Short- and Long-Run Tradeoff of Monetary Easing

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Motovation

- Unprecedented levels of monetary easing were conducted by many central banks.
  - ▸ helped in preventing an economic catastrophe
  - ▸ but, secular stagnation; lost decades in Japan
- Long-run effects of monetary easing?
  - ▸ Both in terms of levels and growth rates

What We Do

- We construct a dynamic stochastic general equilibrium model with two features
    - endogenous growth due to creative destruction (Schumpeterian)
    - sticky prices due to menu costs (new Keynesian)

Literature

1. Menu cost models. Golosov and Lucas (2007), Nakamura and Steinsson (2010), Midrigan (2011)

2. Creation destruction models. Aghion and Howitt (1992), Grossman and Helpman (1991)

   ▶ a reallocation through creative destruction. Acemoglu et al. (2013)

3. Product substitution (turnover). Empirically by Bils and Klenow (2004), Nakamura and Steinsson (2008), and Bils (2009)

- We need to examine the entry and exit of firms and price stickiness in combination.

  ▶ Chu and Cozzi (2014), Oikawa and Ueda (2015), Bilbiie et al. (2014)

What We Find

- A tradeoff between the short-run positive effects and long-run negative effects of a transitory monetary easing shock through

1. Monetary easing increases the level of consumption due to price stickiness.

2. Inflation due to monetary easing reduces the reward for innovation via menu cost payments. This lowers the frequency of creative destruction (product substitution), and, in turn, the growth rate of consumption.

- In the long run, the latter adverse effect dominates the former short-run positive effect.

Outline

- Introduction (done)
- Model
- Simple cases
- Simulation results
- Concluding remarks

Model

Model Setup

- Discrete time
- A representative household consumes and supplies labor.
- Firms develop a new product by R&D investment and enter a market. At the same time, firms with an old product exit.
  - Labor is used for R&D investment and goods production.
- A central bank controls money supply growth.
  - Aggregate uncertainty: monetary policy shocks

Quality Ladder

$$\tilde{q}(j, K_t(j)) = \Pi_{h=0}^{K_t(j)} q(j, h)$$

$q_t(j)$
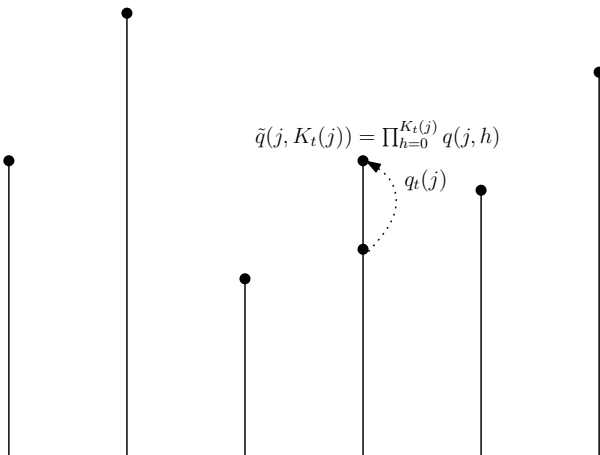
product lines, $j \in [0, 1]$

Household

$$U_t = \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta^i \left(\log C_{t+i} - \chi L_{t+i} \right) \right], \tag{1}$$

$$C_t = \left[\int_0^1 \left[\left(\sum_{k=0}^{K_t(j)} \tilde{q}(j,k) x_t(j,k) \right)^{\frac{\theta-1}{\theta}} \right] dj \right]^{\frac{\theta}{\theta-1}}, \tag{2}$$

$$P_t C_t + B_t = R_{t-1} B_{t-1} + W_t L_t + \Pi_t. \tag{3}$$

We assume that nominal spending must be equal to the money supply:

$$P_t C_t = M_t. \tag{4}$$

Labor supply optimization yields

$$W_t = \chi M_t. \tag{5}$$

Monetary Policy

Money supply grows as

$$\log(M_t/M_{t-1}) = g_t = (1-\rho)g + \rho g_{t-1} + \varepsilon_t^M, \tag{6}$$

where ε_t^M represents a monetary policy shock that follows $\varepsilon_t^M \sim N(0, \sigma_M)$.

Firm Entry

- R&D to invent a higher quality product.
  - Cost: h units of labor
  - Quality gap: $q_t(j) > 1$, drawn from distribution and constant after entry
- A free entry condition:

$$\frac{W_t}{M_t} h \geq v_t^E \text{ with equality when } \mu > 0 \tag{7}$$

$$\Rightarrow v_t^E = \chi h \text{ if } \mu > 0. \tag{8}$$

Industry-Leading Firms (Incumbents)

Bertrand competition. Linear production.
The firm profit is zero unless

$$p_t(j, k) \leq q_t(j) W_t = q_t(j) \chi M_t. \tag{9}$$

Combined with the competition between different product lines, the optimal price should satisfy

$$p_t(j, k) = \min\left(q_t(j), \frac{\theta}{\theta - 1}\right) \chi M_t, \tag{10}$$

without nominal rigidity.
Hereafter, $\theta = 1$.
Menu cost: firms hire labor when they reset their prices as much as κ/χ.

$$v_t = \max\left(v_t^R, v_t^N\right), \tag{11}$$

$$v_t^R(q_t(j), g_t) = \max_{\tilde{\xi}}\left[\frac{\tilde{\xi}-1}{\tilde{\xi}} - \kappa + \beta\left(1 - \mu_{t+1}(g_t)\right)\mathbb{E}_t^j\left[v_{t+1}(\tilde{\xi}e^{-g_{t+1}}, q_t(j), g_{t+1})\right]\right], \tag{12}$$

$$
\begin{aligned}
&v_t^N(\tilde{\xi}_{t-1}(j)e^{-g_t}, q_t(j), g_t)\\
&\quad = \frac{\tilde{\xi}_{t-1}(j)e^{-g_t}-1}{\tilde{\xi}_{t-1}(j)e^{-g_t}} + \beta\left(1 - \mu_{t+1}(g_t)\right)\mathbb{E}_t^j\left[v_{t+1}(\tilde{\xi}_{t-1}(j)e^{-g_t-g_{t+1}}, q_t(j), g_{t+1})\right],
\end{aligned}
\tag{13}
$$

$$v_t^E(g_t) = \mathbb{E}_t \max_{\tilde{\xi}}\left[\frac{\tilde{\xi}-1}{\tilde{\xi}} + \beta\left(1 - \mu_{t+1}(g_t)\right)v_{t+1}(\tilde{\xi}e^{-g_{t+1}}, q, g_{t+1})\right]. \tag{14}$$

with the real price:

$$1 \le \tilde{\xi}_t(j) \le q_t(j) \tag{15}$$

Simple Cases

1. The Source of Short-Run Positive Impact of $\varepsilon^M > 0$

- Caplin and Spulber (1987) show that money is neutral in a menu cost model without entry/exit.

- Introduce exogenous μ.
  - A new firm produces exactly the same goods as does an exiting firm; that is, $q(j, k) = 1$ (thus, no growth).

- Menu cost $\Rightarrow$ Ss pricing; distribution wrt real price

$$\pi_t = g + \alpha(\mu)\varepsilon_t^M \ (\alpha(\mu) \in [0,1], \alpha'(\mu) < 0, \alpha(0) = 1)$$

$$d\log C_t = \left(1 - \frac{\mu\Delta e^{-\mu\Delta}}{1 - e^{-\mu\Delta}}\right)\varepsilon_t^M.$$

Proposition

Money is not neutral unless the entry and exit rate μ is zero. For $\mu \ll 1$, the real effects of money increase as μ increases.

- Over time, an increasing number of firms exit, and the density of firms whose real price is close to S becomes larger than that of firms whose real price is close to s.
- A monetary policy shock induces the latter firms to reset their prices.
- Because their density is relatively low, the change in the extensive margin and that in the aggregate price level are small.
- This generates the real effects of monetary policy.

Density wrt Real Prices
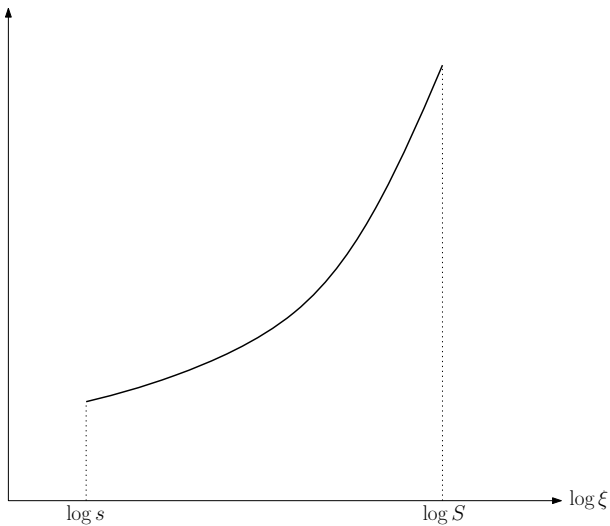
2. The Source of Long-Run Negative Impact of $\varepsilon^M > 0$

- We assume that constant $q > 1$ and nonstochastic g.
- μ is now endogenous.

The frequency of creative destruction, μ, is decreasing in $|g|$.
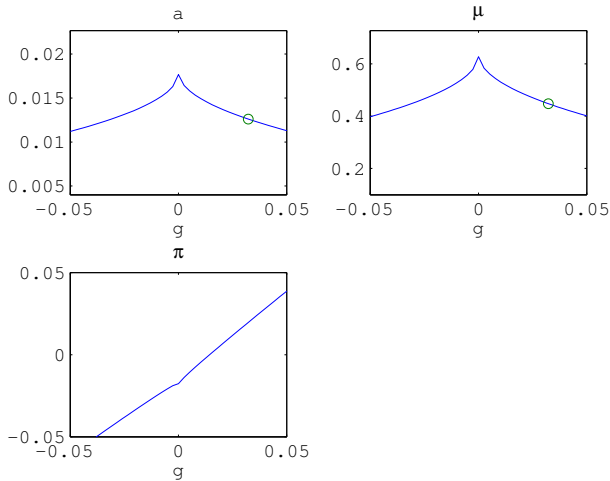
Figure: Quantitative impacts of money growth.

Firm value:

$$v^E = \begin{cases} \frac{1}{\rho+\mu}\left(1 - \frac{e^{g\Delta(g,\mu)}}{q}\right) + \kappa & \text{for } g > 0, \\ \frac{1}{\rho+\mu}\left(1 - \frac{e^{-g\Delta(g,\mu)}}{q}\right) & \text{for } g < 0. \end{cases} \tag{16}$$

At the same time, the free-entry condition requires

$$v^E = \chi h. \tag{17}$$

- A permanent monetary shock g functions to decrease v_t^E.
  - No money growth $g = 0 \Rightarrow$ no need to reset prices $\Rightarrow v^E$ is the largest.
- To keep it constant, μ has to decrease.
- A permanent monetary shock has a negative impact on the real growth rate $a = \mu \log q$.

Numerical Simulation

Back to the Full Model

An equilibrium is a collection of prices and allocations, $\xi_t(j)$, P_t, C_t, and μ_t such that taking prices as given, the allocations and prices solve

1. the household's and firm's problems
2. the goods and labor markets clear, given the exogenous shocks ε_t^M and $q(j)$.

We make the following iterative steps to solve for the equilibrium:

1. We specify a finite grid of points for the state variables, $\xi_t(j)$, $q_t(j)$, and g_t.
2. We solve for the firm's policy function F by value function iteration, where we use $\mu_{t+1}(g_t)$ obtained in the previous iteration and we update $\mu_{t+1}(g_t)$ using the freen entry condition. This enables us to obtain v_t^E, v_t^R, v_t^N, v_t, F, and η_t.
3. We calculate other features of the equilibrium values such as M_t/P_t, C_t, π_t, and Ω_t.

Calibration

- US Economy from 1995 to 2012
- Week
- The size of menu cost, we set $\kappa = 0.05$, which is several times larger than that in previous studies: 0.007 in Levy et al. (1997) and 0.022 in Midrigan (2011).
  - Due to the Bertrand competition within product lines

Calibrated parameters		Assigned parameters	
h	2.1647	β	$0.96^{1/52}$
$\bar{q}$	1.0286	g	$1.0328^{1/52} - 1 = 6.20 \cdot 10^{-4}$
χ	0.9983	ρ	$0.40476^{1/13} = 0.9328$
κ	0.05	σ_M	$3.11 \cdot 10^{-4}$
		σ_q	0.005

Moments	Data	Stochastic model (benchmark)
Real growth rate a	$1.0127^{1/52} - 1$ $= 2.43 \cdot 10^{-4}$	$2.29 \cdot 10^{-4}$
Entry-exit rate μ	$1 - (1 - 0.034)^{1/4}$ $= 8.61 \cdot 10^{-3}$	$8.37 \cdot 10^{-3}$
Frequency of price changes	$0.022 \sim 0.087$	0.083
Frequency of price changes including product substitution	$0.028 \sim 0.109$	0.090
Size of price changes	0.085	0.009
Size of price changes when product substitution	–	0.004

Stochastic Case
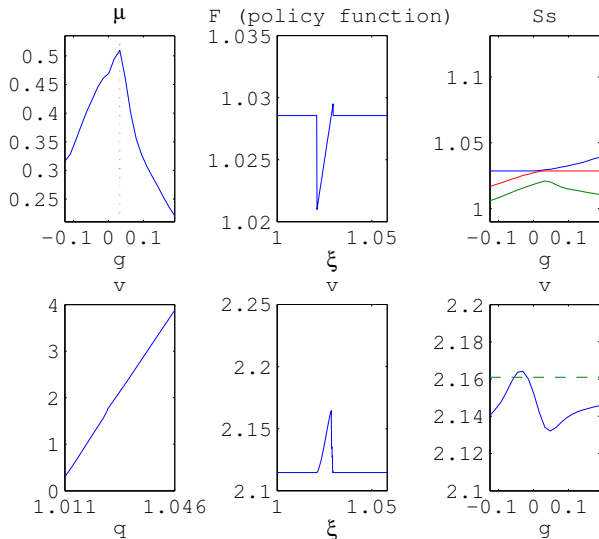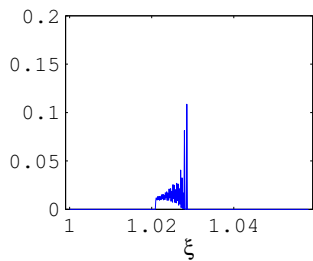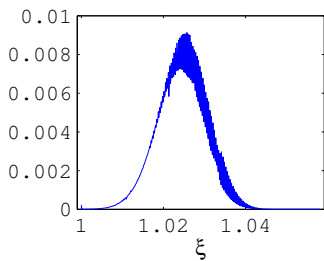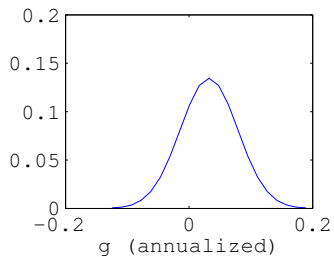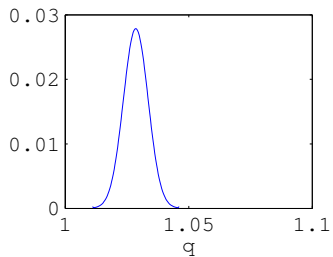
price changes for a matched sample excluding no change
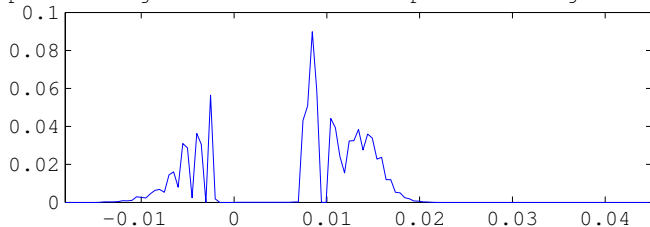
price changes when entry including no change
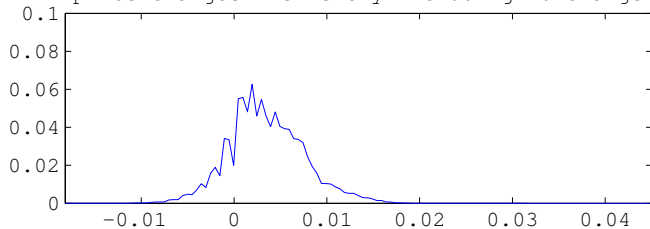
Transition Path

- g_t changes unexpectedly by a sequence of monetary policy shocks.
    - Initially in period $t = 0$, firms are distributed according to their stationary distribution and $g_{t=0}$ equals its steady state level g.
    - Positive shocks of the size of σ_M lasting for a quarter from $t = 14$ to 26.
    - The transition path up to two years (104 weeks) is simulated.

g (annualized) π (annualized)

μ (annualized) c change (annualized)

c from benchmark Fraction of price changing firm
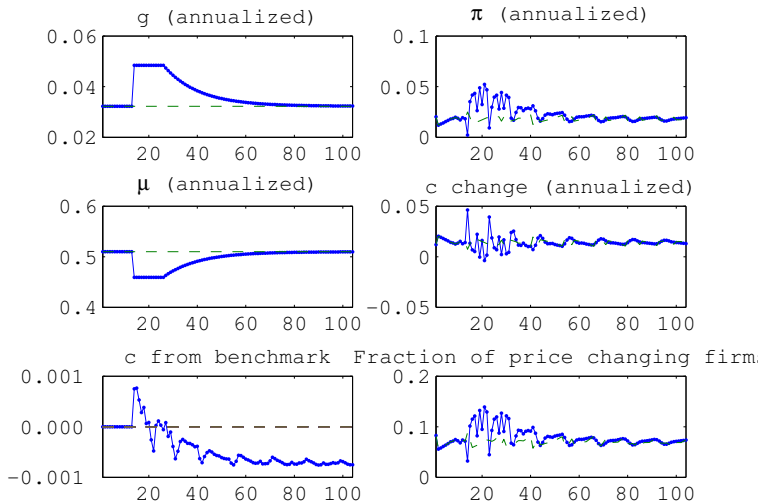
The real growth rate:

$$a_t = \log\left(\frac{C_t}{C_{t-1}}\right) = \log\left(\frac{M_t/P_t}{M_{t-1}/P_{t-1}}\right) = g_t - \pi_t. \tag{18}$$

The inflation rate:

$$
\begin{aligned}
\pi_t &= (1 - \mu_t(g_{t-1})) \cdot \int d\tilde{\xi}_{t-1} \int dq \cdot \Gamma_{t-1} \cdot \log\left(\frac{F\left(\tilde{\xi}_{t-1}e^{-g_t}, q, g_t\right)}{\tilde{\xi}_{t-1}e^{-g_t}}\right) \\
&\quad + \mu_t(g_{t-1}) \cdot \left(\int d\Omega_q \cdot \log\left(\frac{F\left(\infty, q, g_t\right)}{qe^{-g_t}}\right) - \int d\tilde{\xi}_{t-1} \int dq \cdot \Gamma_{t-1} \cdot \log\tilde{\xi}_{t-1}\right).
\end{aligned}
$$

$$
\begin{aligned}
&= g_t \\
&\quad - \mu_t(g_{t-1}) \cdot \int d\Omega_q \cdot \log q + O(\mu_t(g_{t-1})) \tag{19} \\
&\quad + (1 - \mu) \cdot \int d\tilde{\xi}_{t-1} \int dq \cdot \Gamma_{t-1} \cdot \log\left(\frac{F\left(\tilde{\xi}_{t-1}e^{-g_t}, q, g_t\right)}{\tilde{\xi}_{t-1}}\right) \tag{20} \\
&\quad + \mu \cdot \left(\int d\Omega_q \cdot \log F\left(\infty, q, g_t\right) - \int d\tilde{\xi}_{t-1} \int dq \cdot \Gamma_{t-1} \cdot \log\tilde{\xi}_{t-1}\right). \tag{21}
\end{aligned}
$$

4 factors drive inflation rate changes.

> (i) the money growth rate g_t
>
> (ii) the change in firm entry-exit rate (19): negative long-run effect
>
> (iii) the change in real prices for existing firms, (20): positive short-run effect
>
> (iv) the change in real prices due to firm entry, (21): negative long-run effect

(iii): If the prices are sticky and the number of marginal firms is not too large, real prices for existing firms tend to fall when $g_t > 0$. As g_t increases and moves away from g, the size of the fall in real prices increases, and yields the positive effect on consumption.

(ii): Note that, in a deterministic case, this is equal to $a = \mu \log q$. The monetary easing shock lowers μ_t, and, in turn, the growth rate of consumption.
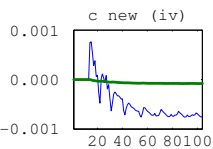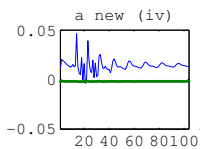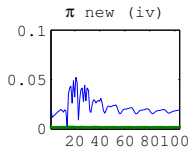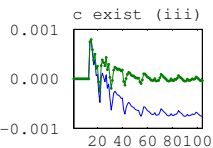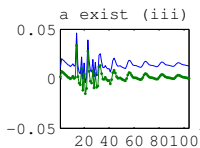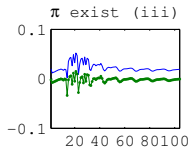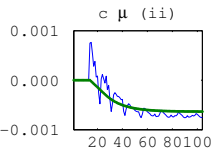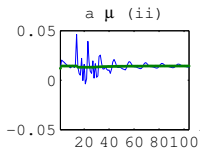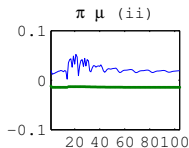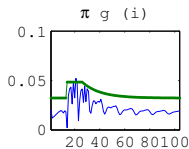
Direction of Future Research

- Should be improved to match actual price data, namely, the frequency of price changes, the size of price changes, the rate of product substitution, and the size of price changes when products are substituted.
- Firm dynamics and the reallocation efficiency on growth paths.
  - ▶ Because a monetary shock has different impacts on incumbents and potential entrants in this model, monetary policy may affect firm size distribution and the decomposition of real growth if we allow firms to have multiple product lines as in Klette and Kortum (2004) and Lentz and Mortensen (2008).

Thank you!