Optimal Trend Inflation

Klaus Adam
University of Mannheim

Henning Weber
Deutsche Bundesbank

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Introduction

- Add firm heterogeneity to otherwise standard sticky price economy
- Key conclusions regarding optimal inflation rate change discontinously
  - optimal steady state inflation different from zero
  - inflation optimally responds to productivity disturbances

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- Firm side microdynamics display **systematic trends**:
  - firm life cycle: start small/unproductive, become productive, exit
  - product life cycle: new products, higher quality, initially higher price

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  - firm life cycle: start small/unproductive, become productive, exit
  - product life cycle: new products, higher quality, initially higher price
- Taking into account firm-level trends
  $\Longrightarrow$ discontinously affects optimal inflation
  & rationalizes positive steady state inflation

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  abstracts from firm level heterogeneity, except for price heterogeneity

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  Strong economic implications: zero inflation optimal

- Productivity of price adjusting firms equal to productivity of non-adjusting firms

- Adjusting firms' price = price of non-adjusting firms

  $\Longrightarrow$ strong force towards zero inflation

  Woodford(2003), Kahn, King & Wolman(2003), Schmitt-Grohé & Uribe(2010)

Introduction

- Golosov&Lucas (2007), Nakamura&Steinsson (2010)

  idiosyncratic firm level productivity $\Leftrightarrow$ without systematic trend

- Do not look at optimal inflation

- Their results suggests zero inflation optimal:
  av. prod. of adjusting firm $\approx$ av. prod. of non-adjusting firm

Introduction

Add firm life cycle to basic homogeneous firm setup:

- Firm entry & exit
- Measure δ of randomly selected firms:
  very negative productivity shock $\Rightarrow$ exit
- Exiting firms replaced by same measure of newly entering firms
- Alternative interpretations of setup possible: product/quality life cycle

Introduction

Firm-level productivity trends driven by 3 underlying trends:

- **aggregate trend**: productivity gains experienced by all firms
- **experience trend:** firms become more productive over time
- **cohort trend:** productivity level for new cohort of firms

Introduction

- Production function of firm $j \in [0, 1]$:

$$Y_{jt} = A_t Q_{t-s_{jt}} G_{jt} \left(K_{jt}^{1-\frac{1}{\phi}} L_{jt}^{\frac{1}{\phi}} - F_t \right),$$

where s_{jt} is firm age

$$\begin{aligned} A_t &= a_t A_{t-1}, \\ Q_t &= q_t Q_{t-1}, \\ G_{jt} &= \begin{cases} 1 & \text{if } s_{jt} = 0, \\ g_t G_{jt-1} & \text{otherwise.} \end{cases} \end{aligned}$$

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  (a_t, q_t, g_t) arbitrary stationary process w mean $\mathbf{a}, \mathbf{q}, \mathbf{g}$

- Three productivity trends: $\mathbf{a}$, $\mathbf{q}$ and $\mathbf{g}$
- Measure δ of firms: productivity drops to zero & exit
- Special cases w/o firm level trends: $\delta = 0$ or if $\mathbf{q}_t \equiv \mathbf{g}_t$

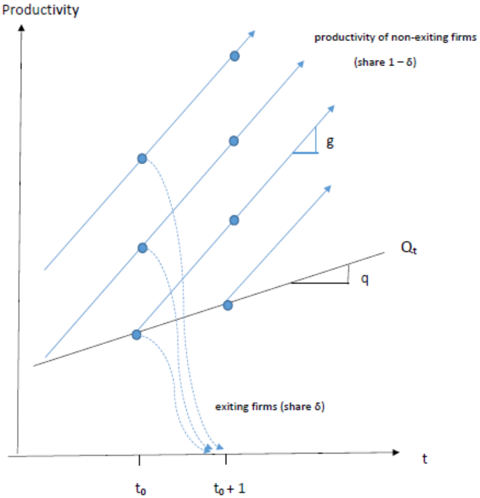

Figure: Productivity dynamics in a setting with firm entry and exit

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- **Strength of effect independent of turnover rate** $\delta > 0$

  Discontinous jump of optimal inflation: $\delta = 0 \;\; \rightarrow \delta > 0$

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- Optimal inflation

- cannot be inferred from aggregate productivity trends

- has to know firm level trends & shocks to these trends

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  - cannot be inferred from aggregate productivity trends

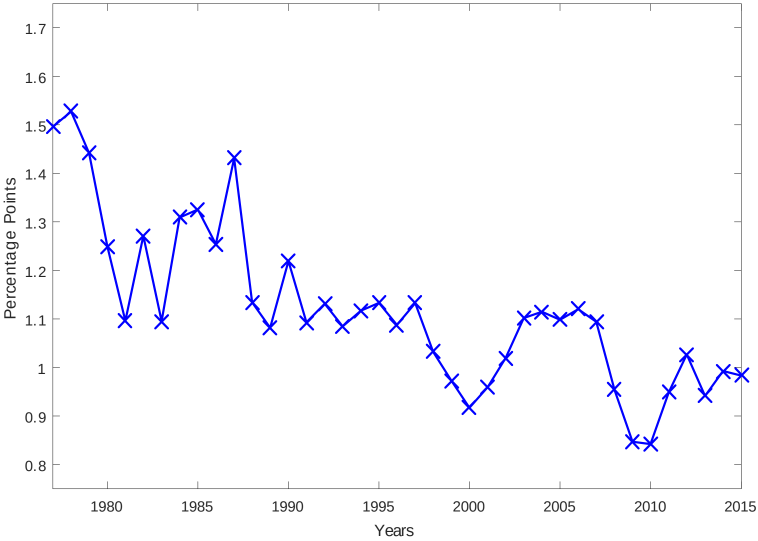
  - has to know firm level trends & shocks to these trends

- For $\delta = 0$: optimal inflation $\Pi^* = 1$.

Introduction

- What is the optimal inflation rate of the US economy?
- Use establishment-level data from Business Dynamics Statistics (US Census Bureau): all private U.S. establishments 1977-2015.
- Estimate historically optimal inflation path for the U.S. economy in model-consistent way

Historically Optimal U.S. Inflation: Baseline Estimation



Related Literature

- Few papers: inflation $\Leftrightarrow$ productivity dynamics
- The ones with SS implications find negative inflation rates optimal:
  - Wolman (JMCB, 2011): two sector economy with different sectorial productivity trends and different degree of price stickiness, homogeneous firms in each sector, neg. inflation optimal despite monetary frictions being absent
  - Amano, Murchison & Rennison (JME, 2009): homogeneous firm model with sticky prices and wages & aggregate growth; wages more sticky than prices; to depress wage-markups deflation turns out optimal.
- Aoki (JME 2001): sticky price & flex price sector, inflation following asymmetric productivity shocks in both sectors, no SS inflation

Related Literature

- Zero inflation approx. optimal in models w homogeneous firms Woodford (2003), Kahn, King & Wolman (2003), Schmitt-Grohé and Uribe (2010)
- Zero lower bound cannot justify positive average rates of inflation: Adam & Billi (2006), Coibion, Gorodnichenko & Wieland (2012)
- Brunnermeier and Sannikov (2016): idiosyncratic risk -> positive inflation increasingly optimal
- Downward nominal wage rigidity may justify positive inflation rates Kim & Ruge-Murcia (2009), Benigno & Ricci (2011), Schmitt-Grohe & Uribe (2013), Carlsson & Westermark (2016)
- Positive inflation possibly optimal in models with endogenous entry: Corsetti & Bergin (2008), Bilbiie, Ghironi & Melitz (2008), Bilbiie, Fujiwara & Ghironi (2014)

Outline of Remaining Talk

1. **Sticky price model with δ-shocks (death-shocks)**
2. Aggregation & efficient allocation
3. Optimal inflation: main result
4. Optimal inflation for the U.S. economy

Sticky Price Model

- Calvo price stickiness with parameter α

  (theoretical results extend to menu cost setting)
- Continuum of sticky price firms, Dixit-Stiglitz aggregate Y_t
- Random sample δ receives δ-shocks
- Firm productivity dynamics as described before
- Competitive labor and capital markets

Sticky Price Model

- Household problem

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \xi_t \left(\frac{\left[C_t V(L_t)\right]^{1-\sigma} - 1}{1-\sigma} \right)$$

$$s.t.$$

$$C_t + K_{t+1} + \frac{B_t}{P_t} =$$

$$(r_t + 1 - d) K_t + \frac{W_t}{P_t} L_t + \int_0^1 \frac{\Theta_{jt}}{P_t} \, \mathrm{dj} + \frac{B_{t-1}}{P_t}(1 + i_{t-1}) - T_t$$

- Existence of balanced growth path:

$$\beta < (aq)^{\phi\sigma} \quad and \quad (1-\delta)\,(g/q)^{\theta-1} < 1$$

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Aggregation

- Will spare you the derivation behind the results...
- Highlight key differences relative to homogeneous firm setup
- Abstract from price indexation in the presentation

Aggregate Output, Capital & Labor

- Aggregate output Y_t :

$$Y_t = \frac{A_t Q_t}{\Delta_t} \left(K_t^{1-\frac{1}{\phi}} L_t^{\frac{1}{\phi}} - F_t \right),$$

with K_t, L_t aggregate capital, labor and $F_t \geq 0$ fixed costs

- Δ_t: captures joint distribution of prices **&** productivities:

$$\Delta_t = \int_0^1 \left(\frac{Q_t}{G_{jt} Q_{t-s_{jt}}} \right) \left(\frac{P_{jt}}{P_t} \right)^{-\theta} dj \tag{1}$$

Price Level

- Price level: exp.-weighted average of product prices

$$
\begin{aligned}
P_t &= \left(\int_0^1 (P_{jt})^{1-\theta} \, \mathrm{dj} \right)^{\frac{1}{1-\theta}} \\
&= \int_0^1 \left(\frac{Y_{jt}}{Y_t} \right) P_{jt} \, \mathrm{dj}
\end{aligned}
$$

Price level accounts for prod. substitution (as statistical agencies do)

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  Price level accounts for prod. substitution (as statistical agencies do)

- Inflation:

$$\Pi_t = P_t / P_{t-1}.$$

Aggregate Price Level Dynamics

Evolution of the aggregate price under opt. price setting:

$$P_t^{1-\theta} = (\underbrace{\delta}_{\text{new firms}} + \underbrace{(1-\alpha)(1-\delta)}_{\text{old adj.firms}} \underbrace{\frac{(p_t^n)^{\theta-1} - \delta}{1-\delta}}_{\text{rel. price factor}}) \underbrace{P_{t,t}^{\star}}_{\text{opt price new firm}}{}^{1-\theta} + \underbrace{\alpha(1-\delta)}_{\text{old firms, w/o adj.}} P_{t-1}{}^{1-\theta}$$

$$(p_t^n)^{\theta-1} = \delta + (1-\delta)\left(p_{t-1}^n \frac{g_t}{q_t}\right)^{\theta-1}.$$

Aggregate Price Level Dynamics

$g_t \equiv q_t \implies$ no firm level trends and $(p_t^n)^{\theta-1} \to 1$ and

$$P_t^{1-\theta} = (\delta + (1-\alpha)(1-\delta))(P_{t,t}^{\star})^{1-\theta} + \alpha(1-\delta)(P_{t-1})^{1-\theta}$$

If - in addition - $\delta = 0$:

$$P_t^{1-\theta} = (1-\alpha)(P_{t,t}^{\star})^{1-\theta} + \alpha(P_{t-1})^{1-\theta}$$

Standard price evolution equation in homogeneous firm models.

Conditions Insuring Efficiency

- Attaining efficiency requires

  - eliminating firm's monopoly power by an output subsidy

  - choosing Δ_t in the production function

$$Y_t = \frac{A_t Q_t}{\Delta_t} \left(K_t^{1-\frac{1}{\phi}} L_t^{\frac{1}{\phi}} - F_t \right),$$

  equal to

$$\Delta_t = \Delta_t^e = \left(\int_0^1 \left(\frac{Q_t}{G_{jt} Q_{t-s_{jt}}} \right)^{1-\theta} \mathrm{dj} \right)^{\frac{1}{1-\theta}}$$

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- $\Delta_t = \Delta_t^e$ decentralized by prices satisfying

$$P_{jt} \propto \frac{1}{G_{jt} Q_{t-s_{jt}}}$$

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Efficiency under Sticky Prices

- **Proposition:** Suppose there is an appropriate output subsidy and initial prices in $t = -1$ reflect firms' relative productivities. The eq. allocation under sticky prices is efficient if

$$\Pi_t^\star = \left(\frac{1}{\delta \left(rp_t \right)^{\theta - 1} + (1 - \delta)} \right)^{\frac{1}{\theta - 1}}$$

where rp_t is the **relative productivity between new and old firms:**

$$rp_t \equiv \frac{A_t Q_t}{a_t g_t \frac{A_{t-1} Q_{t-1}}{\Delta_{t-1}^e}}.$$

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- With homogeneous firms $(rp_t \equiv 1 \text{ or } \delta = 0)$:

$$\Pi_t^\star \equiv 1.$$

Familiar result: price stability optimal at all times.

Efficiency under Sticky Prices

- Consider setting **with firm level trends** ($rp_t \neq 1$ and $\delta > 0$)

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- Steady state inflation ($g_t \equiv g$, $q_t \equiv q$) is

$$\lim \Pi_t^* = \frac{g}{q}$$

SS inflation *positive* when $g > q$

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$$\lim \Pi_t^* = \frac{g}{q}$$

  SS inflation *positive* when $g > q$

- SS independent of turnover rate $\delta > 0$:

  - fewer unproductive firms enter $\longrightarrow$ lower inflation

  - existing firms accumulate experience for longer $\longrightarrow$ higher inflation

Efficiency under Sticky Prices

- Derived optimal nonlinear inflation dynamics, but linearization still instructive:

$$\pi_t^\star = (1-\delta)\pi_{t-1}^\star + \delta\left(\frac{g_t}{q_t} - 1\right) + O(2)$$

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- Positive experience shock (g_t): persistent rise in opt. inflation
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The Optimal U.S. Inflation Rate

- Quantify **historically optimal inflation path** Π_t^* for U.S. economy
- Allow for arbitrary historical stochastic disturbances and potentially sub-optimal historical inflation rates Π_t

The Optimal U.S. Inflation Rate

- Theoretical result showing how to recover Π_t^* given
  - values for (α, δ, θ)
  - the observed historical inflation rate Π_t
  - the ratio $\overline{L}_t^c / \overline{L}_t$, where

    $\overline{L}_t$ average employment per establishment in t
    $\overline{L}_t^c$ average employment of continuing establishments in t
- Data for $\overline{L}_t^c / \overline{L}$ taken from the Business Dynamic Statistics

The Optimal U.S. Inflation Rate

Proposition: Suppose an efficient output subsidy, initial prices reflect relative productivities, and no fixed costs in production ($F_t \equiv 0$). The optimal inflation rate $\Pi_t^\star$ then satisfies

$$\left(\frac{\Delta_t}{\Delta_t^e}\right)^{-1}\left(\frac{1-\alpha(1-\delta)\left(\Pi_t\right)^{\theta-1}}{1-\alpha(1-\delta)\left(\Pi_t^\star\right)^{\theta-1}}\right)^{\frac{\theta}{\theta-1}} = \frac{1-(1-\delta)\overline{L}_t^c/\overline{L}_t}{1-(1-\delta)(\Pi_t^\star)^{\theta-1}} \quad \text{for } t \geq 0, \tag{2}$$

where Δ_t/Δ_t^e evolves recursively according to

$$\frac{\Delta_t}{\Delta_t^e} = \left[1-\alpha(1-\delta)\left(\Pi_t^\star\right)^{\theta-1}\right]\left(\frac{1-\alpha(1-\delta)\left(\Pi_t\right)^{\theta-1}}{1-\alpha(1-\delta)\left(\Pi_t^\star\right)^{\theta-1}}\right)^{\frac{\theta}{\theta-1}} + \alpha(1-\delta)\left(\frac{\left(\Pi_t\right)^{\theta}}{\Pi_t^\star}\right)\frac{\Delta_{t-1}}{\Delta_{t-1}^e},$$

with $\Delta_{-1}/\Delta_{-1}^e = 1$.

- Special case with historically optimal inflation ($\Pi_t = \Pi_t^*$)....

The Optimal U.S. Inflation Rate

- Special case with historically optimal inflation ($\Pi_t = \Pi_t^*$):

$$\Pi_t^\star = \left(\frac{\overline{L}_t^c}{\overline{L}_t} \right)^{\frac{1}{\theta - 1}}$$

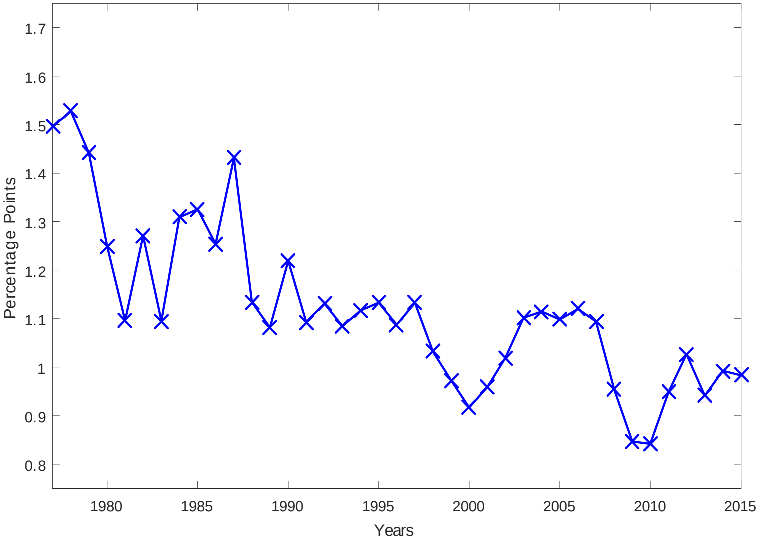
- Relative firm size determines optimal inflation!
- Related firm size: a measure of relative productivities given demand elasticity θ

The Optimal U.S. Inflation Rate

- Baseline parameters (annual model, BDS data annual):

Parameter		Assigned value
Price stickiness	α	0.0915
δ-shock probability	δ	11.5%
Demand elasticity	θ	7

The Optimal U.S. Inflation Rate



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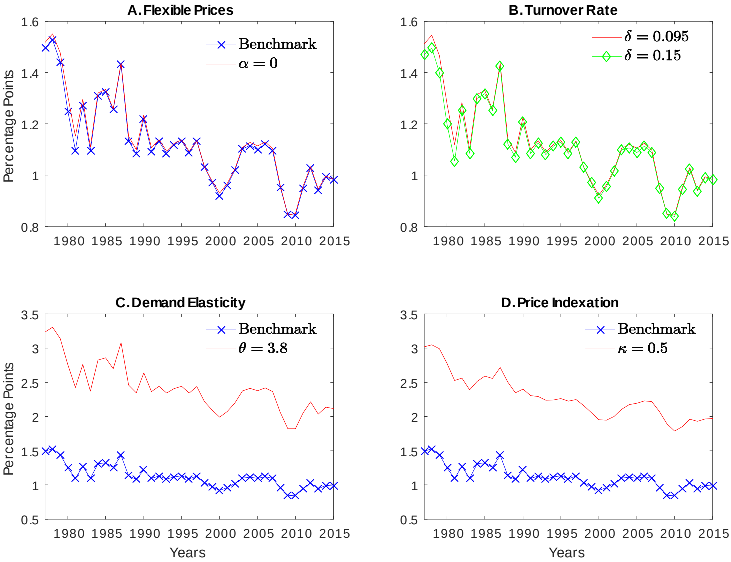

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- Firm level productivity trends key for optimal inflation rate in sticky price models
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- Productivity disturbances have persistent effects on optimal inflation
- Optimal US inflation: dropped from approx 1.5% in 1977 to 1.0% in 2015
- Lower demand elasticities/price indexation: optimal inflation rates double

The Welfare Costs of Strict Price Stability

- Suppose MP implements $\Pi = 1$ in an economy where $\Pi^{\star} \neq 1$
- Analytical result: strictly positive welfare costs even in the limit $\delta \longrightarrow 0$
- Numerical illustration highlighting the source of welfare distortions

The Welfare Costs of Strict Price Stability

Assumptions for the analytical result:

- there is an optimal output subsidy and initial prices reflect initial productivities
- there are no aggregate productivity disturbances and $\delta > 0$
- fixed costs of production are zero ($f = 0$)
- disutility of work is given by

$$V(L) = 1 - \psi L^{\nu}, \text{ with } \nu > 1, \psi > 0.$$

- $g/q > \alpha(1 - \delta)$, so that a well-defined steady state with strict price stability exists
- consider the limit $\beta(\gamma^{e})^{1-\sigma} \to 1$

The Welfare Costs of Strict Price Stability

Proposition: Consider a policy implementing the optimal inflation rate $\Pi_t^\star$, which satisfies $\lim_{t\to\infty} \Pi_t^\star = \Pi^\star = g/q$. Let $c(\Pi^\star)$ and $L(\Pi^\star)$ denote the limit outcomes for $t \to \infty$ for consumption and hours under this policy. Similarly, let $c(1)$ and $L(1)$ denote the limit outcomes under the alternative policy of implementing strict price stability. Then,

$$L(1) = L(\Pi^\star)$$

and

$$\frac{c(1)}{c(\Pi^\star)} = \left(\frac{1-\alpha(1-\delta)(g/q)^{\theta-1}}{1-\alpha(1-\delta)}\right)^{\frac{\phi\theta}{\theta-1}} \left(\frac{1-\alpha(1-\delta)\left(g/q\right)^{-1}}{1-\alpha(1-\delta)(g/q)^{\theta-1}}\right)^{\phi} \leq 1. \tag{3}$$

For $g \neq q$ the previous inequality is strict and

$$\lim_{\delta\to 0} c(1)/c(\Pi^\star) < 1$$

.

The Welfare Costs of Strict Price Stability

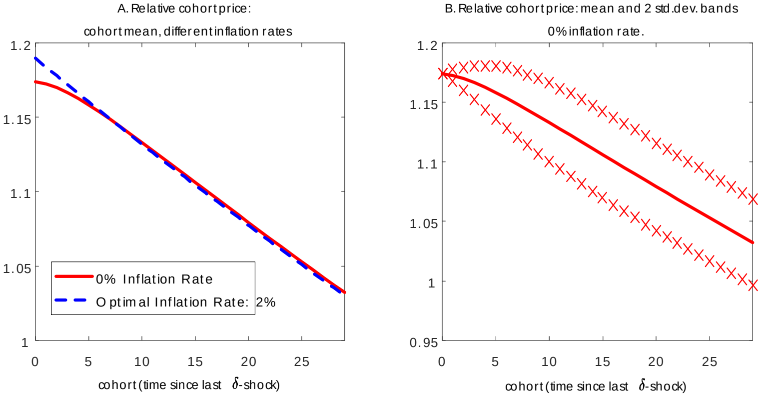

Figure: Relative prices and inflation

The Welfare Costs of Strict Price Stability

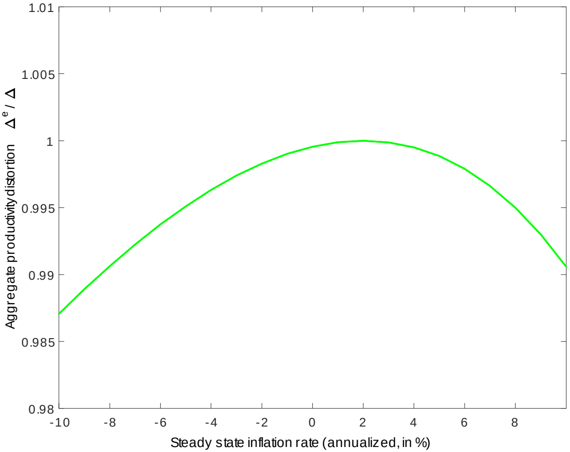

Figure: Aggregate productivity as a function of gross steady state inflation (optimal inflation rate is 1.02)