Pricing Frictions and Innovation

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Disclaimers

Researcher(s) own analyses calculated (or derived) based in part on (i) retail measurement/consumer data from Nielsen Consumer LLC ("NielsenIQ"); (ii) media data from The Nielsen Company (US), LLC ("Nielsen"); and (iii) marketing databases provided through the respective NielsenIQ and the Nielsen Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ and Nielsen data are those of the researcher(s) and do not reflect the views of Nielsen. Nielsen is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

Introduction

- Prices can be distorted (not optimal) in the short run but are restored in the long run.
    - Menu cost; Calvo; Woodford (2003); Liu (2024)
- This paper shows that prices are *not* restored in the long run.
    - Nominal price of the average product is mostly unchanged; Real price declines with age.
- The nominal price index increases due to introduction of new products.
    - High price premium on new products – price overshooting
- Research questions:
    - What are the firms' pricing and innovation decisions when they have following conditions?
        1. Own multiple products.
        2. Not allowed to change price of the existing products
        3. Be able to innovate and set the price for new products
    - What are the macroeconomic implications of these decisions?
        1. Long-run growth rate
        2. Response of output and innovation to a monetary shock

Outline of Talk

1. Empirics
2. Model
3. Quantification
4. Conclusion

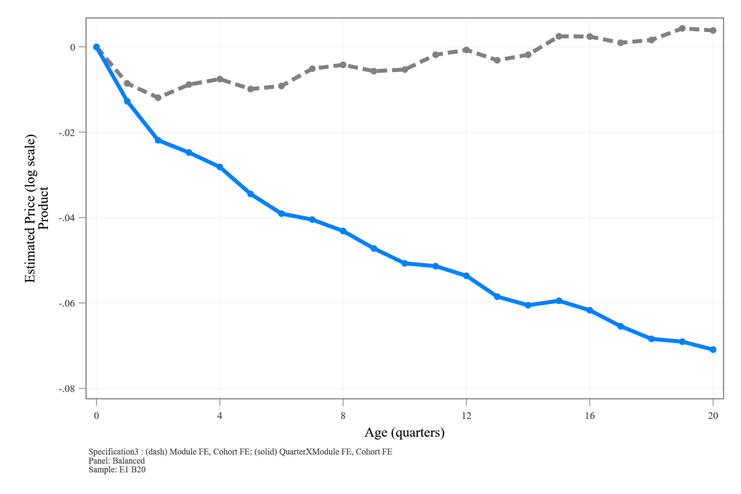
Empirics

Overview of empirical findings

- Long-run price distortion:
  - Nominal price of the average product is mostly unchanged. Real price declines with age.
  - Prices mostly decrease when approximating exit. The long-run price distortion is even worse.
- The role of innovation:
  - Aggregate price index goes up because of introduction of new products.
  - Firms introduce new products with prices above their existing products – “price-overshooting”.
- Firm heterogeneity:
  - Entrants charge higher price premium than incumbents, but their prices of existing products decline with age at similar rate.
  - Innovating firms charge higher price premium and their prices of existing products decline faster.
- Product Category heterogeneity:
  - Non-food categories charge higher price premium.
  - More innovative categories charge higher price premium. The prices of existing products decline faster

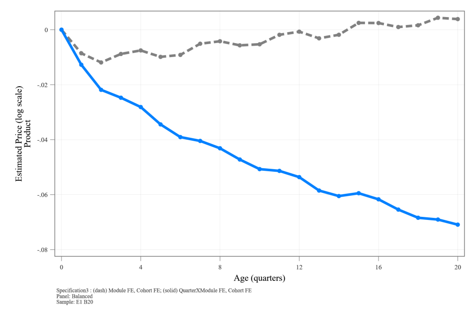
FACT 1: Prices of incumbent products

- Nominal price of the average product is mostly unchanged. Real price declines with age.

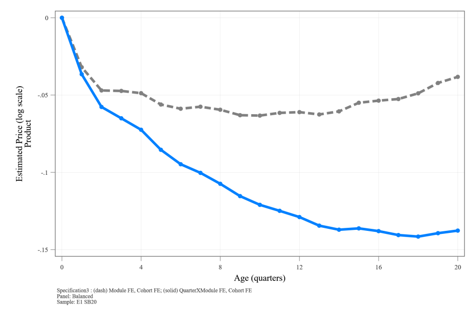


- Nominal price of the average product is mostly unchanged. Real price declines with age.
- Prices mostly decrease when approximating exit. The long-run price distortion is even worse.

Only surviving products

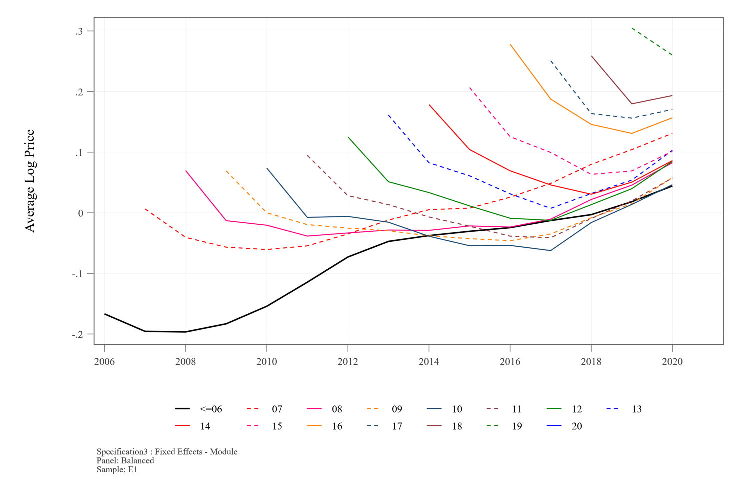


All products



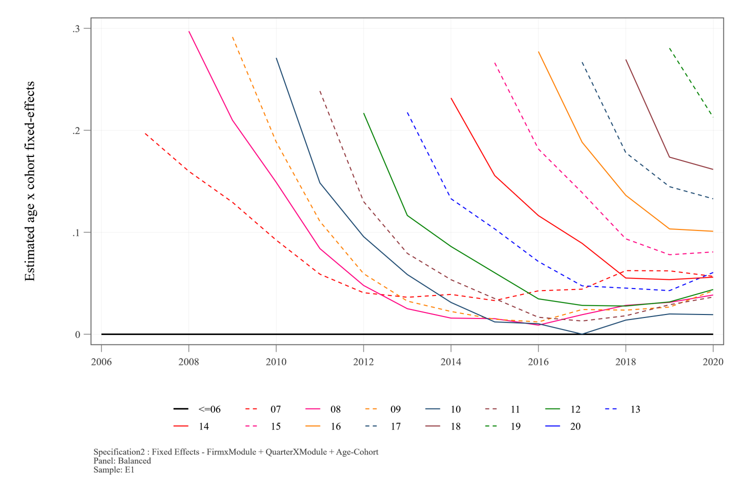
FACT 2: Role of Innovation

- Aggregate price index goes up because of introduction of **new products**.



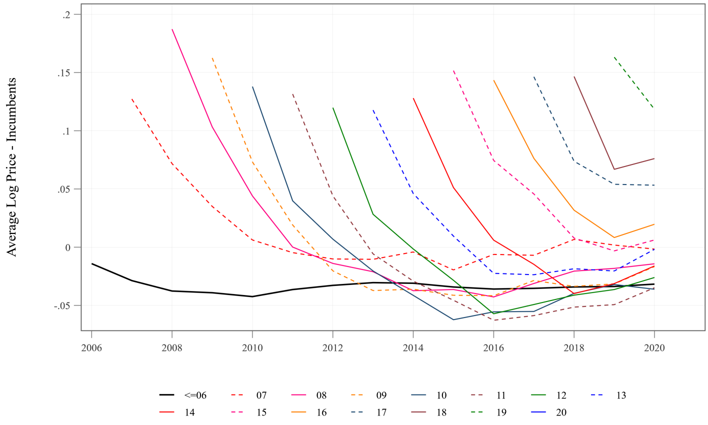
FACT 2: Role of Innovation

- Firms introduce new products with prices above their existing products – "price-overshooting".



FACT 2: Role of Innovation

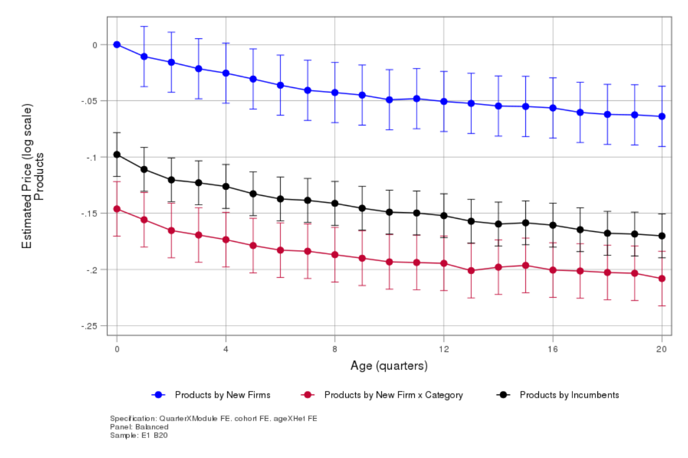
- Price premium is lower for **Incumbents**. Figures shows the price premium for incumbents.



Specification1 : Fixed Effects - FirmxModule + QuarterXModule
Panel: Balanced
Sample: E1

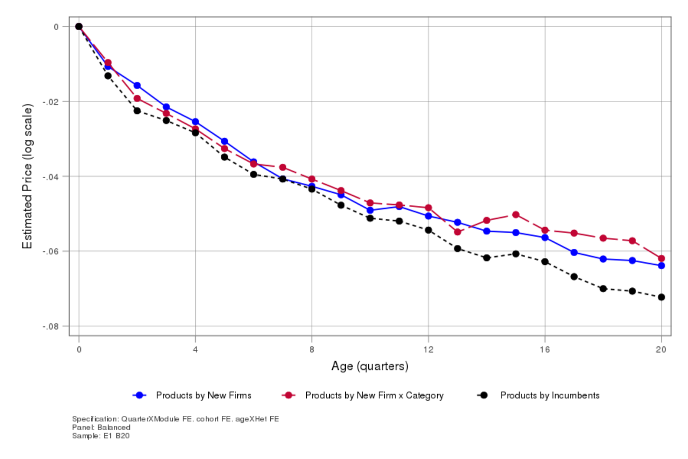
FACT 2: Role of Innovation - Firm Heterogeneity

- Products introduced by new firms have higher prices than products introduced by incumbent firms



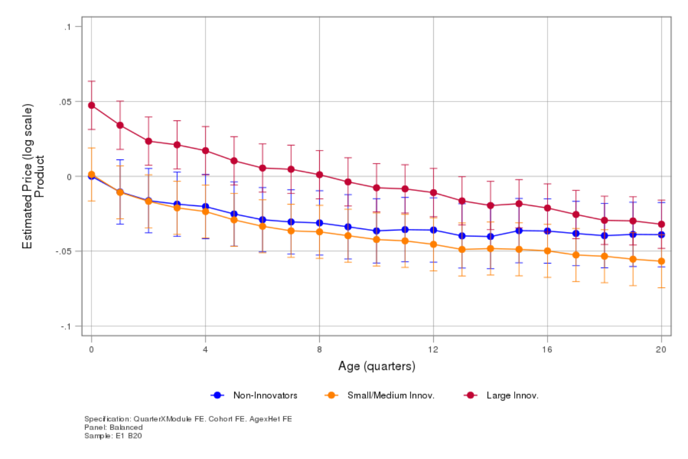
FACT 2: Role of Innovation - Firm Heterogeneity

- Products introduced by new firms have higher prices than products introduced by incumbent firms
- Prices of products by new firms and incumbent firms decline with age at similar rate.



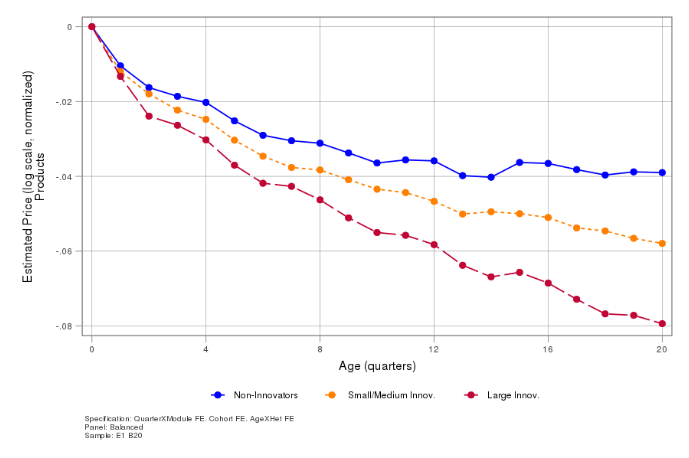
FACT 2: Role of Innovation - Firm Heterogeneity

- Products introduced by innovating firms have higher prices than products introduced by non-innovating firms



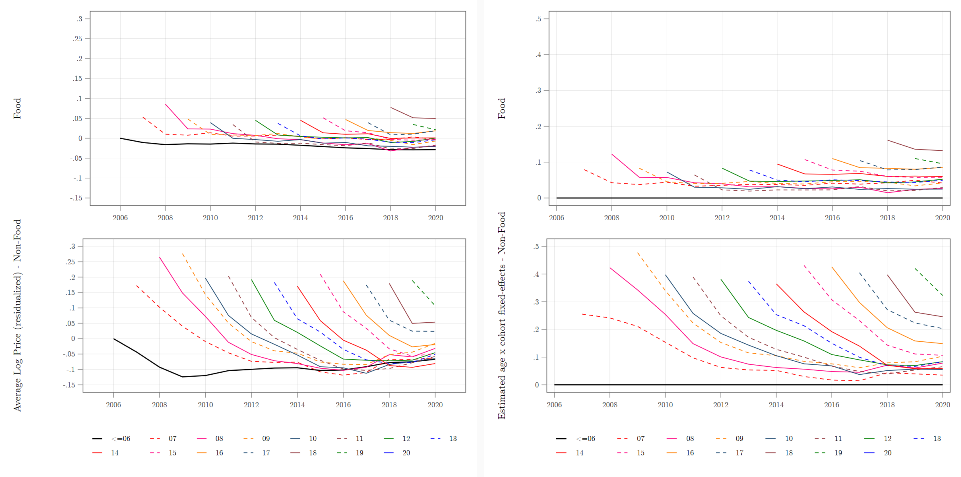
FACT 2: Role of Innovation - Firm Heterogeneity

- Products introduced by innovating firms have higher prices than products introduced by non-innovating firms
- Prices of products by innovating firms decline with age at higher pace.



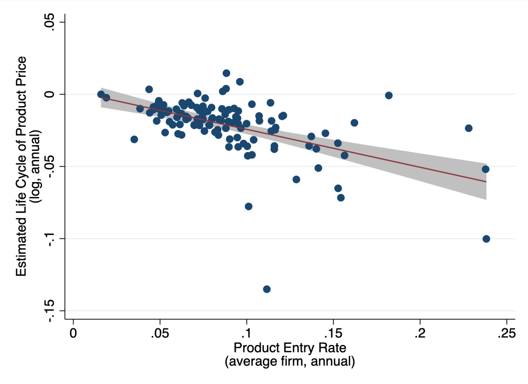
FACT 2: Role of Innovation - Category Heterogeneity

- Aggregate price index goes up because of **new products**, not because of increases in existing products. This is particularly stronger in non-food product categories.



FACT 2: Role of Innovation - Category Heterogeneity

- Product categories with higher innovation have higher declines in relative prices over the life cycle.



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Model

Concepts

- Prices has three components,

$$p_t = \underbrace{p_t^*}_{\textit{optimal price}} + \underbrace{\delta_t}_{\textit{trend}} + \underbrace{\varepsilon_t}_{\textit{business cycle}} \tag{1}$$

- Menu cost; Calvo; Woodford (2003); Liu (2024) make p_t deviate from p_t^* by ε_t
- This paper concerns price friction that affects long-run trend of prices: δ_t.
  - Based on empirics, this friction is large.
  - We do *not* show the reason for such friction. Instead, we are interested in its impact on innovation, output and growth.

Setup: Monetary Economy

- Representative household supplies one unit of labor inelastically and maximizes following utility,

$$\int_0^\infty e^{-\rho t}(\ln C_t + \log(\frac{M_t}{P_t}))dt$$

$$s.t. \quad P_t C_t + \dot{A}_t + \dot{M}_t = W_t L_t + \Pi_t + R_t A_t$$

- FOCs are given by,

$$R_t - \pi_t = \rho + g_t \qquad \textbf{Euler Equation}$$

$$P_t C_t = R_t M_t \qquad \textbf{Money Demand}$$

where g_t is growth rate; π_t is inflation rate.

- Monetary authority controls money supply M_t^s. Money market clears, $M_t = M_t^s$.
- M_t^s increases at rate π_t.

Setup: Firms

- Unit measure of product lines. The set $\mathcal{N}$ of lines are active and others are inactive. We also denote measure of active lines by N.
- Final good is produced by active product lines:

$$Y_t = \left(\int_{\mathcal{N}} (q_{it} y_{it})^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$$

  q_{it} is quality of product. $\sigma > 1$
- Firm can set price for its product when
  - Introducing it at the first time
  - Drawing a Calvo lottery (very low probability)
- Incumbent firms can own several products; entrants are firms currently do not have any products.
- Firms produce use only labor $y_{it} = l_{it}$

Setup: Firms

- Demand for each product line and quality-adjusted price index are,

$$y_{it} = q_{it}^{\sigma-1}(\frac{p_{it}}{P_t})^{-\sigma} Y_t; \quad P_t = \left(\int_N (\frac{p_{it}}{q_{it}})^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$$

- We define the quality index Q and price index $\hat{P}$ as:

$$Q_t = \left(\int_N q_{it}^{\sigma-1} di\right)^{\frac{1}{\sigma-1}} ; \hat{P}_t = \left(\int_N p_{it}^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}$$

- We guess that the price of a product does not depend on its quality. Then, $P_t = \frac{\hat{P}_t}{Q_t}$
- The labor share of economy is,

$$\frac{W_t L}{P_t Y_t} = \mu_t^{-1}$$

where μ is the aggregate markup.

$$\mu_t = \frac{\int_N \mu_{it}^{1-\sigma} di}{\int_N \mu_{it}^{-\sigma} di}$$

Individual markup is defined as $p_{it} = \mu_{it} W_t$. Also denote $\hat{\mu}_t = (\int_N \mu_{it}^{1-\sigma} di)^{\frac{1}{1-\sigma}}$

Price Duration

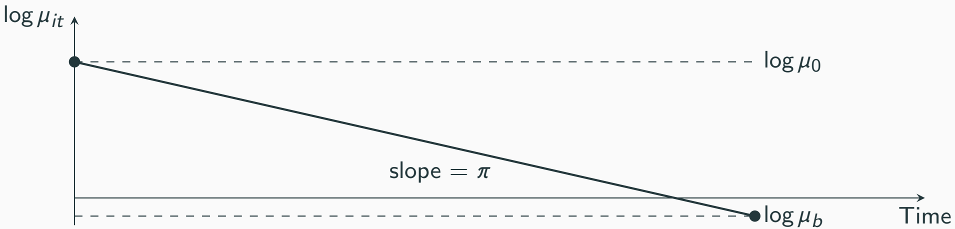
- Let τ the last time when the price was set and $\Delta = t - \tau$ the price duration.
- The markup or real price keeps decreasing, and the relative quality declines.
  - when $\Delta = b_t$, value of product is zero. It is no longer profitable to operate that product line.
  - I guess b_t is the same for all products. Therefore, $\Delta \in [0, b_t]$.
  - Let the distribution of markups be $H_t(\mu_\Delta)$.
- The real profit of individual product is ($\hat{q}_{it} = \frac{q_{it}}{Q_t}$),

$$\frac{\pi_{it}}{P_t} = \upsilon_t^{-1} L \hat{\mu}_t^{\sigma-1} \left[(\mu_\Delta - 1) \hat{q}_{it}^{\sigma-1} \mu_\Delta^{-\sigma} Q_t \right] = \hat{\pi}_t(\hat{q}_{it}, \mu_\Delta) Q_t$$

- When $\mu_\Delta < 1$, the markup is lower than one, the real profit is negative. However, the firm may still want to hold the product since it has option value of innovation. Therefore, $\mu_b < 1$.

Steady State

- $g_t = g$ and $\pi_t = \pi$.
- From Euler equation and money demand,
  - $R_t = R = \rho + g + \pi$
  - P_t increases at rate $\pi - g$, C_t at g, M_t at π.
- The distribution of markups is stationary. $\mu_t = \mu$; $\hat{\mu}_t = \hat{\mu}$.
- Labor share implies W_t increases at rate π. Firm's profit is $\hat{\pi}(\hat{q}_{it}, \mu_\Delta) Q_t$
- Recall $p_{it} = \mu_{it} W_t$. If $p_{it} = p_{i\tau}$, then μ_{it} decreases at π.



Innovation

- Assumption 1: External innovation is directed to the same $\hat{q}_{it}$ as the current product firm has.
  - Firms only improve upon products with same relative-quality as its own product.
  - It guarantees the guesses we made are correct – price does not depend on relative quality; b is the same for all product lines.
- The cost of innovation for incumbents is,

$$c_t(x^E, \hat{q}_{it}) = \xi^E x^{E\,\frac{1}{1-\alpha}} \hat{q}_{it}^{\sigma-1} W_t$$

  Conditional on successfully innovate new product, the quality is $q_{it+} = q_{it} + \lambda^E q_{it}$.
- The cost of innovation for entrants is,

$$c_t(x^N) = \xi^N x^{N\,\frac{1}{1-\alpha}} W_t$$

  Conditional on successfully innovate new product, the quality is $q_{it+} = q_{it} + \lambda^N q_{it}$.
- Let τ be overall creative destruction rate: $\tau = Nx^E + x^N$. Exogenous death rate is ψ.

Value Functions

- The value function of a product is $V_{it} = \Gamma_{it} Q_t$,

$$r\Gamma_t(\hat{q}_{it}, \mu_\Delta) = \max\Big\{0, \quad \dot{\Gamma}_t(\hat{q}_{it}, \mu_\Delta) + \hat{\pi}(\hat{q}_{it}, \mu_\Delta) - (\tau + \psi)\Gamma(\hat{q}_{it}, \mu_\Delta)$$
$$+ \max_{x^E}\left[x^E \Gamma_t(\hat{q}_{it} + \lambda^E \hat{q}_{it}, \mu_0) - \xi^E L^{-1} \mu^{-1} x^{E\,\frac{1}{1-\alpha}} \hat{q}_{it}^{\sigma-1}\right]$$
$$+ \gamma\Big[\Gamma(\hat{q}_{it}, \mu_0) - \Gamma(\hat{q}_{it}, \mu_\Delta)\Big]\Big\}$$

where γ is Calvo parameter. It is straightforward that

$$\frac{\partial Q_t}{\partial t} = gQ_t; \quad \frac{\partial \mu_\Delta}{\partial t} = -\pi\mu_\Delta$$

Also,

$$\dot{\Gamma}(\hat{q}_{it}, \mu_\Delta) = \frac{\partial \Gamma_t}{\partial \mu_\Delta}\frac{\partial \mu_\Delta}{\partial t} + \frac{\partial \Gamma_t}{\partial \hat{q}_{it}}\frac{\partial \hat{q}_{it}}{\partial Q_t}\frac{\partial Q_t}{\partial t}$$

Guess value function $\Gamma(\hat{q}_{it}, \mu_\Delta) = A(\mu_\Delta)\hat{q}_{it}^{\sigma-1}$.

Proposition

The value function $A(\mu_\Delta)$ is given by,

$$A(\mu_\Delta) = \left[\xi_1\mu^{1-\sigma}\left(1-(\frac{\mu_b}{\mu_\Delta})^{\frac{\varphi}{\pi}+1-\sigma}\right) - \xi_2\mu^{-\sigma}\left(1-(\frac{\mu_b}{\mu_\Delta})^{\frac{\varphi}{\pi}-\sigma}\right) + \xi_3\left(1-(\frac{\mu_b}{\mu_\Delta})^{\frac{\varphi}{\pi}}\right)\right]$$

where

$$\xi_1 = \frac{C}{\pi}(\frac{\varphi}{\pi}-\sigma+1)^{-1}; \quad \xi_2 = \frac{C}{\pi}(\frac{\varphi}{\pi}-\sigma)^{-1}; \quad \xi_3 = \frac{\Lambda_E + \gamma A(\mu_0)}{\varphi}$$

and μ_b is given by,

$$C(\mu_b - 1)\mu_b^{-\sigma} + \Lambda_E(\mu_0) + \gamma A(\mu_0) = 0 \tag{2}$$

And $\mu_b > 0$.

Optimal Markup μ_0

Recall that firms Firm can only set prices when $\Delta = 0$.

Proposition

Optimal markup μ_0 is solved by the following equation,

$$(r + \tau + \psi + g(\sigma - 1))A(\mu_0) = C(\mu_0 - 1)\mu_0^{-\sigma} + \Lambda_E(\mu_0) \tag{3}$$

It is easy to show that the option value of external innovation is,

$$\Lambda_E = \xi^E \frac{\alpha}{1-\alpha} x^{E*\frac{1}{1-\alpha}} \tag{4}$$

The arrival rate of external innovation,

$$x^{E*} = \left(\frac{1-\alpha}{\xi^E} A(\mu_0)\right)^{\frac{1-\alpha}{\alpha}} \tag{5}$$

Entrants

- Entrants creatively destruct one product from incumbents. The optimization problem for entrants:

$$\max_{x^N} \left\{ x^N E_q E_\mu \Gamma_t(\hat{q} + \lambda^E \hat{q}, \mu_\Delta) - \xi^N {x^N}^{\frac{1}{1-\alpha}} E_q E_\mu \Gamma_t(\hat{q}, \mu_\Delta) \right\}$$

  The arrival rate of innovation by entrants is,

$$x^{N*} = \left(\frac{1-\alpha}{\xi^N} (1+\lambda^N)^{\sigma-1} \right)^{\frac{1-\alpha}{\alpha}} \tag{6}$$

- Combine (5), (6), (4), (2) and (3), we can solve out $\{\Lambda_E, x^{E*}, x^{N*}, \mu_b, \mu_0\}$. The only missing piece is measure N.

Quantification

Conclusion