin, with no increase in average firm size at the intensive margin. This must be the case in equilibrium, since any rise in firm size would indicate there were extra sales and hence profits net of the fixed entry costs which potential entrants are not exploiting. The effects of a 1% drop in entry cost, K_t , are illustrated in figure 4. New firms enter and firm size falls proportionately, as an unchanged level of output is divided among the larger number of firms.

An anticipated shock to marginal costs (α_{t+1}), however, has ambiguous effects on the allocation. While it encourages entry because of its effect on future entry costs (investment will be cheaper in the future), its impact on future goods prices is not necessarily good news for profitability. Intuitively, with falling marginal cost, each firm will try to increase profits by lowering its own price. But since the shock is common to all, in the new equilibrium the product prices will be uniformly lower, reducing profits.

The above equation also suggests that the number of firms temporarily rises in response to an anticipated higher investment requirement (a higher K_{t+1} , which is a negative shock to expectations about the investment technology). By the same token, n_t is higher in response to anticipated growth in market size (a larger L_{t+1}).¹⁰

Observe that with efficiency gains in investment due to goods variety ($\gamma_K \neq 1$), the expression (22) is a non linear second-order difference equation in n : any temporary deviations of n from its long run value induce persistent effects on the costs of investment. Hence investment demand and entry change over time in response to any shock, also driving consumption demand. These effects would disappear as the system returns to steady state.

To gain further insight on the equilibrium allocation, it is analytically convenient to focus on the case of a stationary economy with i.i.d. shocks to productivity and no serial dependence in entry ($\gamma_K = 1$). Expected discounted profits are constant, and entry is directly proportional to current productivity shocks α_t while varying inversely with investment requirement at entry K_t .

$$n_{t+1}^{flex} = \frac{\alpha_t \beta}{K_t \sigma} E_t \left[\frac{L}{\kappa} \frac{\sigma - 1}{\sigma} + \frac{n_{t+2}^{flex}}{\alpha_{t+1}} K_{t+1} \right]$$

⁹It is easy to show that in this economy the steady state share of investment expenditure in output equals $\frac{\beta}{\sigma}$, so it does not depend at all on the calibration of the fixed cost parameter K (which is difficult to calibrate).

¹⁰See Corsetti, Martin and Pesenti (2005) for an analysis of similar results in an open economy.

Taking expectation at time $t - 1$ and rearranging yield

$$E_{t-1} n_{t+1}^{flex} \frac{K_t}{\alpha_t} = E_t n_{t+2}^{flex} \frac{K_{t+1}}{\alpha_{t+1}} = \frac{\sigma - 1}{\sigma - \beta} \frac{1}{\kappa} \frac{\beta}{\sigma} L$$

Substituting this result in the previous expression, we obtain

$$n_{t+1}^{flex} \frac{K_t}{\alpha_t} = \frac{\sigma - 1}{\sigma - \beta} \frac{1}{\kappa} \frac{\beta}{\sigma} L \quad (23)$$

In a stationary economy with flexible prices, the number of firms moves in proportion to the productivity index K_t/α_t . If K is constant, all the adjustment takes place at the extensive margin: firm size is unaffected.

By using the resource constraint of the economy, we also obtain a second important result (details are in appendix):

$$\ell_t^{flex} = \frac{\sigma - 1}{\sigma - \beta} \frac{1}{\kappa} = \ell^{flex} \quad (24)$$

The equilibrium rate of employment is constant. Output and entry (along the intensive and the extensive margins) fluctuates with productivity. Adding up quantities across goods (ignoring differences across products), this economy produces $\alpha_t L \ell^{flex}$. Of this aggregate quantity, a proportion β/σ goes into investment, $(\sigma - \beta)/\sigma$ into consumption. Unless $\gamma = 1$, however, these quantities are not appropriate measures of GNP , C and I , because they ignore the utility value of product diversification.

4.2 Entry and Pareto efficiency

In our economy, a competitive allocation can be characterized by either excessive or insufficient creation of varieties, depending on the interaction between love for variety and monopolistic distortions. If an interior solution for n exists, the efficient mass of varieties satisfies

$$\frac{K_t}{\alpha_t} = E_t \beta \frac{L_t}{L_{t+1}} \left\{ (\gamma - 1) \frac{1}{n_{t+1}^{P.O.}} \frac{L_{t+1}}{\kappa} + (\gamma_k - 1) \frac{\beta}{\alpha_{t+1}} \frac{n_{t+2}^{P.O.} K_{t+1}}{n_{t+1}^{P.O.}} \right\}$$

As in the market equilibrium, the Pareto-optimal number of varieties in a stationary economy (with *i.i.d.* shocks and $\gamma_K \neq 1$) will be proportional to α_t/K_t

$$n_{t+1}^{P.O.} = \frac{\alpha_t}{K_t} \frac{1}{\kappa} \beta L (\gamma - 1) \quad (25)$$

Observe first that, $\gamma \rightarrow 1$ implies that $n_{t+1}^{P.O.} \rightarrow 0$, while n_{t+1}^{flex} tends to a positive number. In the case of no love for varieties, the efficient mass of varieties is zero: it would be efficient for firms to supply only one good variety, at a price equal to the marginal cost. But this would clearly be inconsistent with a market allocation, as firms would not be able to finance their entry costs.

Take the ratio of n^{flex} to $n^{P.O.}$.

$$\frac{n_{t+1}^{flex}}{n_{t+1}^{P.O.}} = \frac{\sigma - 1}{\sigma(\sigma - \beta)(\gamma - 1)}$$

It is easy to verify that this ratio will be larger than unity with a Dixit-Stiglitz aggregator in consumption, i.e. for $\gamma \rightarrow \frac{\sigma}{\sigma-1}$. A market allocation would not deliver enough product diversity. To gain further insight, posit $\beta \simeq 1$. In the Dixit-Stiglitz case, the above ratio is then approximately equal to $1 - 1/\sigma$: the lower the elasticity of substitution across products, the larger firms' monopoly power, the larger the gap in variety between a market allocation and the Pareto optimal allocation.¹¹

By the same token, compare individual consumption in a flex price equilibrium and a Pareto efficient allocation (indexed by the superscript 'P.O.')

$$\begin{aligned} C_t^{flex} &= \alpha_t \frac{\sigma - 1}{\sigma \kappa} \left(n_t^{flex} \right)^{\gamma - 1} \\ C_t^{P.O.} &= \alpha_t \frac{1}{\kappa} \left(n_t^{P.O.} \right)^{\gamma - 1} \\ \implies \frac{C_t^{P.O.}}{C_t^{flex}} &= \frac{\sigma}{\sigma - 1} \left(\frac{n_t^{P.O.}}{n_t^{flex}} \right)^{\gamma - 1} \end{aligned}$$

The wedge in consumption depends on two sources of inefficiency: the markup charged by firms; and the equilibrium supply of varieties, that however only matters if $\gamma > 1$. Distortions in the labor market will also be a function of the 'gap' in the number of varieties. Not surprisingly, employment in the consumption sector, ℓ_{C_t} , inherits the same distortions affecting consumption

$$\frac{\ell_{C_t}^{P.O.}}{\ell_{C_t}^{flex}} = \frac{\sigma}{\sigma - 1} \left(\frac{n_t^{P.O.}}{n_t^{flex}} \right)^{\gamma - 1}$$

while the wedge of employment in investment activities between a Pareto Optimal and a market allocation will simply be equal to the wedge in the number of varieties, $n_{t+1}^{P.O.}/n_{t+1}^{flex}$. Overall, the efficient labor supply is constant and equal to

$$\ell^{P.O.} = \frac{1}{\kappa} [1 + \beta(\gamma - 1)] \quad (26)$$

In general, as a decentralized equilibrium generally will not be Pareto efficient, welfare-optimizing policymakers would want to adopt fiscal instruments to correct distortions. An instance of an optimal fiscal policy correcting monopolistic distortions consists of subsidies to production and investment, financed with lump-sum taxation. The former induce firms

¹¹Using the above expression, it is also easy to calculate which value of γ would make the number of firms in a competitive equilibrium converge to the Pareto optimal number of firms. This happens to be the case when γ is close to $1 + 1/\sigma$. It is worth stressing that, even if γ happens to be equal to $1 + 1/\sigma$, the market allocation will not be Pareto-optimal, because of monopoly power in production.

to raise production up the point in which prices equal to marginal costs (therefore making expected discounted profits identically equal to zero). The subsidy covering the costs of entry should be limited to a mass of goods variety optimally chosen in relation to efficiency gains in preferences — however the amount of information required to pursue such policy in practice is unrealistically large.

Relative to the standard macroeconomic model with imperfect competition but a given set of varieties, therefore, an explicit specification of entry costs is helpful in clarifying the source of monopoly power in production. Entry and market dynamics is nonetheless distorted, creating a need for a fiscal correction similar in spirit to the interventions envisaged by recent contributions on monetary policy, whereas appropriate taxes are assumed in order to approximate the market equilibrium (with an optimal monetary policy in place) around the first-best allocation.

5 Nominal rigidities and the transmission of monetary and real shocks

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

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

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

Hereafter, we will use these conditions to trace the transmission of monetary and real shocks.

Clearly, money is not neutral. Consider a once-and-for-all unanticipated temporary shock to μ at time t (money stocks go back to their initial value from $t + 1$ on). From the RHS of the above equation, we see that a monetary shock μ_t that lowers real interest rates translates into a higher discount factor, therefore boosting expected discounted profits. With preset goods prices the overall entry costs does not change.¹² Hence, by reducing the real interest rate a temporary monetary shock will lead to entry: at time $t + 1$ there will be a higher number of firms and goods. Since the number of firms is predetermined and cannot rise in the same period in which the shock occurs, the rise in demand (for both investment and consumption) driven by a monetary shock is met by a rise in output per

¹²In our model nominal wages move in proportion to the nominal shock, raising the marginal costs of firms supplying goods to new firms. If entry costs consisted exclusively of labor input, a nominal shock raising the present discounted value of profits in nominal terms, would also raise entry costs proportionally. There would be no effect on entry.

firm solely at the intensive margin. The extensive margin takes effect only after one period, when the number of firms rises. 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.

Figure 5 illustrates the effects of a monetary shock using the linearized and calibrated version of the model.¹³ Observe first that, just as with the productivity shock discussed in the previous section, entry raises the output effects of monetary shocks. In the experiment in Figure 5, steady state investment is about 12% of output and the rise in output is approximately by this amount.¹⁴ Since we set $\gamma_K \neq 1$, there is some persistence in the effect of a monetary shock on entry. In the second period after the shock, there still is a noticeable amount of extra firms, due to the fact that the larger number of varieties available in the previous period make entry less costly. However, persistence in the effect of money on entry does not translate into persistence in the effect on output.

Perhaps most interesting is the observation that, with endogenous entry, the inflationary effects of monetary expansion are diminished by about 17%. Under love of variety, the rise in entry works to lower the cost of one unit of the consumption index. This indicates that the inflationary consequences of monetary expansions may be less severe than suggested by the official measures of the CPI, to the extent that these fail to properly take into consideration entry and variety effects.

As prices are preset during the period, temporary productivity shocks (changes in α_t lasting only one period) do not impact either the allocation of consumption or entry — they cause temporary employment fluctuations. Productivity shocks to α_t can affect entry if they are persistent, as illustrated in Figure 6. The effects of such a shock closely resemble those of the flexible price case, though entry is delayed an extra period. This is because under sticky prices it takes a period before the productivity gain is able to lower prices and hence entry costs. Regarding a shock to entry costs (K_t), since this shock did not imply any change in marginal cost or price setting under the flexible price case discussed previously, the effects under sticky prices are the same as those shown previously in figure 4. Thus, different from productivity innovations to α_t , shocks to investment efficiency raise n_{t+1} also when prices are sticky.

¹³Calibrated values are the same as in the previous simulation, except that we re-introduce love of variety in investment ($\gamma_K = \gamma$): $\sigma = 6$, $\gamma = \frac{\sigma}{\sigma-1} = 1.2$, $\gamma_K = 1.2$, $\beta = 1$, $K = 0.012$, $L = 1$.

¹⁴The steady state investment share no longer exactly equals exactly $\frac{\beta}{\sigma}$ since love of variety in investment affects the investment price index.

6 Monetary policy rules and the consequences of lack of stabilization

In this section we turn to stabilization policy, focusing on the effects of monetary rules, whereas we express our indicator of monetary stance μ as a function of exogenous shocks to productivity. To facilitate analytical solution, we again limit ourselves to the case of i.i.d. shocks and no serial dependence in entry ($\gamma_K = 1$).

6.1 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 much simpler economy without entry. Suppose that monetary authorities pursue policy rules such that

$$\mu_t = \Upsilon_t \alpha_t$$

at all times, whereas Υ_t is a possibly time-varying variable anchoring the level of nominal prices. Setting $\Upsilon_t = 1$ for simplicity, it is easy to verify that marginal costs are identically equal to κ , and preset prices are constant

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

In other words, marginal costs are completely stabilized. Using this expression in the free entry condition, we obtain exactly the same expression characterizing a flex price allocation (22). As discussed in Corsetti and Pesenti (2005a,b), this result nicely generalizes to more articulated specifications of nominal rigidities, including costs of nominal price adjustment or Calvo-Yun pricing, which allow some price flexibility ex post (either by all firms, or by some firms only). The reason is that rules that stabilize marginal costs take away any incentive to change prices ex post. A firm that can re-optimize its pricing decisions would not alter the nominal price of its product. 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 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.

As discussed above, however, 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. The above monetary stabilization rule in general must be complemented with appropriate taxes and subsidies.

It is nonetheless useful to analyze the behavior of our economy when no taxes or subsidies address these supply side distortions, as to dissect the macroeconomic implications of a lack of stabilization. Posit that monetary authorities pursue policy rules implying:

$$\mu = \alpha^\xi, \quad 0 \leq \xi \leq 1$$

i.e., they pursue rules that make them react to productivity shocks only, although they may react to them with different intensity. When $\xi = 1$, clearly $\mu = \alpha$: we are in the case discussed above, whereas stabilization rules are supporting a flex-price allocation. When $\xi \leq 1$, instead, stabilization is ‘incomplete,’ in the sense that policy makers do not fully stabilize marginal costs and product prices.

6.2 Incomplete stabilization

What are the consequences of incomplete stabilization? For tractability in what follows we keep our assumption that productivity is stationarity, so that in equilibrium n_{t+2} will be independent of n_{t+1} . Also, we set $\xi = 0$: 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. In this case, the optimal preset price is

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

Since 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 ($\xi = 1$) and no stabilization ($\xi = 0$) of productivity shocks yields a conclusion consistent with the analysis in Corsetti and Pesenti (2005a,b). Prices are higher in the absence of stabilization.¹⁵ Marginal

¹⁵If 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.

cost uncertainty exacerbates monopolistic distortions in the economy, creating a production inefficiency. Without stabilization, firms employment will tend to grow when productivity is low, while it will fall when productivity is high. Expected employment is constant, but average output falls relative to the flex price equilibrium.

In the model with a fixed number of varieties by Corsetti and Pesenti (2005a, b), lack of stabilization implies that because of nominal rigidities employment falls suboptimally when productivity is high, while rise suboptimally when productivity is low. For a given average employment level, this implies that output and consumption will be below the average level in a flex price equilibrium. The same can be said regarding the level of output of each firm in our economy with entry. To generalize such result to the aggregate level of output, however, we first need to establish what happens to the number of firms and goods varieties in an equilibrium without stabilization.

Observe that 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), we can write for the no-stabilization case

$$\begin{aligned} & \frac{\kappa\sigma}{\sigma-1} E_{t-1} \left[\frac{1}{\alpha_t} \right] K_t \\ &= E_t \left\{ \beta \left[\frac{\sigma}{\sigma-1} \kappa E_t \left[\frac{1}{\alpha_{t+1}} \right] - \frac{\kappa}{\alpha_{t+1}} \right] \left[\frac{L}{n_{t+1}^{no\ stabilize}} \frac{1}{\frac{\kappa\sigma}{\sigma-1} E_t \left[\frac{1}{\alpha_{t+1}} \right] + \frac{n_{t+2}^{no\ stabilize} K_{t+1}}{n_{t+1}^{no\ stabilize}}} \right] \right\} \end{aligned} \quad (31)$$

As shown in the appendix, this expression can be simplified as follows:

$$E_{t-1} [n_{t+1}^{no\ stabilize} K_t] = \left(\frac{\sigma-1}{\sigma-\beta} \right) \frac{\beta}{\sigma} \frac{1}{\kappa} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \quad (32)$$

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 $\mu_t = \alpha_t$, we can derive (details are in the appendix):

$$E_{t-1} [n_{t+1}^{stabilize} K_t] = \left(\frac{\sigma-1}{\sigma-\beta} \right) \frac{\beta}{\sigma} \frac{1}{\kappa} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} - \frac{cov_{t-1} \left[\frac{1}{\alpha_t}, n_{t+1}^{stabilize} K_t \right]}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \quad (33)$$

Comparing the two expressions (32) and (33): since the covariance term is negative (as a rise in α leads to higher n next period), it follows that:

$$E_{t-1} [n_{t+1}^{stabilize} K_t] > E_{t-1} [n_{t+1}^{no\ stabilize} K_t]. \quad (34)$$

On average, for any given path of K , there are more varieties and firms in a fully stabilized economy (whose allocation coincides with the flexible price allocation).

In principle, one might have conjectured that higher preset prices due to lack of stabilization (our first result above) may actually encourage entry by raising expected profits (the opposite of our second result). This conjecture however ignores the fact that higher goods prices also raise investment costs. Overall, in our economy above entry is discouraged by lack of stabilization.

Observe that in our distorted economy with no stabilization, employment suboptimally 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 $\alpha_t L \ell^{no\ stabilize}$ will simply be proportional to the productivity shock:

$$\frac{\alpha_t L \ell^{no\ stabilize}}{\alpha_t L \ell^{flex}} = \frac{1}{\alpha_t} \left[E_t \left(\frac{1}{\alpha_{t+1}} \right) \right]^{-1}$$

Yet, as shown in appendix, 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:

$$E_{t-1} \ell^{no\ stabilize} = \ell^{flex}.$$

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.

6.3 Welfare

In the previous subsection, we have shown that 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. Now, 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. Can we be sure that incomplete stabilization 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, we 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 appendix). Thus, in a stationary economy:

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

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:

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

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

$$\begin{aligned} E_0 U_t^{stabilize} - E_0 U_t^{no\ stabilize} &= \\ &= E_0 [\ln(\alpha_t) + (\gamma - 1) \ln n_t^{stabilize}] - E_0 \left[(\gamma - 1) \ln n_t^{no\ stabilize} - \ln E_{t-1} \left(\frac{1}{\alpha_t} \right) \right] = \\ &\simeq \{0.5var \ln \alpha_t\} + (\gamma - 1) E_0 (\ln n_t^{stabilize} - \ln n_t^{no\ stabilize}) > 0 \end{aligned}$$

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.

Setting for simplicity $K = 1$, we can write

$$\begin{aligned} &E_0 (\ln n_t^{stabilize} - \ln n_t^{no\ stabilize}) \\ &= E_0 (\ln n_{t+1}^{stabilize} - \ln n_{t+1}^{no\ stabilize}) \\ &= E_0 (E_{t-1} \ln n_{t+1}^{stabilize} - \ln n_{t+1}^{no\ stabilize}) \\ &= E_0 \left(E_{t-1} \ln \left(\frac{\sigma - 1}{\sigma - \beta} \frac{1}{\kappa} \frac{\beta}{\sigma} L \alpha_t \right) - \ln \left(\left(\frac{\sigma - 1}{\sigma - \beta} \right) \frac{\beta}{\sigma} \frac{1}{\kappa} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \right) \right) \\ &= E_0 \left(E_{t-1} \ln(\alpha_t) + \ln \left(E_{t-1} \left[\frac{1}{\alpha_t} \right] \right) \right) \\ &= E_0 \left(E_{t-1} \ln(\alpha_t) + E_{t-1} \ln \left(\frac{1}{\alpha_t} \right) + 0.5var_{t-1} \left(\ln \frac{1}{\alpha_t} \right) \right) \\ &= E_0 (E_{t-1} \ln(\alpha_t) - E_{t-1} \ln(\alpha_t) + 0.5var_{t-1} (\ln \alpha_t)) \\ &= 0.5var_{t-1} (\ln \alpha_t) \end{aligned}$$

So to simplify the earlier expression:

$$E_0 U_t^{stabilize} - E_0 U_t^{no\ stabilize} = 0.5var (\ln \alpha_t) + (\gamma - 1) [0.5var_{t-1} (\ln \alpha_t)] = \frac{\gamma}{2} var_{t-1} (\ln \alpha_t) > 0$$

That is, the utility gap opened by insufficient stabilization becomes proportional to the variability of productivity shocks. Note that in our set up, such 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:

$$\begin{aligned}
E_0 U^{no\ stabilize}((1+x)C_t, \ell_t) &= E_0 U_t^{stabilize} \\
E_0 \ln(C^{no\ stabilize}(1+x)) &= E_0 \ln(C^{stabilize}) \\
E_0 \ln(C^{no\ stabilize}) + \ln(1+x) &= E_0 \ln(C^{stabilize}) \\
x &\simeq E_0 \ln(C^{stabilize}) - E_0 \ln(C^{no\ stabilize}) = \frac{\gamma}{2} \text{var}(\ln \alpha_t)
\end{aligned}$$

A first conclusion we can draw is that welfare gains from stabilization are therefore of the same order of magnitude as Lucas (1987, 2003). However, there is now a new element. Love for variety tends to amplify these gains: to the extent that stabilization raises average entry, preferences for product variety add another dimension to the costs of lack of stabilization. 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. This confirms the point made in the introduction, that the extra welfare cost of entry fluctuations is of the same magnitude as the price markup.

7 Endogenous entry and market competitiveness

The analysis above showed that there is a role for stabilization policy to improve welfare by affecting the number of entrants, provided there is love for variety in consumption. Another reason why the number of entrants might affect welfare is that this may influence the degree of competitiveness within markets. One way to get at this idea is to use the endogenous markup implied by translog preferences, as discussed in Bergin and Feenstra (2000) and Feenstra (2003). Building on Feenstra (2003), characterize household preferences over varieties by the following price index unit cost function:

$$\ln P_t = \left[\sum_{h=1}^{n_t} \frac{\ln p_t(h)}{n_t} + \phi \sum_{h=1}^{n_t} \sum_{i=1}^{n_t} \omega_{hi} \ln p_t(h) \ln p_t(i) \right] - \ln A_{TL,t} \quad (35)$$

over some large number of entrants, n , where

$$\omega_{h,i} = \begin{cases} -\frac{n_t-1}{n_t}, & h = i \\ \frac{1}{n_t}, & h \neq i \end{cases}$$

$$A_{TL,t} = A_t n_t^{\frac{1}{\sigma-1}} = n_t^{\gamma-1}.$$

Here we have included an additive term $A_{TL,t}$ to capture love of variety, and an extra scale parameter ϕ to scale the demand elasticity for use later. As in the CES preferences in

previous sections, $\gamma = 1$ ($A_{TL} = 0$) indicates no love of variety. Note that aggregating this price index over identical firms delivers the same price index as equation (18) for the previous set of preferences:

$$\begin{aligned}\ln P_t &= \ln p_t(h) - \ln A_{TL,t} \\ P_t &= p_t(h)n_t^{1-\gamma}\end{aligned}\tag{36}$$

We use (35) to compute the demand function facing each firm. We compute the share of spending going to each good ($s(h)$) as the derivative of the unit cost function with respect to the firm's price:

$$s_t(h) = \frac{p_t(h)c_t(h)}{P_t C_t} = \frac{\partial P}{\partial P(h)} = \frac{1}{n_t} + \sum_{i=1}^{n_t} \omega_{hi} \ln p(i)\tag{37}$$

or

$$p_t(h)C_t(h) = \left[\frac{1}{n_t} + \sum_{i=1}^{n_t} \omega_{hi} \ln p(i) \right] P_t C_t\tag{38}$$

Note that when aggregating over identical firms, this produces the same allocation of demand over varieties as in the previous model in equation (13): $c_t(h) = C_t/n_t^\gamma$.

Denoting the time-varying demand elasticity as η_t , one can compute $1 - \eta_t$ as the derivative of the share with respect to the good's price by differentiating (37) and evaluating over symmetric firms:

$$\frac{\partial \ln s_t(h)}{\partial \ln p_t(h)} = \frac{-\phi}{s_t(h)} \left(\frac{n_t - 1}{n_t} \right) = -\phi(n_t - 1)$$

This indicates that the demand elasticity facing a variety is $\eta_t = 1 - \phi(1 - n_t)$. For the special case of $\phi = 1$, $\eta_t = n$, the elasticity equals the number of entrants. But if we wish to consider cases with a large number of entrants, the scale parameter ϕ can be set small.

Combining the demand facing a firm (38) with the firm price setting problem from earlier in the paper, one finds the following price setting condition:

$$p_{t+1}(h) = MU_t \frac{E_t \frac{\kappa}{\alpha_{t+1}} \left[\frac{L_{t+1} \mu_{t+1}}{n_{t+1}^\gamma P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}} \right]}{E_t \frac{1}{\mu_{t+1}} \left[\frac{L_{t+1} \mu_{t+1}}{n_{t+1}^\gamma P_{t+1}} + \frac{n_{t+2} K_{t+1}}{n_{t+1}} \right]}\tag{39}$$

where

$$MU_t = \frac{\eta_t}{\eta_t - 1} = 1 - \frac{1}{\phi(1 - n_{t+1})}\tag{40}$$

which is identical to the price-setting equilibrium condition from the previous version of the model, except that the constant demand elasticity σ has been replaced by the time-varying elasticity that is a function of the number of entrants. We restrict the number of firms to be large enough, so that firms take the elasticity as beyond their control. Note that

while this elasticity is time varying, it is known at the time prices are set. So it remains like the earlier model in this respect without adding an extra dimension of uncertainty to complicate model solution. Once aggregated over identical firms, all other equilibrium conditions remain unchanged.

Figures 7 and 8 illustrate the dynamics for shocks in the linear approximation to the model.¹⁶ Observe first that in each case the markup in pricing falls in inverse proportion to the new entry. This is a useful implication, since countercyclical markups are a well-documented feature of business cycle data (see Bills, 1987; Rotemberg and Woodford, 1991). Next observe that there is now some positive persistence in the effects of monetary policy on output, though the effect is small. Finally, observe that the initial impact on entry for both shocks is about half of that observed with CES preferences and exogenous markups. The reason is that as more entry drives down the markup and hence profits, it takes fewer new entrants to drive monopolistic profits back down to the fixed entry cost. One interesting implication of this feature, is that now the rise in output is evenly split between the extensive and intensive margins, rather than all taking place at the extensive margin whenever entry is permitted. While empirical work is yet to be done on the precise breakdown of output deviations into intensive and extensive margins, the fact that endogenous markups allow this breakdown to be calibrated will likely prove useful as future research brings models of entry to the data.

The fact that the endogenous markup generates some persistence here means that serial dependence no longer can be eliminated by choosing $\gamma_K = 1$. This precludes the type of analytical solution used in the previous section to rank formally the effects of alternative monetary policies on entry and welfare analysis. Nonetheless, it is clear that endogenous markups provide an additional reason why entry matters for welfare. As more firms enter and the market becomes more dense, the demand elasticity rises and markups fall, reducing the monopolistic distortion in the market. Consequently, this version of the model should predict an even wider range of cases where policies promoting greater entry would improve welfare.

8 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

¹⁶The calibration is the same as previous cases, with the additional parameter ϕ set to unity. So $\sigma = 6$, $\gamma = \frac{\sigma}{\sigma-1} = 1.2$, $\gamma_K = 1$ for productivity for the shock experiment and 1.2 for the monetary shock experiment, $\beta = 1$, $K = 0.012$, $L = 1$.

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 either love of variety in preferences, or the possibility that new entry may raise competitiveness in the market and reduce the monopolistic distortion.

We analyze 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] Benassy, J-P., 1996, Taste for variety and optimum production patterns in monopolistic competition, *Economics Letters* 52, 41-47.
- [2] Bergin P. and R. Feenstra, 2000, Staggered price setting and endogenous persistence, *Journal of Monetary Economics* 45 (3), 657-680.
- [3] Bilbiie, F., F. Ghironi, and M. Melitz, 2005, Business cycles and firm dynamics, Mimeo.
- [4] Bilts, M., 1987, The cyclical behavior of marginal cost and price, *American Economic Review* 77 (5) 647-666.
- [5] Broda, C. and D. Weinstein, 2004, Globalization and the gains from variety, NBER Working Paper No. 10314
- [6] Campbell, J. 1998, Entry, exit, embodied technology, and business cycles, *Review of Economic Dynamics* 1, 371-408.
- [7] 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.
- [8] 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 and eds., *Handbook of Macroeconomics*.
- [9] Corsetti, G., P. Martin and P. Pesenti, 2005, Productivity spillovers, terms of trade and the ‘home market effect’, CEPR DP 4964, NBER WP 11165.
- [10] Corsetti, G. and P. Pesenti, 2001, Welfare and macroeconomic interdependence, *Quarterly Journal of Economics* 116(2), 421-445.
- [11] Corsetti, G. and P. Pesenti, 2005a, International dimensions of optimal monetary policy, *Journal of Monetary Economics* 52(2), 281-305.
- [12] Corsetti, G. and P. Pesenti, 2005b, The simple geometry of transmission and stabilization in closed and open economy, NBER wp no. 11341, CEPR dp no. 5080, New York Fed Staff Report no. 209.
- [13] 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.

- [14] Dixit, A.K. and J. Stiglitz , 1974, Monopolistic competition and optimum product diversity, working paper version, published in *The monopolistic competition revolution in retrospect*, edited by Brakman and Heijdra, 2003, Cambridge University Press.
- [15] Eichenbaum, Martin, and Charles L. Evans, 1995, Some empirical evidence on the effects of shocks to monetary policy on exchange rates, *Quarterly Journal of Economics* 110 (4), 975-1009.
- [16] _____, 2003, A homothetic utility function for monopolistic competition models, without constant price elasticity, *Economics Letters* 78, 79-86.
- [17] Ghironi, F. and M. Melitz, 2005, International trade and macroeconomics dynamics with heterogenous firms, Mimeo.
- [18] Jaimovich, Nir, 2004, Firm dynamics, markup variations, and the business cycle, Mimeo
- [19] Kim, J. 2004, What determines aggregate returns to scale? *Journal of Economic Dynamics and Control* 28, 1577-1594.
- [20] Lucas, Robert E., Jr., 1987, *Model of Business Cycles*, Basil Blackwell
- [21] Lucas, Robert E., Jr., 2003, Macroeconomic Priorities, *American Economic Review* 1, 1-14.
- [22] Rotemberg, J. and M. Woodford, 1991, Markups and the business cycle, in O. J. Blanchard and S. Fischer (eds.), *NBER Macroeconomics Annual 1991*. Cambridge, MIT Press.

Appendix

Nonstochastic Steady state

In a non-stochastic steady state, the optimal price and the free entry conditions defined above are

$$p = \frac{\sigma}{\sigma - 1} \frac{\kappa\mu}{\alpha}$$

$$n^{\gamma_k - 1} \left[\frac{\beta \cdot L \cdot n^{-[\gamma + (1-\gamma)\psi]}}{\alpha^{1-\psi} (\sigma - 1)^{1-\psi} (\kappa\sigma)^\psi} - \frac{1}{\nu} \right] = \frac{K}{\alpha(\sigma - 1)} (\sigma - \beta)$$

In general, the model is highly non linear, and the steady state allocation may not be unique.

In some special cases, however, the solution becomes quite tractable. If $\gamma_k = 1$, for instance, the number of firms and varieties is

$$n^{\gamma - (\gamma - 1)\psi} = \frac{\frac{\beta \cdot L}{\alpha^{1-\psi} (\sigma - 1)^{1-\psi} (\kappa\sigma)^\psi}}{\frac{K}{\alpha(\sigma - 1)} (\sigma - \beta) + \frac{1}{\nu}}$$

Note that, as long as ψ is not too large – so that the exponent of n is positive – the number of firms is increasing in the size of the country and patience (i.e., increasing in L and β), and decreasing in entry costs (i.e., decreasing in K , increasing in ν). Lower marginal costs (an increase in productivity α) have however ambiguous implications.

Furthermore, with $K = 0$, the expression simplifies to

$$n^{[\gamma - (\gamma - 1)\psi]} = \frac{\nu \cdot \beta \cdot L}{\alpha^{1-\psi} (\sigma - 1)^{1-\psi} (\kappa\sigma)^\psi}$$

When entry costs consist of labor costs only, and ψ is sufficiently high, higher manufacturing productivity (a higher α) leads to exit in steady state (i.e., it leads to a lower n).

Pareto optimal allocation

This section of the appendix sets the planner problem and characterize the efficient allocation. Write the resource constraint for individual good h

$$Y_t(h) = L_t C_t(h) + n_{t+1} K_t(h)$$

In the aggregate

$$\begin{aligned} n_t Y_t(h) &= n_t \left[L_t \frac{C_t}{n_t^\gamma} + n_{t+1} \frac{K_t}{n_t^{\gamma_K}} \right] = \\ &= n_t^{1-\gamma} L_t C_t + n_{t+1} n_t^{1-\gamma_K} K_t \end{aligned}$$

Combining this expression with technology

$$\alpha_t L_t \ell_t = n_t Y_t(h)$$

we can rewrite the resource constraint for the economy as follows:

$$L_t \ell_t = \frac{n_t^{1-\gamma} L_t C_t + n_{t+1} n_t^{1-\gamma_K} K_t}{\alpha_t} \quad (\text{A.1})$$

Write the Pareto problem

$$\begin{aligned} & \text{Max} \sum_{\tau=0}^{\infty} \beta^\tau [\ln C_\tau - \kappa \ell_\tau] + \\ & \lambda_t \left\{ L_t \ell_t - \frac{n_t^{1-\gamma} L_t C_t + n_{t+1} n_t^{1-\gamma_K} K_t}{\alpha_t} \right\} + \\ & E_t \beta \lambda_{t+1} \left\{ L_{t+1} \ell_{t+1} - \frac{n_{t+1}^{1-\gamma} L_{t+1} C_{t+1} + n_{t+2} n_{t+1}^{1-\gamma_K} K_{t+1}}{\alpha_{t+1}} \right\} + \dots \end{aligned} \quad (\text{A.2})$$

The first order conditions with respect to ℓ and C are

$$\begin{aligned} -\kappa + \lambda_t L_t &= 0 \implies \lambda_t = \frac{\kappa}{L_t} \\ \frac{1}{C_t^{P.O.}} - \lambda_t \frac{(n_t^{P.O.})^{1-\gamma} L_t}{\alpha_t} &= 0 \end{aligned}$$

which imply:

$$C_t^{P.O.} = \frac{\alpha_t (n_t^{P.O.})^{\gamma-1}}{\kappa}$$

The first order condition with respect to n_{t+1} yields

$$-\lambda_t \left[\frac{(n_t^{P.O.})^{1-\gamma_K} K_t}{\alpha_t} \right] - E_t \beta \lambda_{t+1} \left[(1-\gamma) \frac{L_{t+1} C_{t+1}^{P.O.}}{\alpha_{t+1}} (n_{t+1}^{P.O.})^{-\gamma} + (1-\gamma_K) \frac{n_{t+2}^{P.O.} K_{t+1}}{\alpha_{t+1}} (n_{t+1}^{P.O.})^{-\gamma_K} \right] = 0$$

Substituting the Lagrange multiplier and optimal consumption, we can also write:

$$-\left[\frac{(n_t^{P.O.})^{1-\gamma_K} K_t}{\alpha_t} \right] - E_t \beta \frac{L_t}{L_{t+1}} \left[(1-\gamma) \frac{L_{t+1}}{n_{t+1}^{P.O.}} \frac{1}{\kappa} + (1-\gamma_K) \frac{n_{t+2}^{P.O.} K_{t+1}}{\alpha_{t+1}} (n_{t+1}^{P.O.})^{-\gamma_K} \right] = 0$$

In the case of no efficiency gains from variety in investment, $\gamma_K = 1$, this expression simplifies to:

$$(n_{t+1}^{P.O.})_{\gamma_K=1} = \frac{\alpha_t}{K_t} \beta L_t \left[(\gamma-1) \frac{1}{\kappa} \right].$$

which we use in the text. It is easy to verify that efficient labor supply is constant and equal to (26) in the text.

Ranking entry over policy rules

In this section of the appendix, we derive the expressions (32) and (33) discussed in the main text. First, consider the case of no stabilization policy, where $\mu_t = 1$. From (31) we can write

$$\begin{aligned} & \frac{\kappa \sigma}{\sigma-1} E_{t-1} \left[\frac{1}{\alpha_t} \right] K_t = \\ & = \beta \frac{1}{n_{t+1}^{no \text{ stabilize}}} \left\{ \frac{1}{\sigma} L + \frac{\sigma}{\sigma-1} \kappa E_t \left[\frac{1}{\alpha_{t+1}} \right] E_t [n_{t+2}^{no \text{ stabilize}} K_{t+1}] - \kappa E_t \left[\frac{n_{t+2}^{no \text{ stabilize}} K_{t+1}}{\alpha_{t+1}} \right] \right\}. \end{aligned}$$

Rearranging:

$$n_{t+1}^{no\ stabilize} K_t = \beta \frac{\frac{\sigma-1}{\kappa\sigma^2} L + E_t \left[\frac{1}{\alpha_{t+1}} \right] E_t \left[n_{t+2}^{no\ stabilize} K_{t+1} \right] - \frac{\sigma-1}{\sigma} E_t \left[\frac{n_{t+2}^{no\ stabilize} K_{t+1}}{\alpha_{t+1}} \right]}{E_{t-1} \left[\frac{1}{\alpha_t} \right]}$$

We see here that the product $n_{t+1}^{no\ stabilize} K_t$ is a function of constants and expectations dated t , which are constant. So $n_{t+1}^{no\ stabilize} K_t$ is not time varying under this policy rule.

Take expectations as of $t-1$:

$$\begin{aligned} E_{t-1} \left[n_{t+1}^{no\ stabilize} K_t \right] &= \\ &= \beta \frac{E_{t-1} \frac{\sigma-1}{\kappa\sigma^2} L + E_t \left[\frac{1}{\alpha_{t+1}} \right] E_t \left[n_{t+2}^{no\ stabilize} K_{t+1} \right] - \frac{\sigma-1}{\sigma} E_t \left[\frac{n_{t+2}^{no\ stabilize} K_{t+1}}{\alpha_{t+1}} \right]}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \\ &= \beta \frac{\frac{\sigma-1}{\kappa\sigma^2} L + \frac{1}{\sigma} E_{t-1} \left[\frac{1}{\alpha_{t+1}} \right] E_{t-1} \left[n_{t+2}^{no\ stabilize} K_{t+1} \right] - \frac{\sigma-1}{\sigma} cov_{t-1} \left[\frac{1}{\alpha_{t+1}}, n_{t+2}^{no\ stabilize} K_{t+1} \right]}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \end{aligned}$$

Since shocks are i.i.d., we can further simplify this:

$$\begin{aligned} E_{t-1} \left[n_{t+1}^{no\ stabilize} K_t \right] &= \\ &= \beta \left\{ \frac{\sigma-1}{\kappa\sigma^2} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} + \frac{1}{\sigma} E_{t-1} \left[K_{t+1} n_{t+2}^{no\ stabilize} \right] - \frac{\sigma-1}{\sigma} \frac{cov_{t-1} \left[\frac{1}{\alpha_{t+1}}, K_{t+1} n_{t+2}^{no\ stabilize} \right]}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \right\} \end{aligned}$$

Entry is serially independent, expectations of the product of $n_{\tau+1}^{no\ stabilize} K_\tau$ are the same for all periods τ :

$$\left(1 - \frac{\beta}{\sigma} \right) E_{t-1} \left[n_{t+1}^{no\ stabilize} K_t \right] = \beta \left\{ \frac{\sigma-1}{\kappa\sigma^2} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} - \frac{\sigma-1}{\sigma} \frac{cov_{t-1} \left[\frac{1}{\alpha_{t+1}}, n_{t+2}^{no\ stabilize} K_{t+1} \right]}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \right\}$$

$$\begin{aligned} \left(1 - \frac{\beta}{\sigma} \right) E_{t-1} \left[n_{t+1}^{no\ stabilize} K_t \right] &= \\ &= \left(\frac{\beta}{1 - \frac{\beta}{\sigma}} \right) \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} \left\{ \frac{\sigma-1}{\kappa\sigma^2} L - \frac{\sigma-1}{\sigma} cov_{t-1} \left[\frac{1}{\alpha_{t+1}}, n_{t+2}^{no\ stabilize} K_{t+1} \right] \right\} \end{aligned}$$

Since with nominal rigidities, entry does not respond to productivity shocks, as discussed above, we know that in the case of *i.i.d.* shocks the covariance terms on the right hand side is zero. We therefore can write (32) in the text.

Second, consider the case of stabilization policy with $\mu_t = \alpha_t$, in which case the allocation coincides with the flexible price one. Again using (29) in (28), we can write

$$\begin{aligned} \frac{\kappa\sigma}{\sigma-1} \frac{K_t}{\alpha_t} &= E_t \left\{ \frac{\beta}{\alpha_{t+1}} \left[\frac{\kappa\sigma}{\sigma-1} - \kappa \right] \left[\frac{L}{n_{t+1}^{stabilize} \frac{\kappa\sigma}{\sigma-1}} + \frac{n_{t+2}^{stabilize} K_{t+1}}{n_{t+1}^{stabilize}} \right] \right\} \\ &= \beta \left(\frac{1}{\sigma} \right) \frac{L}{n_{t+1}^{stabilize}} + \beta \left(\frac{1}{\sigma-1} \right) \kappa \frac{1}{n_{t+1}^{stabilize}} E_t \left[\frac{1}{\alpha_{t+1}} n_{t+2}^{stabilize} K_{t+1} \right]. \end{aligned}$$

Rearranging

$$\begin{aligned} n_{t+1}^{stabilize} \frac{K_t}{\alpha_t} &= \left(\frac{\sigma - 1}{\kappa \sigma} \right) \beta \left\{ L \frac{1}{\sigma} + \left(\frac{1}{\sigma - 1} \right) \kappa E_t \left[\frac{1}{\alpha_{t+1}} n_{t+2}^{stabilize} K_{t+1} \right] \right\} \\ &= \beta \left\{ \frac{\sigma - 1}{\kappa \sigma^2} L + \frac{1}{\sigma} E_t \left[\frac{1}{\alpha_{t+1}} \right] E_t [K_{t+1} n_{t+2}^{stabilize}] + \frac{1}{\sigma} cov_t \left[\frac{1}{\alpha_{t+1}}, n_{t+2}^{stabilize} K_{t+1} \right] \right\} \end{aligned}$$

and take expectations as of $t - 1$:

$$\begin{aligned} E_{t-1} \left[n_{t+1}^{stabilize} K_t, \frac{1}{\alpha_t} \right] &= \\ = \beta \left\{ \frac{\sigma - 1}{\kappa \sigma^2} L + \frac{1}{\sigma} E_{t-1} \left[\frac{1}{\alpha_{t+1}} \right] E_{t-1} [n_{t+2}^{stabilize} K_{t+1}] + \frac{1}{\sigma} cov_{t-1} \left[\frac{1}{\alpha_{t+1}}, n_{t+2}^{stabilize} K_{t+1} \right] \right\} \end{aligned}$$

or

$$\begin{aligned} E_{t-1} \left[\frac{1}{\alpha_t} \right] E_{t-1} [n_{t+1}^{stabilize} K_t] + cov_{t-1} \left[\frac{1}{\alpha_t}, n_{t+1}^{stabilize} K_t \right] \\ = \beta \frac{\sigma - 1}{\kappa \sigma^2} L + \frac{\beta}{\sigma} \left\{ E_{t-1} \left[\frac{1}{\alpha_{t+1}} \right] E_{t-1} [n_{t+2}^{stabilize} K_{t+1}] + cov_{t-1} \left[\frac{1}{\alpha_{t+1}}, n_{t+2}^{stabilize} K_{t+1} \right] \right\} \end{aligned}$$

As above, with i.i.d. shocks:

$$\begin{aligned} E_{t-1} \left[\frac{1}{\alpha_t} \right] E_{t-1} [n_{t+1}^{stabilize} K_t] + cov_{t-1} \left[\frac{1}{\alpha_t}, n_{t+1}^{stabilize} K_t \right] &= \beta \frac{\sigma - 1}{\kappa \sigma^2} L \\ &+ \frac{\beta}{\sigma} \left\{ E_{t-1} \left[\frac{1}{\alpha_t} \right] E_{t-1} [n_{t+1}^{stabilize} K_{t+1}] + cov_{t-1} \left[\frac{1}{\alpha_t}, n_{t+1}^{stabilize} K_{t+1} \right] \right\} \\ \left(1 - \frac{\beta}{\sigma} \right) \left\{ E_{t-1} \left[\frac{1}{\alpha_t} \right] E_{t-1} [n_{t+1}^{stabilize} K_t] + cov_{t-1} \left[\frac{1}{\alpha_t}, n_{t+1}^{stabilize} K_t \right] \right\} &= \beta \frac{\sigma - 1}{\kappa \sigma^2} L \end{aligned}$$

The expression (33) in the text follows.

Expected labor supply and the natural rate of employment

In this appendix we derive the expected labor supply under nominal rigidities. Using the resource constraint (A.1) and setting $\gamma_K = 1$

$$\ell_t = n_t^{1-\gamma} C_t \frac{1}{\alpha_t} + n_{t+1} \frac{K_t}{\alpha_t} \frac{1}{L_t}$$

Since $C = \mu/P_t$ and $P_t = n^{\gamma-1} p = n^{1-\gamma} \frac{\sigma \kappa}{\sigma-1} E_{t-1} \left(\frac{\mu}{\alpha_t} \right)$, we can rewrite the above as

$$\ell_t = \frac{\mu_t}{\frac{\sigma \kappa}{\sigma-1} E_{t-1} \left(\frac{\mu}{\alpha_t} \right)} \frac{1}{\alpha_t} + n_{t+1} \frac{K_t}{\alpha_t} \frac{1}{L_t}$$

Take expectations at time $t - 1$:

$$\begin{aligned} E_{t-1} \ell_t &= \frac{\sigma - 1}{\sigma \kappa E_{t-1} \left(\frac{\mu}{\alpha_t} \right)} E_{t-1} \left(\frac{\mu}{\alpha_t} \right) + E_{t-1} \left(n_{t+1} \frac{K_t}{\alpha_t} \frac{1}{L_t} \right) = \\ &= \frac{\sigma - 1}{\kappa \sigma} + E_{t-1} \left(n_{t+1} \frac{K_t}{\alpha_t} \frac{1}{L_t} \right) \end{aligned}$$

In the case of full stabilization of marginal costs, the monetary rule replicates the flexible price equilibrium. Hence, using the expectations of (23), and substituting into the above, we obtain

$$\begin{aligned}
E_{t-1} \ell_t^{stabilize} &= \frac{\sigma - 1}{\sigma \kappa} + \frac{\sigma - 1}{\sigma - \beta} \frac{1}{\kappa} \frac{\beta}{\sigma} = \\
&= \frac{\sigma - 1}{\sigma \kappa} \left[1 + \frac{\beta}{\sigma - \beta} \right] = \\
&= \frac{\sigma - 1}{\sigma \kappa} \left[\frac{\sigma}{\sigma - \beta} \right] = \frac{1}{\kappa} \frac{\sigma - 1}{\sigma - \beta} = \ell^{flex}
\end{aligned}$$

In the case of no stabilization we know that entry is independent of productivity shocks. Hence

$$\begin{aligned}
&\frac{1}{L_t} E_{t-1} \left(n_{t+1}^{no\ stabilize} K_t \frac{1}{\alpha_t} \right) = \\
&= \frac{1}{L_t} E_{t-1} \left(n_{t+1}^{no\ stabilize} K_t \right) E_{t-1} \left(\frac{1}{\alpha_t} \right)
\end{aligned}$$

From the previous section of the appendix we know that:

$$E_{t-1} \left[n_{t+1}^{no\ stabilize} K_t \right] = \left(\frac{\sigma - 1}{\sigma - \beta} \right) \frac{\beta}{\sigma} \frac{1}{\kappa} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]}$$

hence

$$\begin{aligned}
&\frac{1}{L_t} E_{t-1} \left(n_{t+1}^{no\ stabilize} K_t \frac{1}{\alpha_t} \right) = \\
&= \frac{1}{L_t} \left(\frac{\sigma - 1}{\sigma - \beta} \right) \frac{\beta}{\sigma} \frac{1}{\kappa} L \frac{1}{E_{t-1} \left[\frac{1}{\alpha_t} \right]} E_{t-1} \left(\frac{1}{\alpha_t} \right) = \\
&= \left(\frac{\sigma - 1}{\sigma - \beta} \right) \frac{\beta}{\sigma} \frac{1}{\kappa}
\end{aligned}$$

exactly as for the previous case above, leading to the same result for $E_{t-1} \ell_t^{no-stabilize} = \ell^{flex}$.