Reallocation Effects of Monetary Policy

Koki Oikawa    Kozo Ueda

Waseda University

June, 2018

CIGS Conference on Macroeconomic Theory and Policy
Introduction

Motivating Facts

Model

Impacts of MP

Simulation
Introduction

- There exist sizable and persistent heterogeneity among firms. (e.g. survey by Syverson, 2011)
  - productivity dispersion
  - innovating firms and no-R&D firms
  - heavy-tailed firm size distribution
- Misallocation and reallocation (e.g. Hsieh and Klenow, 2009)
  - Zombie firms and secular stagnation in Japan. (Cabarello, Hoshi and Kashyap, 2008)
- Reallocation and growth (Lentz and Mortensen, 2008)
  - From decomposition of aggregate growth, the selection effect accounts for about 50% of aggregate productivity growth in Denmark.
- Many of previous papers in this strand only consider the real aspect of the economy.
This Study: How about the Nominal Aspect?

- The role of monetary policy in firm reallocation
  - between good and bad firms
  - between small and large firms
  - What kind of monetary policy (e.g. inflation target) improves economic growth and welfare?

- The optimal inflation rate.

To this aim, we combine

- Endogenous growth with firm dynamics (Klette and Kortum, 2004; Lentz and Mortensen, 2005, 2008)
- Nominal rigidity à la menu cost.
Main Results

- In Japan, large firms tend to grow faster than small firms under inflation.

- In the model, inflation reallocates resources from inferior to superior firms. If this reallocation effect is sufficiently strong, positive nominal growth improves both real growth and welfare.

- The optimal nominal growth rate can be strictly positive if the reallocation effect is strong.

- Nominal rigidity can improve welfare.
Related Literature


Introduction

Motivating Facts

Model

Impacts of MP

Simulation
Cross-country relation b/w inflation and firm distribution

- No direct study about relation b/w inflation and firm distribution.
- But in less developed countries (i.e., higher inflation), big firms account for a larger share. (Bartelsman et al, 2004; Alfaro et al, 2009; Poschke, 2017)

(from Alfaro et al, 2009)
Inflation and Firm Size Distribution in Japan

- Relationship between inflation and firm size distribution using Japanese firm-level data.

- Firm size dispersion in sales and employment,
  - Top-Middle ratio: 90 percentile/50 percentile
  - Top-Bottom ratio: 90 percentile/10 percentile

- Inflation: PPI input (average of the previous two years) by 14 industries in the manufacturing sector.

- Control: D.I. (financing) from Tankan, industry-level real sales, industry and year FEs.

- IV: inflation in international commodity price.
# Inflation and Reallocation: Sales

<table>
<thead>
<tr>
<th></th>
<th>Top/Middle ratio</th>
<th>Top/Bottom ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)  OLS</td>
<td>(4) OLS</td>
</tr>
<tr>
<td></td>
<td>(2)  OLS</td>
<td>(5) OLS</td>
</tr>
<tr>
<td></td>
<td>(3)  2SLS</td>
<td>(6)  2SLS</td>
</tr>
<tr>
<td><strong>π</strong> input</td>
<td><strong>100.6</strong>* (20.16)</td>
<td><strong>282.7</strong>* (63.48)</td>
</tr>
<tr>
<td></td>
<td><strong>102.7</strong>* (20.58)</td>
<td><strong>289.0</strong>* (64.53)</td>
</tr>
<tr>
<td></td>
<td><strong>194.6</strong>* (27.73)</td>
<td><strong>620.5</strong>* (87.52)</td>
</tr>
<tr>
<td>D.I. gap (T/M or T/B)</td>
<td>-0.0454 (0.18)</td>
<td>-0.134 (0.49)</td>
</tr>
<tr>
<td></td>
<td>0.135 (0.18)</td>
<td>0.365 (0.53)</td>
</tr>
<tr>
<td>D.I.</td>
<td>-0.358 (0.22)</td>
<td>-1.220* (0.70)</td>
</tr>
<tr>
<td></td>
<td>-0.547** (0.23)</td>
<td>-1.876** (0.73)</td>
</tr>
<tr>
<td>Industry RS</td>
<td>2.168 (5.69)</td>
<td>17.9800 (17.00)</td>
</tr>
<tr>
<td></td>
<td>3.437 (6.08)</td>
<td>104.8 (226.40)</td>
</tr>
<tr>
<td></td>
<td>-6.377 (17.85)</td>
<td>106.2000 (244.40)</td>
</tr>
<tr>
<td>Constant</td>
<td>4.591 (5.40)</td>
<td>17.9800 (17.00)</td>
</tr>
<tr>
<td></td>
<td>-20.99 (72.16)</td>
<td>104.8 (226.40)</td>
</tr>
<tr>
<td></td>
<td>-33.84 (77.19)</td>
<td>106.2000 (244.40)</td>
</tr>
<tr>
<td>Year/Industry FE</td>
<td>yes/yes</td>
<td>yes/yes</td>
</tr>
<tr>
<td>Obs.</td>
<td>322</td>
<td>322</td>
</tr>
<tr>
<td></td>
<td>316</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td>302</td>
<td>302</td>
</tr>
<tr>
<td>R²</td>
<td>0.509</td>
<td>0.679</td>
</tr>
<tr>
<td></td>
<td>0.507</td>
<td>0.679</td>
</tr>
<tr>
<td></td>
<td>0.483</td>
<td>0.653</td>
</tr>
<tr>
<td>Underidentification</td>
<td>164.1</td>
<td>165.4</td>
</tr>
<tr>
<td>Weak identification</td>
<td>22.97</td>
<td>23.37</td>
</tr>
</tbody>
</table>

Notes: *p < 0.1, **p < 0.05, ***p < 0.01
### Inflation and Reallocation: Employment

<table>
<thead>
<tr>
<th></th>
<th>Top/Middle ratio</th>
<th>Top/Bottom ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) OLS</td>
<td>(2) OLS</td>
</tr>
<tr>
<td>$\bar{\pi}^\text{input}$</td>
<td>3.484***</td>
<td>3.343***</td>
</tr>
<tr>
<td></td>
<td>(1.027)</td>
<td>(0.992)</td>
</tr>
<tr>
<td>D.I. gap (T/M or T/B)</td>
<td>-0.0215***</td>
<td>-0.0116</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>D.I.</td>
<td>-0.0245**</td>
<td>-0.0279***</td>
</tr>
<tr>
<td>Industry RS</td>
<td>1.097***</td>
<td>1.290***</td>
</tr>
<tr>
<td></td>
<td>(0.273)</td>
<td>(0.284)</td>
</tr>
<tr>
<td>Constant</td>
<td>4.510***</td>
<td>-9.090***</td>
</tr>
<tr>
<td></td>
<td>(0.275)</td>
<td>(3.455)</td>
</tr>
<tr>
<td>Year/Industry FE</td>
<td>yes/yes</td>
<td>yes/yes</td>
</tr>
<tr>
<td>Obs.</td>
<td>322</td>
<td>316</td>
</tr>
<tr>
<td>$\bar{R}^2$</td>
<td>0.7</td>
<td>0.729</td>
</tr>
<tr>
<td>Underidentification</td>
<td>163.7</td>
<td></td>
</tr>
<tr>
<td>Weak identification</td>
<td>22.84</td>
<td></td>
</tr>
</tbody>
</table>

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Firm Size and Growth under Inflation

- Divide firm size distribution into 10 deciles (size groups: 1, 2, ..., 10) and take the average growth rates of real sales and employment within size groups.

- Check the cross effect: inflation \( \times \) size group index
## Introduction

Motivating Facts

Model

Impacts of MP

Simulation

<table>
<thead>
<tr>
<th></th>
<th>Sales growth</th>
<th>Employment growth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1) OLS</td>
<td>(2) OLS</td>
</tr>
<tr>
<td>$\bar{\pi}^{\text{input}}$</td>
<td>-0.592***</td>
<td>-0.628***</td>
</tr>
<tr>
<td></td>
<td>(0.0792)</td>
<td>(0.0797)</td>
</tr>
<tr>
<td>Size group</td>
<td>-0.00687***</td>
<td>-0.00838***</td>
</tr>
<tr>
<td></td>
<td>(0.0007)</td>
<td>(0.0008)</td>
</tr>
<tr>
<td>$\bar{\pi}^{\text{input}} \times \text{Size group}$</td>
<td><strong>0.0524</strong>*</td>
<td><strong>0.0570</strong>*</td>
</tr>
<tr>
<td></td>
<td>(0.0118)</td>
<td>(0.0118)</td>
</tr>
<tr>
<td>Average D.I.</td>
<td>0.00156***</td>
<td>0.00155***</td>
</tr>
<tr>
<td></td>
<td>(0.0004)</td>
<td>(0.0004)</td>
</tr>
<tr>
<td>Industry RS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0024)</td>
<td>(0.0024)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.0881***</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>(0.0125)</td>
<td>(0.1830)</td>
</tr>
<tr>
<td>Year/Industry FE</td>
<td>yes/yes</td>
<td>yes/yes</td>
</tr>
<tr>
<td>Obs.</td>
<td>2940</td>
<td>2880</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.179</td>
<td>0.181</td>
</tr>
<tr>
<td>Underidentification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak identification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Introduction

Motivating Facts

Model

Impacts of MP

Simulation
Model Ingredients

- Endogenous growth with firm heterogeneity (Lentz and Mortensen, 2005, 2008)
  - Multi-product firms
  - Creative destruction. Innovation ability (size of quality update) is ex ante heterogeneous.

- Menu cost (Oikawa and Ueda, 2015ab)
  - Because inflation/deflation reduces real firm values under nominal rigidity, monetary policy affects innovation incentives and real growth.
**Model**

- Households; Firms with different innovation ability \( q \); Central bank
  - Firms: entrants and incumbents
  - A firm draws \( q \) at entry. Once drawn, \( q \) does not change.

- Focus on a balanced growth path.
  - \( n \): nominal growth rate. We focus on \( n \geq 0 \). ← exogenous
  - \( g \): real growth rate ← endogenous
  - \( \delta \): creative destruction rate ← endogenous

**Note:**
- \( n \) is equivalent to the quality-unadjusted inflation rate;
- \( \pi = n - g \) is the quality-adjusted inflation rate.
Household

- Household consumes version $a \in \{0, 1, \ldots, A_t(j)\}$ of final goods $j \in [0, 1]$ whose qualities are $Q(j, a)$. The welfare of the representative household is

$$U_t = \int_t^\infty e^{-\rho(t'-t)} \log C_{t'} \, dt',$$

$$\log C_t = \int_0^1 \log \left[ \sum_{a=0}^{A_t(j)} Q(j, a) x_t(j, a) \right] \, dj,$$

- Quality evolves as

$$Q(j, a) = \prod_{a'=0}^{a} q(j, a'), \quad q(j, a') > 1 \quad \forall j, a'$$

- Inelastic labor supply.
Incumbent Firms and Creative Destruction

Incumbents produce multiple products for which they compete through innovation (quality updates).
Incumbents’ Decision

1. Pricing under menu cost
   • Find the optimal Ss rule to maximize the value of a product line.

2. R&D investment
   • To maximize firm value (bundle of product lines).
Ss-pricing and Product Line Value

- Fix $q > 1$.
- Linear one-to-one production from labor. Bertrand competition in each product line.
- Posted price: $p_t$. Relative price: $\xi_t \equiv p_t e^{-nt}$.
- Menu cost: $\kappa E_t / P_t$, where $\kappa > 0$. Entrants must pay at entry.
- We write $E_0 \equiv E$, $P_0 \equiv P$, $W_0 \equiv W$.

($E_t$: nominal expenditure; $P_t$: general price; $W_t$: nominal wage)

Then,
- The optimal pricing follows an Ss-rule.
- The upper bound of $\xi$ is the limit price, $qW$.
• Higher nominal growth $\rightarrow$ relative price is going down more rapidly $\rightarrow$ higher frequency of price reset $\rightarrow$ lower product line value.
The damage from $n \uparrow$ is relatively small for high-$q$ firms

- Let $\nu_\tau(q|\delta, n)$ be the value of product line with elapsed time of $\tau$ from the previous price reset.

**Proposition**

If $\nu_0 > 0$, $\nu_0(q|\delta, n)$ is increasing in $q$ and decreasing in $n$. Moreover,

$$\frac{\partial^2 \nu_0(q|\delta, n)}{\partial q \partial n} > 0.$$ 

- The loss caused by faster nominal growth (high inflation) is relatively small for more creative firms (high $q$).
- The cross impact occurs because the cost of price reset is independent of $q$ while the return of price reset is increasing in $q$. 
Let $q(\delta, n)$ be the threshold below which $\nu_0 < 0$.

**Proposition**

If $\kappa < (\rho + \delta)^{-1}$, then $q(\delta, n)$ uniquely exists and is increasing in $n$.

- Under greater $n$, less creative firms cannot survive.
- One of the main sources of reallocation effect.
Firm Value and Incumbents’ R&D (1/4)

- The probability of success in R&D is $k\gamma$, where $k$ is the number of product lines and $\gamma$ is R&D intensity.
  - This property is often assumed to have Gibrat’s law: The growth rate of firm is independent of firm size.

- Real R&D cost is $kwc(\gamma)$, where $c' > 0$, $c'' > 0$, $c(0) = 0$. ($w \equiv \frac{W}{E}$)
Firm Value and Incumbents’ R&D (2/4)

Bellman Equation

\[ \rho v_k(T_k, q|\delta, w, n) = \max_{\gamma} \sum_{i \notin \Omega} \left[ \pi^0(\xi_0 e^{-n\tau_i}) + \frac{\partial v_k(T'_k, q|\delta, w, n)}{\partial \tau_i} \right] \]

\[ + \sum_{i \in \Omega} \left[ \pi^0(\xi_0 e^{-n\tau_i}) - \kappa + \frac{\partial v_k(T'_k, q|\delta, w, n)}{\partial \tau_i} \right] \]

\[ - kwc(\gamma) + k\gamma \left[ v_{k+1}(\{T'_k, 0\}, q|\delta, w, n) - v_k(T'_k, q|\delta, w, n) \right] \]

\[ + k\delta \left[ \frac{1}{k} \sum_{i=1}^{k} v_{k-1}(T'_{k-1,<i>}, q|\delta, w, n) - v_k(T'_k, q|\delta, w, n) \right], \]

- \( T_k \equiv \{\tau_i\}_{i=1}^{k} \). \( T_{k-1,<i>} \) is the set of elapsed time of the firm when it exits from \( i \)-th product market.

- \( \Omega \equiv \{i|\tau_i = \Delta(q|\delta, n)\} \), the set of products whose prices are revised. \( T'_k \) is \( \{\tau'_i\}_{i=1}^{k} \) and

\[ \tau'_i = \begin{cases} \tau_i & \text{for } \tau_i \in [0, \Delta(q|\delta, n)), \\ 0 & \text{for } \tau_i = \Delta(q|\delta, n). \end{cases} \] (1)
Firm Value and Incumbents’ R&D (3/4)

The Maximized Firm Value

- Firm value:

\[ v_k(T_k, q|\delta, w, n) = \sum_{i=1}^{k} \nu_{\tau_i}(q|\delta, n) + k \psi(q|\delta, w, n) \]

future R&D return

- FOC about R&D intensity (\(\gamma\)):

\[ \nu_0(q|\delta, n) + \psi(q|\delta, w, n) = wc'(\gamma). \]
Firm Value and Incumbents’ R&D (4/4)
Heterogeneous impact of $n \uparrow$ on R&D

**Proposition**

Fix $n \geq 0$ and $\delta > 0$. $\gamma(q|\delta, w, n)$ uniquely exists for sufficiently large $w$. **Being well-defined, $\gamma(q|\delta, w, n)$ is increasing in $q$ and decreasing in $n$, $\delta$, and $w$. Moreover, for $n \neq 0$,**

$$\frac{\partial^2 \gamma(q|\delta, w, n)}{\partial q \partial n} > 0 \quad \text{and} \quad \frac{\partial^2 \gamma(q|\delta, w, n)}{\partial q \partial w} < 0.$$  

The decline in R&D intensity under higher $n$ is relatively small for firms with greater $q$. 
Impact of $n \uparrow$ on Distribution

Let $K(q|\delta, w, n)$ be the measure of product lines produced by type-$q$ firms.

- $q(\delta, n) \uparrow$. Low R&D quality firms exit.
- R&D intensity is less sensitive for firms with greater $q$.
  $\Rightarrow$ The product line share of firms with higher $q$ increases.
- The average quality improvement by each innovation is higher under greater $n$. 
A measure $h$ of potential entrants do R&D without knowing its $q$. Their types are drawn from density $\Phi(q)$ on $(1, \infty)$.

If an entrant draws $q < q(\delta, n)$, it gives up entry.

**Free entry condition (FE):**

$$\int_0^{\infty} \Phi(q) v_1(\{0\}, q|\delta, w, n) dq = wc' (\gamma_\eta(\delta, w, n)),$$

where $\gamma_\eta(\delta, w, n)$ is entrants’ R&D intensity to have the ex-post entry rate of $\eta$. 

Labor Market

- Relative price distribution for a product line with $q$: $f(\xi(\tau))$
- Labor demand from the production sector is

$$L_X = \int_{q(\delta,n)}^{\infty} K(q|\delta, w, n) \left[ \int_{0}^{\Delta(q|\delta,n)} f(\xi(\tau)) \frac{1}{\xi(\tau)} d\tau \right] dq$$

- Labor demands from the R&D sector:

$$L_R = hc(\gamma_{\eta}(n)) + \int_{q(\delta,n)}^{\infty} K(q|\delta, w, n)c(\gamma(q|\delta, w, n))dq$$

- The labor market clearing condition (LMC):

$$L = L_X + L_R$$
Stationary Equilibrium

Equilibrium conditions:

1. FE
2. LMC

Proposition

For given \( n \geq 0 \), there exists a stationary equilibrium with a positive entry rate.
• $\delta \uparrow \Rightarrow \eta \uparrow$ and $v_1 \downarrow$. To satisfy FE, $w \downarrow$ should compensate the decline of innovation reward.

• $\delta \uparrow \Rightarrow L_{R,entrant} \uparrow$, $L_{R,incumbent} \downarrow$, and $L_X \uparrow\downarrow (?)$. The total impact is ambiguous but LMC is basically upward-sloping under typical distributions.
Introduction

Motivating Facts

Model

Impacts of MP

Simulation
Impacts of \( n \uparrow \) on Real Growth

- Real growth effect:
  - \( n \uparrow \Rightarrow \) Average quality update \( \uparrow \).
  - \( n \uparrow \Rightarrow \delta \downarrow \) (\( \because \) R&D reward \( \downarrow \)).
  - The overall impact on real growth,
    
    \[
    \delta \times \int_{q(n,\delta)}^{\infty} K(q|\delta, w, n) \log q \, dq
    \]

    is ambiguous.

- Note: If \( \kappa = 0 \), the model conforms to Lentz-Mortensen. Firm distribution, real growth, and welfare are independent of \( n \).
Impacts of $n \uparrow$ on Welfare

\[ U = \frac{\log C}{\rho} + \frac{g}{\rho^2} \]
\[ C \propto \frac{1 - \text{menu costs}}{P} \]

- Consumption
  - Menu cost $\uparrow$ ($-$)
  - Markup $\uparrow\downarrow$ ($\pm$?)
- Real growth $\uparrow\downarrow$ ($\pm$?)
  - Spillover effect
  - Business-stealing effect: Innovators ignore what the previous producers lose. This negative externality is decreasing in $q$.
- The overall impact on welfare is ambiguous.
Optimal Inflation Rate

- Standard New Keynesian: \( n = 0 \) is the best.
- Oikawa and Ueda (2015a), w/o firm heterogeneity: \( n > 0 \) could be optimal if R&D is overinvested.
  - Chu and Cozzi (2014): the same mechanism to get out of the Friedman rule.

- With firm heterogeneity and reallocation, \( n > 0 \) improves welfare if the reallocation effect is sufficiently strong (even when R&D is underinvested).
Introduction

Motivating Facts

Model

Impacts of MP

Simulation
Simulation: Parameter Setting

Denmark Economy

- Menu cost: $\kappa = 0.022$ (Midrigan, 2011)
- We assume $\bar{\phi}(q) = \zeta q^{-\zeta-1}$ is Pareto.
  - Set $\zeta = 17.5$ to have the same variance as in the estimated distribution (a discrete distribution with three $q$’s) in Lentz and Mortensen (2008).
- Other parameters are set to be consistent with Lentz and Mortensen (2008) when $n = 0$.
  - $L = 1$.
  - R&D cost: $c_0 = 1.02 \cdot 10^5$, $c_1 = 3.728$ where $c(\gamma) = c_0 \gamma^{c_1}$.
  - $\rho = 0.0361$ to attain $g = 0.0139$ when $n = 0$.
  - Potential entrants: $h = 1.1667$. 
Impact of Nominal Growth

- $g, U$
- $\delta, \eta$
- $q$
- $k(q)$
- $k$
- $Lr$
- $Lx, w$
- menu cost

Graphs depicting the relationship between different variables with respect to $n$. The graphs show trends and changes in various economic indicators as nominal growth changes.
Firm size distribution and nominal growth in the model

Tail distributions of sales and employment. $n$ is the nominal growth rate.
Firm size distribution and nominal growth in the model

Sales and Employment dispersion

Sales (# of products) ratio

Employment ratio

Ratio of top 10% to median
Ratio of top 1% to median
Ratio of top 0.1% to median
Various Menu Cost Parameters

Changes in welfare under various $\kappa$.

$\kappa = 0$ means no nominal rigidity.
It reminds me a phrase in Keynes (1936)...

*It is sometimes said that it would be illogical for labour to resist a reduction of money-wages but not to resist a reduction of real wages. For reasons given below, this might not be so illogical as it appears at first; and, as we shall see later, fortunately so.*

*General Theory (Ch.2)*

—We might be fortunate to have nominal rigidity.
Growth Decomposition

The impact of $n$ on real growth can be decomposed into four components:

- Entry barrier effect ($n \uparrow \Rightarrow q \uparrow$)
- Entry/exit effect ($n \uparrow \Rightarrow$ entrants’ contribution $\downarrow$)
- Selection effect ($n \uparrow \Rightarrow$ product line share of high type $\uparrow$)
- Within effect ($n \uparrow \Rightarrow$ average growth without selection $\uparrow$)

\[
g(n) - g(0) = -\delta(0) \int_{q(0)}^{q(n)} K(q|0) \log q \, dq \\
+ \int_{q(n)}^{\infty} \{\eta(n)\phi(q|n) - \eta(0)\phi(q|0)\} \log q \, dq \\
+ \int_{q(n)}^{\infty} \left\{[K(q|n) - \phi(q|n)] \gamma(q|n) - [K(q|0) - \phi(q|0)] \gamma(q|0)\right\} \log q \, dq \\
+ \int_{q(n)}^{\infty} \{\phi(q|n)\gamma(q|n) - \phi(q|0)\gamma(q|0)\} \log q \, dq
\]
In the Danish economy, the selection effect is dominant especially under higher inflation.
Reallocation effects in Japanese Economy

- Murao and Nirei (2011) apply an extended model of Lentz and Mortensen (2008) to Japanese economy. We use their results to calibrate our model to Japanese economy.

- Parameters:
  - $\rho = 0.0385$
  - $c_1 = 1.923$; $h = 11.682$
  - Pareto coefficient of $\phi$: 4.821.
Concluding Remarks

- Larger firms tend to grow faster than small firms under inflation in Japan.

- We developed a model to analyze long-run effect of monetary policy (like trend inflation) in an endogenous growth model with nominal rigidity, firm heterogeneity, and reallocation.

- Positive nominal growth improves real economic growth and welfare if the reallocation effect is sufficiently large. Thus, the optimal inflation rate can be strictly positive.

- Inflation may improve welfare with nominal rigidity because it hinders R&D by firms whose quality updates are small.