Quality of Intermediate Goods: The Growth and Welfare Implications

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Motivation

- Witnessing the advances in computing science, we recognize the quality of intermediate products has been increasingly important.
- Production technology has been greatly improved by high quality (high-tech) instruments and devices. For example, computer-aided-design and computer-aided-manufacturing (CAD/CAM) software.

- These intermediate products have improved firms' productivity and expanded their capacity. Other examples, telematics devices and fully automatic machines...etc..

Motivation

- The evidence shows that importing more varieties of high quality intermediate goods has enhanced the productivity of firms in either developed (see Bas and Strauss-Kahn, 2011; Halpern et al., 2011), or developing countries (see Goldberg et al. 2010)
- Meanwhile, these contributions have reflected a significantly high ratio of intermediate goods to GDP: Grobovšek (2012) and Moro (2012) report that the share of intermediate goods in gross output has been around one half and it is as high as 60% in Belgium and Korea.
- The quality of intermediate goods seems to be crucial for growth. But, there is few literature working on this issue. **Therefore, the purpose of this paper is to examine the interaction between the quality of intermediate products and the quantity of final outputs, and to provide its implication for growth and welfare.**

The Related Literature

- The literature on product quality can be traced to traditional quality-ladder models, which focus on the quality-improved R&D innovations, taking the variety of R&D as given.(see Grossman and Helpman,1991; Aghion and Howitt,1992) By contrast, in our framework, **both of the product variety and the product quality are endogenously determined**.
- Peretto (1998, 1999) and Gil et al. (2008) involve both variety-expanded and quality-improved R&D, and aim at removing the scale effect of population growth to match industrial organization facts. Moreover, Fan (2004, 2005) consider the qualities of intermediate goods and focus on examining the patterns of international trade. Their purposes are obviously different.

The Related Literature

- Besides, to differentiate from these studies which focus on quality innovations, we adopt a broad interpretation of quality improvement where intermediate firms may upgrade their product quality if they are willing to incur higher costs, and the final production may be enhanced by the adoption of high quality of intermediate products.

The Model

- **There are two types of goods: homogeneous final goods, and differentiated intermediate goods** which are both vertically and horizontally differentiated with the number of quality levels n^v and varieties n^s. (The total number is $n = n^v \times n^s$.)
- **The production technology of final goods is:**

$$Y = n^{1+\lambda-\frac{1}{\rho}} \left\{ \int_0^{n^v} \int_0^{n^s} [\eta(v) y(s,v)]^\rho ds dv \right\}^{\frac{1}{\rho}}, \quad 0 < \rho < 1,$$

  where $y(s,v)$ denotes the inputs of intermediate product with quality v and variety s. *More importantly, $\eta(v) > 0$, $\eta'(v) > 0$ and $\eta''(v) < 0$, which intends to capture that higher quality of intermediate products improves the final-good productivity, and the improvement is decreasing.*

Final-good Firms

- **The optimization problem of the final-good producer is:**

$$\max_{\{y(s,v)\}} \pi^f = p^f Y - \int_0^{n^v} \int_0^{n^s} p(s,v)y(s,v)dsdv,$$

where $p^f = 1$ and $p(s,v)$ is the price of the intermediate good with quality v and variety s.

- **The optimal condition of the final-good producer is:**

$$p(s,v) = n^{\rho(1+\lambda)-1} Y^{1-\rho} \eta(v)^{\rho} y(s,v)^{\rho-1}, \tag{1}$$

which is the inverse demand function for intermediate goods. It is shown that *the demand for intermediate goods increases with product quality* $\eta(v)$.

Intermediate-good firms

- **The production technology of intermediate goods is:**

$$y(s,v) = z\left[\frac{k(s,v)}{\alpha(v,\widetilde{g})}\right]^{a}\left[\frac{h(s,v)}{\beta(v,\widetilde{g})}\right]^{1-a} G^{b} - \phi, \tag{2}$$

  where $z = z_0\overline{K}^{\varphi}$($\bar{K}$ is the average capital stock), and $\alpha(v,\widetilde{g})>0$, $\beta(v,\widetilde{g})>0$, $\alpha_v(v,\widetilde{g})>0$, $\beta_v(v,\widetilde{g})>0$, implying producing higher quality of intermediate goods requires more labors and capitals.

- **Government's budget constraint is**: $\tau(wH + rK) = G + \widetilde{G}$. $G = gY$ is the Barro-type government spending on infrastructure; $\widetilde{G} = \widetilde{g}Y$ is the spending on reducing the costs of quality upgrading, meaning $\alpha_{\widetilde{g}}(v,\widetilde{g}) < 0$, $\beta_{\widetilde{g}}(v,\widetilde{g}) < 0$, $\alpha_{v,\widetilde{g}}(v,\widetilde{g}) < 0$ and $\beta_{v,\widetilde{g}}(v,\widetilde{g}) < 0$.

- **The problem of each intermediate-good firm is:**

$$\max_{\{k(s,v),h(s,v),v\}} \pi(s,v) = p(s,v)y(s,v) - rk(s,v) - wh(s,v), \quad \text{s.t. } (1)\&(2)$$

where w and r are the prices of labors and capitals, respectively.

Households

- There is a unit of identical and infinitely lived households. Each of them supplies one unit of labor inelastically ($H = 1$). **The problem of each household is:**

$$\underset{\{C,K\}}{Max} \int_0^{\infty} e^{-\theta t} \ln C dt,$$

$$s.t. \quad \dot{K} = (1-\tau)(wH + rK + \Pi) - C - \delta K,$$

where τ is the income tax rate, θ is the time preference, δ is the capital depreciation rate, and Π_t is the aggregate dividends.
- The optimal condition is:

$$\gamma \equiv \dot{C}/C = r - \delta - \theta,$$

where the transversality condition $\lim_{t\to\infty} K_t e^{-\rho t}/C_t = 0$.
- Incorporating the individual and government budget constraints as well as the firm's profits, we have $\dot{K} = Y - C - (G + \widetilde{G}) - \delta K$.

Equilibrium of Intermediate Goods

- In a *symmetric equilibrium, free entry* gives: $y(s, v) = \frac{\rho\phi}{1-\rho}$.
  - When ρ is higher (lower markup), the market size of each firm is lower. This is the **business-stealing effect (BSE)** argued by Mankiw and Whinston (1986), which says that a new entrant lowers the sales of incumbent firms.
- Moreover, *the equilibrium varieties in intermediate-good market* is:

$$n = \left\{ z_0 \overline{K}^{\varphi} \left[\frac{1-\rho}{\phi} \right]^{1-b} \left[\frac{K}{\alpha(v^e, \widetilde{g})} \right]^{a} \left[\frac{H}{\beta(v^e, \widetilde{g})} \right]^{1-a} [\eta(v^e)g]^{b} \right\}^{\frac{1}{1-b(1+\lambda)}}$$

- Furthermore, the equilibrium quality, v^e, satisfies:

$$a\frac{\alpha_v(v^e, \widetilde{g})}{\alpha(v^e, \widetilde{g})} + (1-a)\frac{\beta_v(v^e, \widetilde{g})}{\beta(v^e, \widetilde{g})} = \rho\frac{\eta'(v^e)}{\eta(v^e)}.$$

Quality Effect of Market Competition

Proposition 1

Keener competition in the intermediate-good market (a higher ρ) raises the equilibrium quality of intermediate products (v^e), i.e., $\frac{\partial v^e}{\partial \rho} > 0$.

- This is because firms have more incentives to produce higher quality of intermediate goods in order to escape from the keen competition.
- If applying higher quality inputs is viewed as more cost-reduction R&D, this result supports Nickell (1996) and Aghion et al. (2001) which argue that the relationship between competition and R&D is positive. However, this result contrasts with that in Schumpeterian models, where less competition motivates more R&D, due to higher monopoly rents.

Balanced Growth Path

Theorem 1

Under $\varphi = \frac{1}{1+\lambda} - a - b$, there exists a nondegenerate, unique balanced-growth-path equilibrium with the consideration of product quality. The balanced-growth rate is:

$$\gamma = a(1\text{-}g\text{-}\tilde{g})\rho \left\{ \eta(v^e)\left(\frac{1\text{-}\rho}{\phi}\right)^{\lambda} \left[\frac{z_0 g^b}{\alpha(v^e,\tilde{g})^a \beta(v^e,\tilde{g})^{1-a}} \right]^{1+\lambda} \right\}^{\frac{1}{1-b(1+\lambda)}} \text{-}\theta\text{-}\delta.$$

Lemma 1 Under the BGP, *there is a non-monotonic relationship between growth and product quality as shown below:*

$$\frac{\partial \gamma}{\partial v} \gtreqless 0, \text{ if } \frac{1}{1+\lambda}\frac{\eta'(v)}{\eta(v)} \gtreqless a\frac{\alpha_v(v,\widetilde{g})}{\alpha(v,\widetilde{g})} + (1-a)\frac{\beta_v(v,\widetilde{g})}{\beta(v,\widetilde{g})}. \blacksquare$$

- A higher quality level does not necessarily imply higher growth.
- Intuition: First, because producing high-quality intermediate product is more costly, it results in a smaller number of intermediate firms n, due to fewer entrants. Second, there is a effect of increasing return to specialization (IRTS) denoted by λ, which means that more varieties are beneficial to the production of the final good, as stressed by Romer (1987). $\Longrightarrow$ *If the IRTS λ is not so large, the positive relationship between growth and quality exists. In contrast, if the IRTS is large, the higher input quality decreases the growth due to the smaller number of varieties.*

Growth Effect of Market Competition

Corollary 1 More intense competition (higher ρ) has an ambiguous effect on the balanced-growth rate:

$$\frac{d\gamma}{d\rho} = \underset{(+)}{\frac{\partial\gamma}{\partial\rho}} + \frac{\partial\gamma}{\partial v}\underset{(+)}{\frac{\partial v}{\partial\rho}} \gtreqless 0, \text{ if } \lambda \lesseqgtr \frac{1-\rho}{\rho} \; (\rho \lesseqgtr \frac{1}{1+\lambda}). \blacksquare$$

- That is, more intense competition can be good or bad for the growth while considering the quality of intermediate goods.
- Empirical evidence, such as Aghion et al. (2005) and Aghion and Griffith (2005), shows that there exists an inverted-U relationship between PMC and growth in the U.S. and U.K..

Welfare Analysis

- Social welfare is computed as:

$$W = \int_0^\infty e^{-\theta t} \ln C dt = \frac{\gamma + \theta \ln C_0}{\theta^2},$$

where $C_0 = \{[\frac{1-g-\widetilde{g}}{a(1-\tau)} - 1]\gamma + \frac{(1-g-\widetilde{g})}{a(1-\tau)}(\theta+\delta) - \delta\}K_0$.

- By maximizing the welfare with respect to the product quality, we have

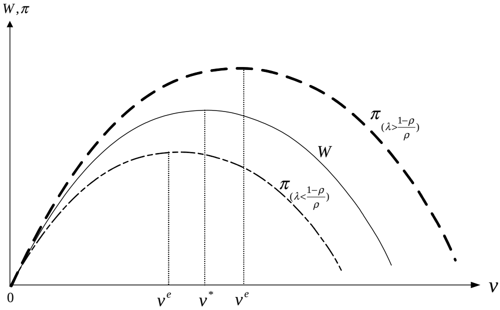
$$\frac{\partial W}{\partial v}\,|_{v=v^e} = \left(\frac{1}{1+\lambda} - \rho\right)\frac{\eta'(v^e)}{\eta(v^e)} \gtreqless 0 \text{ if and only if } \lambda \lesseqgtr \frac{1-\rho}{\rho}. \quad \blacksquare$$

which reveals the relationship between the market-equilibrium quality *(v^e) and* the optimal quality (v^*).

Optimal Quality vs. Market-Equilibrium Quality

Proposition 2

If the IRTS is substantially high, i.e., $\lambda > \frac{1-\rho}{\rho}$, the quality of the market equilibrium is over-supplied, relative to the socially optimal level: $v^e > v^*$. On the contrary, if the IRTS are relatively low ($\lambda < \frac{1-\rho}{\rho}$), the equilibrium quality is under-supplied: $v^e < v^*$.



Optimal Quality vs. Market-Equilibrium Quality

- There are two types of externalities: *the increasing return to specialization (IRTS)*, λ, and *the business-stealing effect (BSE)*, ρ.

$$\begin{cases} \text{If } \lambda > \frac{1-\rho}{\rho}, \text{ IRTS dominates} : n^e < n^* \iff v^e > v^* \\ \text{If } \lambda < \frac{1-\rho}{\rho}, \text{ BSE dominates} : n^e > n^* \iff v^e < v^* \end{cases}$$

- According to Christopoulou and Vermeulen (2012), the monopoly power ρ ranges from 0.62 to 0.73. In addition, Harrigan (1999) and Paul et al. (1999) show that the extent of IRTS $\lambda < 0.3$ in the OECD countries and the US. Their estimates suggest that the case of $\lambda < \frac{1-\rho}{\rho}$ is more empirically possible; in other words, the equilibrium input quality is *more likely* to be *under-supplied* in reality.

Optimal Government Spending

- Assume $\alpha(v, \widetilde{g}) = \beta(v, \widetilde{g}) = e^{v/\widetilde{g}^{\epsilon}}$, and $\eta(v) = v^{\xi}$, where $\epsilon > 0$ such that $\alpha_{\widetilde{g}} < 0$, $\beta_{\widetilde{g}} < 0$, $\alpha_{v,\widetilde{g}} < 0$ and $\beta_{v,\widetilde{g}} < 0$; $0 \leqslant \xi \leqslant 1$ such that $\eta_v > 0$ and $\eta_{vv} < 0$. The parameters ϵ and ξ, respectively, imply the effectiveness of the spending on reducing the quality improving costs, and the productivity-enhancing effect of input quality.
- Under the specification, the quality of intermediate goods is:

$$v^e = \rho\xi\widetilde{g}^{\epsilon}. \quad \blacksquare$$

Lemma 2 *The government spending on reducing the quality-improving costs, $\widetilde{g}$, may increase the equilibrium quality v^e, while the government spending on infrastructure g has no impact on the quality.*

Optimal Government Spending

Proposition 3

In an economy with product quality considerations, the welfare-maximizing government spending is given by: $g^* = \frac{b(1+\lambda)}{1+\epsilon\xi}$; $\widetilde{g}^* = \frac{\epsilon\xi}{1+\epsilon\xi}$.

- That is, $\begin{cases} \lambda\uparrow \text{ or } b\uparrow \implies g^*\uparrow \\ \xi\uparrow \text{ or } \epsilon\uparrow \implies \widetilde{g}^*\uparrow \text{ and } g^*\downarrow \end{cases}$
- The optimal g increases with λ. This is because the spending g may increase firm's profits, which results in a large number of firms. Meanwhile, because higher b implies that the spending g is more effective, it is straightforward that the spending increases with b.
- Besides, ξ and ϵ, respectively, imply the productivity-enhancing effect of input quality, and the effectiveness of the spending on the cost reduction for the quality-improving $\widetilde{g}^*$. So, if they're higher, the social planner'd prefer to adjust the resource allocation by increasing $\widetilde{g}^*$ and lowering g^*.

Conclusion

- When the competition is keener, firms have more incentive to produce higher quality to escape from the competition.
- Either the keener competition or the higher input quality does not necessarily imply a higher growth. This is because, although higher input quality enhances productivity, it leads to less varieties which has a negative effect on production due to the IRTS.
- The equilibrium quality is under-supplied if the business-stealing effect dominates the IRTS one. By contrast, the equilibrium quality is over-supplied if the IRTS dominates the business-stealing effect.
- While the government spending on infrastructure has no effect on the product quality, the spending on reducing the costs of quality upgrades has a positive effect. The optimal allocation of the two spending depends on the IRTS, the productivity-enhancing effect of input quality, and the effectiveness of the two spending.

Thank you