The role of techno-countervailing power in inducing the development and dissemination of new functionality – an analysis of Canon printers and Japan's personal computers

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Abstract: Industrial economics suggests that a competitive environment induces firms to undertake vigorous R&D, while a monopoly enables firms to efficiently acquire R&D resources. Therefore, optimal co-evolution between competition and monopoly is indispensable for significant technological innovation. This paper attempts to demonstrate this postulate by analysing the interacting dynamism between technological development and production in the printers market as well as subsequent demand for the expansion of the personal computer market driven by new functionality development of printers. On the basis of an empirical analysis of Canon printers and Japan's personal computers, the significant role of techno-countervailing power between supply and demand in inducing and disseminating new functionality is demonstrated.

Keywords: functionality development; printers and PCs; price elasticity to technology; techno-countervailing power; technology elasticity to competition.

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1 Introduction

Canon is one of the leading firms in Japan's electrical machinery industry, which have been demonstrating a conspicuous performance in their business development and its printers have been always regarded as the pioneer in the world. From the beginning to produce large laser beam printer in 1976 new printers with high functionality are continually invented such as laser beam printers in 1984 and bubble jet printers in 1990. Shipment of Canon's laser beam printers shared 50% in the world market and shipment of the bubble jet printers shared 44% in Japan's market in 2004. Its conspicuous accomplishment can be attributed not only to its technological diversification strategy by effective utilisation of spillover technology, which is considered the key of competitiveness in an increasing trend in global technology spillover (Watanabe, Hur and Matusmoto, 2004), but also to its cumulative market learning (Watanabe and Ane, 2003) based on the interaction between printers and personal computers. These muliti-effects promoted high performance of functionality development essential for sustaining firms development in an information society (Watanabe, Asgari and Nagamatsu, 2003). This functionality development enables Canon to secure R&D funds by shifting from internal operating income to funds from the marketplace (Watanabe, Hur and Lei, 2005). Thus, Canon's remarkable policy of internal technology spillover, market learning and higher functionality development lead it to maintain pioneer position and provide significant policy implications to the management of technology in a post-information society.

Development trajectories of Canon printers and Japan's PCs are illustrated in Figure 1. Looking at Figure 1, we note that Canon printers have been maintaining a significant share in Japan's market and this significant share governed and accelerated Japan's printers industry. Figure 1 also suggests that the dramatic decrease in Canon printers prices supported by its innovation efforts and corresponding increase in demand its R&D was accelerated leading to increasing competition among printers suppliers in the market, which stimulated continued efforts to innovate the new functionality development of printers inducing demand of PCs. Thus, the following dynamism could be clearly observed:

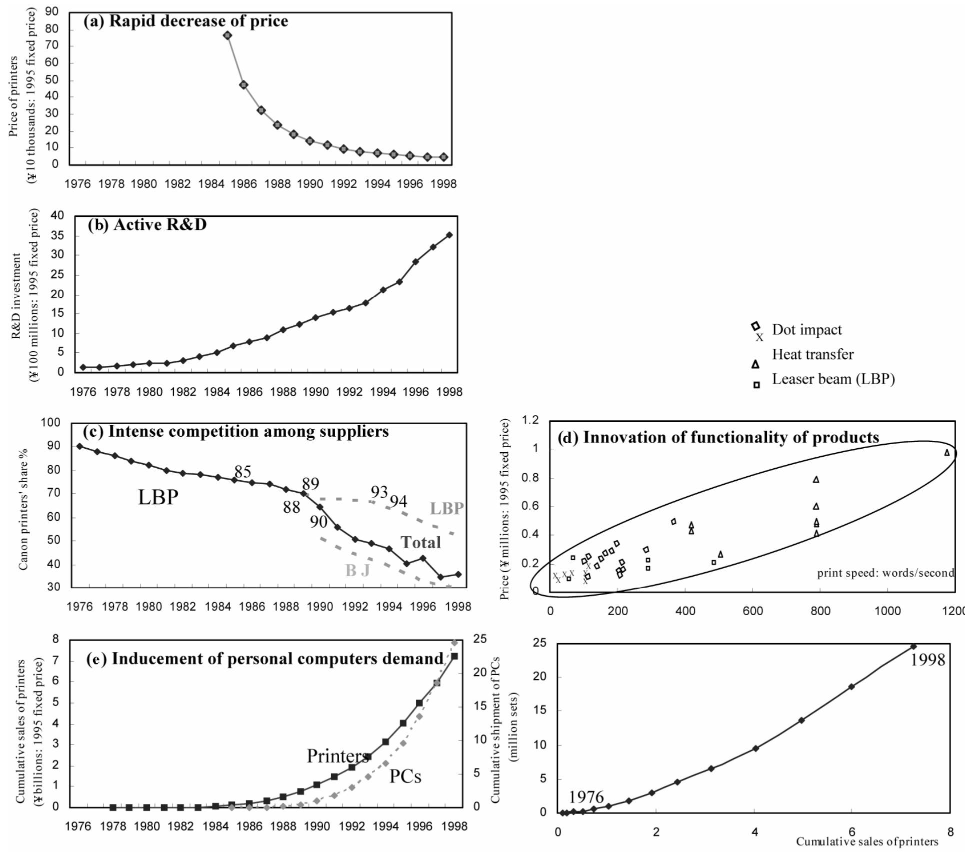
Decrease in prices of Canon printers → acceleration of technological development for more qualified (expensive) printers → increase in competition among suppliers → creation of new functionality development → inducement of demand of PCs.

In addition from the co-evolutionary development trajectory of Canon printers and PCs as illustrated in Figure 2 we note that the gross shipment of PCs also increased corresponding to the increase in the gross sales of Canon printers.

On the basis of the foregoing observation, we realise that suppliers provide printers through technological development and production in response to the demand in the market, and the countervailing power between them accelerates inducement of technological development as well as production.

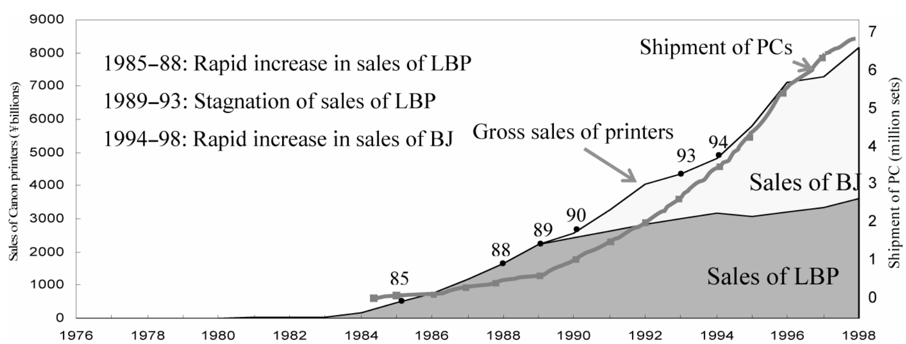
Prompted by the foregoing observations, aiming at demonstrating the following hypothetical views from both supply and demand sides, this paper attempts an empirical analysis of the interacting dynamism between technological development and production in the printers market and subsequent demand expansion of the PC market driven by new functionality development of printers.

Figure 1 Development trajectory of Canon printers (1976–1998)



[a] LBP: leaser beam printer; BJ: bubble jet printer.

Figure 2 Co-evolutionary trajectory between Canon printers and personal computers (1976–1998)



1.1 Supply side hypothesis

Conspicuous improvement in new functionality development of Canon printers can largely be attributed to rapid decrease in prices, which induces the vigorous technological development (high price elasticity to technology) stimulating competitive circumstances, leading to constructing a virtuous cycle by inducing the functional development:

New functionality development → rapid decrease in prices of Canon printers → technological development → improvement of competitive circumstances → further functionality development.

1.2 Demand side hypothesis

This functionality development triggers the following virtuous cycle between supply and demand sides:

Functionality development of Canon printers → increase in PCs demand → inducement of further development of printers → improvement of competitive circumstances → decrease in prices of printers → inducement of further technological development → further acceleration of printers functionality development.

A concept of countervailing power between supply and demand sides in a market can be traced by the Galbratih's pioneer work (Galbraith, 1952). Stimulated by his research not a few researches endeavoured empirical approach for examining the impacts of countervailing power (Lusgarten, 1975; Guth et al., 1976; Ravenscraft, 1983).

To date in light of the increasing significance of buyer (demand side) power in a market, not a few researches primarily by theoretical approach (Sternberg, 1986; Kantarelis and Veendorp, 1987; Veendorp, 1987; Snyder, 1996) demonstrated that buyer power could prevent cartel among sellers (suppliers) and decrease the price and increase the demand in a market accordingly. However, these works are hardly satisfactory for by analysing techno-countervailing power and its influence on technological innovation.

In addition, majority of studies on firm size and R&D are focusing on whether larger or smaller firms (monopoly or competition) promote R&D and innovation. Some of them proved that the firm size could provide technological capabilities, which is necessary to compete effectively (Dampour, 1992; Harrington et al., 1998; Kupfer, 1998; Covin, 1999). However, since small firms can avoid organisational inertia, which is defined as the tendency of an organisation to resist the internal change against external change (Barnett and Carroll, 1995; Larsen and Lomi, 2002), smaller firms can be more innovative as they are more flexible and easier to accept and effect change (Dampour, 1992). Moreover, the contribution of an individual in small firms is likely to have a more visible impact on the firm's overall performance than that in larger firms, which will improve individual's motivation (Kamien and Schwartz, 1982; Stock et al., 2002).

Prompted by the foregoing hypothetical views and stimulated by these works, this paper that focusing on the role of techno-countervailing power in inducing technological innovation attempts to demonstrate these hypothetical views by means of an empirical analysis of Canon printers and Japan's PCs over the last 25 years.

Section 2 demonstrates the hypothesis of supply side by presenting the results of empirical analyses of Canon printers over the period 1986–1998. Similarly, Section 3 demonstrates the hypothesis of demand side by presenting the results of impact of functionality development on induction between supply and demand sides and identifies the contributing factors to price decrease from both supply and demand sides. Section 4 briefly summarises new findings policy implications and the focus of the further studies.

2 Impact of countervailing power among suppliers on functionality development (demonstration of the hypothesis of supply side)

2.1. Dynamism among price elasticity to technology, techno-countervailing and functionality development

In this research prices of printers include current printers prices (P_v), current technology prices (P_t) and relative prices of Printers' Technology (PT) (P), which is defined as the ratio of current technology prices and printers prices. These relative prices can also be expressed as follows (see Appendix A1):

$$P = \frac{1-\dfrac{1}{E_v}}{1-\dfrac{1}{\varepsilon_t}}\frac{\partial V}{\partial T} = \frac{\dfrac{\varepsilon_t}{\varepsilon_t - 1}}{\dfrac{\varepsilon_t}{\varepsilon_v - 1}} \times \frac{\partial V}{\partial T} = \frac{1+\dfrac{1}{\varepsilon_t - 1}}{1+\dfrac{1}{\varepsilon_v - 1}} \times \frac{\partial V}{\partial T} = \frac{1+m_t}{1+m_v} \times \frac{\partial V}{\partial T} = M \times \frac{\partial V}{\partial T} \tag{1}$$

Where M is the ratio of additional prices a firm put on the marginal cost of technology and gross product, which is expressed by the following equation and can be defined as *Techno-Production Non-Countervailing Ratio* (TP-NCR).

$$M = \frac{1+m_t}{1+m_v} = \frac{1+1/(\varepsilon_t - 1)}{1+1/(\varepsilon_v - 1)} \tag{2}$$

M demonstrates the degree of countervailing power in technological development and production in supply side and indicates whether the technology development structure of supply market is under monopoly or competition relative to production structure. M decreases when countervailing power to technology development is greater, which indicates that competitive condition in technology development is promoted towards the similar level to competitive condition in production and monopoly in technology development is decreased. Under perfect competition in which technology is in the similar competitive condition as that of production, M is equal to 1, and when $M > 1$, it indicates that there is no countervailing power in the process of technological development relative to production; thus, market in technology development is under monopoly or imperfect competition.

where $m_t = 1/(\varepsilon_t - 1)$: mark-up ratio of technology, which indicates the extent of additional prices a firm put on the marginal cost; $m_v = 1/(\varepsilon_v - 1)$: mark-up ratio of products.

Provided that gross product V increases as its technology stock T increases, diffusion trajectory of innovative products can be depicted by the following logistic growth function (Watanabe, Hur and Matsumoto, 2004):

$$\frac{\partial V}{\partial T} = aV\left(1-\frac{V}{\overline{\overline{V}}}\right) \tag{3}$$

where *a*: diffusion velocity of technology and $\overline{V}$: carrying capacity.

Synchronising Equations (1) and (3), relative prices of technology can be depicted as follows:

$$P = M \times \frac{\partial V}{\partial T} = M \times aV\left(1 - \frac{V}{\overline{V}}\right) \tag{1a}$$

Partial differentiation of Equation (1a) by technology stock *T*

$$\frac{\partial P}{\partial T} = \frac{\partial M}{\partial T} \times aV\left(1 - \frac{V}{\overline{V}}\right) + M\frac{\partial a}{\partial T}V\left(1 - \frac{V}{\overline{V}}\right) + Ma\frac{\partial}{\partial T}\left[V\left(1 - \frac{V}{\overline{V}}\right)\right]$$

$$= \frac{\partial M}{\partial T} \times \frac{P}{M} + \frac{\partial a}{\partial T} \times \frac{P}{a} + Ma\frac{\partial V}{\partial T}\left(1 - \frac{2V}{\overline{V}}\right)$$

$$\frac{\partial P}{\partial T} \times \frac{T}{P} = \frac{\partial M}{\partial T} \times \frac{T}{M} + \frac{\partial a}{\partial T} \times \frac{T}{a} + aT\left(1 - \frac{2V}{\overline{V}}\right) \tag{4}$$

λ, ϕ and η are defined an elasticity between *P*, *T*, *M* and *a*, respectively as follows:

$\lambda = -(\partial \ln T/\partial \ln P)$ (Elasticity of relative prices of technology to technology: prices decrease induces technology stock) $P\downarrow \rightarrow T\uparrow$

$\phi = -(\partial \ln M/\partial \ln T)$ (Elasticity of technology to technology competition: technology stock increase induces technology competition relative to production competition) $T\uparrow \rightarrow M\downarrow$

$\eta = \partial \ln T/\partial \ln a$ (Elasticity of diffusion velocity to technology: diffusion velocity increase induces technology stock) $a\uparrow \rightarrow T\uparrow$

On the basis of the foregoing explanation Equation (4) can be developed as follows:

$$-\frac{1}{\lambda} = -\phi + \frac{1}{\eta} + aT\left(1 - \frac{2}{\mathrm{FD}}\right) \tag{5}$$

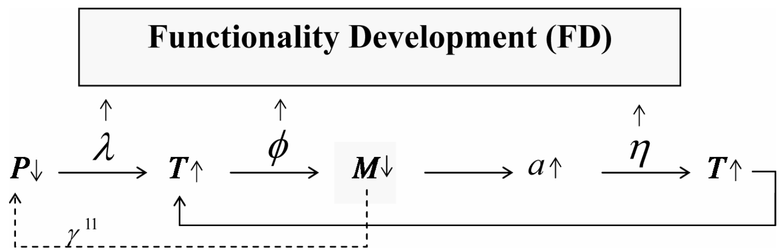
where $\mathrm{FD} \equiv \overline{V}/V$ and is defined functionality development, which indicates the degree of functionality incorporated in the production function *V* (Watanabe, Asagari and Nagamatsu, 2003).

From Equation (5), Functionality Development (FD) can be developed as follows:

$$\mathrm{FD} = \frac{2}{1 + \frac{1}{aT}\left(\frac{1}{\lambda} - \phi + \frac{1}{\eta}\right)} \tag{6}$$

Equation (6) suggests that FD increases as well as λ, ϕ and η[1]. These dynamisms can be illustrated as Figure 3.

Figure 3 Dynamism among price elasticity to technology, techno-countervailing, technological diffusion and functionality development



2.2. *Measurement of elasticity of prices to technology (λ) – a case of Canon printers*

2.2.1. *Technology stock of printers and its relative prices*

Since Canon printers are crystals of technology their technology stock and prices of printers are sensitive to their technology prices (fixed prices: P_{tr}) as well as prices of printers (fixed prices: P_{vr}). Therefore, technology stock of printers T can be depicted as a function of relative prices of printers' technology P and prices of printers' technology P_{tr} as follows:

$$T = T[P(P_{\text{tr}})] \tag{7}$$

Taking partial differentiation of Equation (7) by P_{tr}

$$\frac{\partial T}{\partial P_{\text{tr}}} = \frac{\partial T}{\partial P} \times \frac{\partial P}{\partial P_{\text{tr}}}$$

$$\frac{\partial T}{\partial P} \times \frac{P}{T} = \left(\frac{\partial T}{\partial P_{\text{tr}}} \times \frac{P_{\text{tr}}}{T} \right) \Big/ \left(\frac{\partial P}{\partial P_{\text{tr}}} \times \frac{P_{\text{tr}}}{P} \right)$$

$$\frac{\partial \ln T}{\partial \ln P} = \left(\frac{\partial \ln T}{\partial \ln P_{\text{tr}}} \right) \Big/ \left(\frac{\partial \ln P}{\partial \ln P_{\text{tr}}} \right) = -\lambda$$

$$P = P_t / P_v = (P_{\text{tr}} \times \text{RDEF}) / (P_{\text{vr}} \times \text{WPI}) \tag{8}$$

where P_t: current prices of technology; P_v: current prices of printers; P_{tr} : fixed prices of technology; P_{vr}: fixed prices of printers; RDEF: R&D deflator and WPI: whole sale prices index of electrical machinery equipments.

Taking logarithm of Equation (8):

$\ln P = \ln P_{\text{tr}} - \ln P_{\text{vr}} + \ln(\text{RDEF}/\text{WPI}) \approx \ln P_{\text{tr}} - \ln \text{P}_{\text{vr}}$ [2]

Taking partial differentiation with respect to $\ln P_{\text{tr}}$,

$\frac{\partial \ln P}{\partial \ln P_{\text{tr}}} = 1 - \frac{\partial \ln P_{\text{vr}}}{\partial \ln P_{\text{tr}}}$, therefore,

$$\lambda = -\frac{\partial \ln T}{\partial \ln P} = -\frac{\partial \ln T}{\partial \ln P_{\text{tr}}} \Big/ \left(1 - \frac{\partial \ln P_{\text{vr}}}{\partial \ln P_{\text{tr}}} \right) \tag{9}$$

Equation (9) suggests that the elasticity of relative prices of printers' technology (P) to technology stock of printers (T) increases as the elasticity of fixed prices of printers' technology (P_{tr}) to technology stock of printers (T) as well as the elasticity of fixed prices of printers' technology (P_{tr}) to fixed prices of printers (P_{vr}) increase.

2.2.2 Elasticity of fixed prices of technology to technology stock of printers

Provided that change rate of technology progress (change rate of total factor productivity (TFP), $(\Delta\text{TFP}/\text{TFP})$ is expressed as τ technology stock (T) can be depicted by a Cobb–Douglas type function of fixed prices of printers' technology P_{tr} and τ as follows (see Appendix A2):

$$T = A_1 P_{tr}^{\mu_0 e^{\gamma_\mu \tau}} \tag{10}$$

Since $\gamma_\mu \tau << 1, e^{\gamma_\mu \tau} \approx 1 + \gamma_\mu \tau$

where τ: change rate of Total Factor Product (TFP); μ_0: initial level of the elasticity of fixed prices of PT to their technology stock; and γ_μ: contribution coefficient of change rate of TFP to technology stock.

Therefore, the elasticity of fixed prices of printers' technology to their technology stock μ can be depicted as follows:

$$\mu = -\frac{\partial \ln T}{\partial \ln P_{tr}} \approx -\mu_0 (1 + \gamma_\mu \tau) \tag{11}$$

Table 1 summarises the elasticity coefficient μ and contribution coefficient γ_μ of Canon printers over the period 1985–1998.

Table 1 Regression between prices of printers' technology and technology stock (1985–1998)

$\ln T = \ln A_1 + \mu_0(1 + \gamma_\mu\tau) \ln P_{tr} + b \times D$

γ_μ	$\ln A$	μ_0	b	*adj.* R^2	*DW*	*AIC*
0	4.435 (173.929)	–0.740 (–20.101)	0.281 (3.062)	0.991	1.46	–29.526
1.2	4.429 (172.566)	–0.752 (–20.226)	0.332 (3.788)	0.992	1.42	–31.549
1.3	**4.432** **(172.595)**	**–0.755** **(–20.229)**	**0.332** **(3.792)**	**0.992**	**1.42**	**–31.592**
1.4	4.428 (172.443)	–0.751 (–20.210)	0.334 (3.797)	0.992	1.42	–31.527

D: dummy variables, 1985–1989 = 1, and other years = 0.

By comparing the Akaike Information Criteria (AIC)[3] of regression results in Table 1, elasticity of fixed prices of printers' technology to their technology stock μ can be identified as:

$$\mu = -\frac{\partial \ln T}{\partial \ln P_{tr}} = -\mu_0 (1 + \gamma_\mu \tau) = 0.755(1 + 1.3\tau) \tag{12}$$

Equation (12) demonstrates that given the change rate of printers' technology progress τ is maintained positive elasticity of prices of printers' technology to technology stock maintains positive and increases as the technology progress increases leading to active inducement of technology stock in response to its prices decrease.

2.2.3 *Elasticity of fixed prices of printers' technology to fixed prices of printers*

Similar to analysis (Section 2.2.2) fixed prices of printers P_{vr} can be depicted by a function of fixed prices of PT P_{tr} and τ as demonstrated in Table 2, which summarises the elasticity coefficient ω and contribution coefficient γ_ω of Canon printers over the period 1985–1998.

Table 2 Regression between prices of printers' technology and printers (1985 –1998)

$\ln P_{vr} = \ln A_2 + \omega_0 (1 + \gamma_\omega \tau) \ln P_{tr} + b \times D$

γ_ω	ln*A*	ω_0	*b*	*adj.* R^2	*DW*	*AIC*
0	1.778 (44.761)	0.640 (20.386)	0.547 (5.447)	0.986	2.18	–18.918
0.7	1.778 (44.794)	0.644 (20.409)	0.548 (5.450)	0.986	2.20	–19.014
0.8	**1.778** **(44.901)**	**0.645** **(20.409)**	**0.549** **(5.451)**	**0.986**	**2.18**	**–19.028**
0.9	1.778 (44.823)	0.640 (20.376)	0.546 (5.443)	0.986	2.18	–18.903

ω_0: initial level of the elasticity of fixed price of printers' technology to fixed price of printers and γ_ω: contribution coefficient of change rate of TFP to fixed prices of printers D: dummy variables, 1985–1986 = 1, and other years = 0.

Similarly, elasticity of fixed prices of printers' technology to fixed prices of printers ω can be identified as:

$$\omega = \frac{\partial \ln P_{vr}}{\partial \ln P_{tr}} = \omega_0 (1 + \gamma_\omega \tau) = 0.645(1 + 0.8\tau) \tag{13}$$

Similar to μ in Equation (12), elasticity of prices of PT to prices of printers maintain positive and increases as printers' technology progress τ increases leading to technology prices driven prices decrease in Canon's printers.

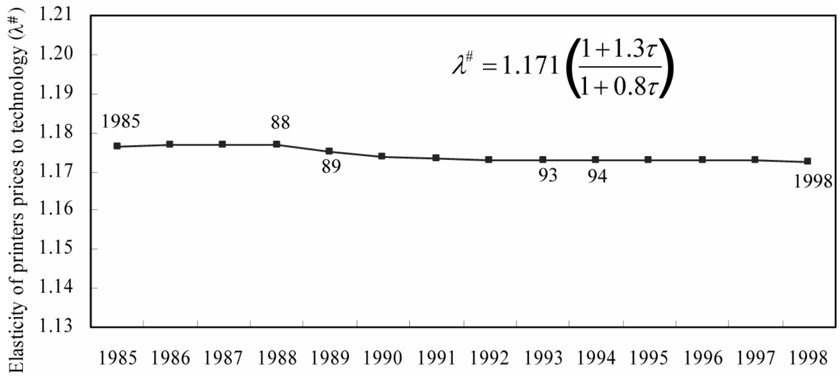
2.2.4 *Elasticity of printers prices to technology*

Utilising the results of Equations (12) and (13), elasticity of printers prices to their technology stock $\lambda^{\#}$ [4] can be developed as follows:

$$\begin{aligned} \lambda^{\#} &= -\frac{\partial \ln T}{\partial \ln P_{vr}} = \left(-\frac{\partial \ln T}{\partial \ln P_{tr}} \Big/ \frac{\partial \ln P_{vr}}{\partial \ln P_{tr}} \right) = \frac{\mu}{\omega} = \frac{0.755(1+1.3\tau)}{0.645(1+0.8\tau)} \\ &= 1.171 \frac{(1+1.3\tau)}{(1+0.8\tau)} \end{aligned} \tag{14}$$

Figure 4 illustrates trend in this elasticity over the period 1985–1998 measured by Equation (14).

Figure 4 Trends in elasticity of printers prices to technology (1985–1998)



Looking at Figure 4 we note that the elasticity of printers prices to their technology exhibited positive and sustained almost the same level ($1.17 \sim 1.18$) over the whole period examined. In addition Equation (14) suggests that this elasticity increases as printers' technology progress τ increases as $d\lambda^{\#}/d\tau = \left[0.585/(1+0.8\tau)^2\right] > 0$. These demonstrate that as prices of printers decrease Canon made vigorous efforts in accelerating technological development for more qualified printers leading to increase its technology stock in printers. This can be attributed its entrepreneur's motivation to sustain its leading position against an increasing competition in the printers market and also to compensate the decrease in unit sales due to the decrease in the prices by supplying the more qualified printers, which afford higher prices. All demonstrates the first hypothetical view that rapidly decrease in prices of Canon printers induced its technological development (price elasticity to technology hypothesis).

2.2.5 Elasticity of relative technology prices to technology

Since our prime concern lays on the countervailing power to technology development relative to production on the basis of the results of Equations (12) and (13) by means of Equation (9), the elasticity of relative technology prices to technology stock was developed as follows:

$$\lambda = -\frac{\partial \ln T}{\partial \ln P} = -\frac{\partial \ln T}{\partial \ln P_{\mathrm{tr}}} \Bigg/ \left(1 - \frac{\partial \ln P_{\mathrm{vr}}}{\partial \ln P_{\mathrm{tr}}}\right) = \mu \Big/ (1-\omega) = \frac{0.755(1+1.3\tau)}{1-0.645(1+0.8\tau)} \tag{15}$$

Figure 5 demonstrates trends in this elasticity over the period 1985–1998 measured by Equation (15).

Looking at Figure 5 we note that, while elasticity of relative prices of printers' technology to their technology stock λ also exhibited positive and demonstrated that decrease in relative prices of technology induces further technology development its level changed as a function of technology progress in printers. λ demonstrated stable with higher level over the period 1985–1988, when sales of printers initiated by LBP (laser beam printers) have shown rapid increase (see Figure 2). λ changed to decreasing trend over the period 1989–1993, when sales of LBP has stagnated λ then stopped its decreasing trend and changed to stable again over the period 1994–1998, when sales of

BJ (bubble jet printers) have shown rapid increase. In addition Equation (15) suggests that this elasticity increases as PT progress τ increases as $d\lambda/d\tau = \{0.738/[1-0.645(1+0.8\tau)]^2\} > 0.$ These observations suggest that the level of the elasticity decreases without rapid increase in production by means of the emergence of the new technology stock even by the decrease in relative prices of technology.

Figure 5 Trends in elasticity of relative prices to PT (1985–1998)

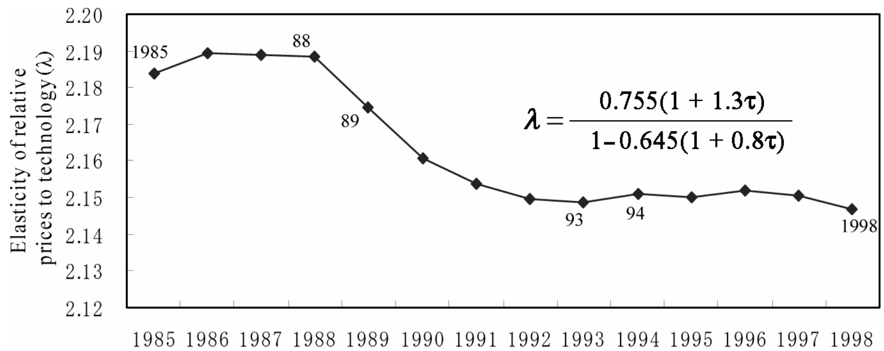


Figure 5 and 6 are with the same vertical range (1.21–1.13 = 2.20–2.12 = 0.08).

2.3 *Measurement of elasticity of technology to technology competition (ϕ) – a case of Canon printers*

2.3.1 *Techno-production non-countervailing ratio: TP-NCR (M)*

From equations of elasticity of prices of printers' technology and elasticity of prices of printers: $\varepsilon_t = -(\partial \ln T / \partial \ln P_t)$ and $\varepsilon_v = -(\partial \ln V / \partial \ln P_v)$, TP-NCR M can be developed as follows:

$$M = \frac{\left(1+\dfrac{1}{\varepsilon_t - 1}\right)}{\left(1+\dfrac{1}{\varepsilon_v - 1}\right)} = \frac{\varepsilon_t}{\varepsilon_v} \times \frac{\varepsilon_v - 1}{\varepsilon_t - 1} = \frac{\left(-\dfrac{\partial \ln T}{\partial \ln P_t}\right)}{\left(-\dfrac{\partial \ln V}{\partial \ln P_v}\right)} \times \frac{\left(-\dfrac{\partial \ln (V \times P_v)}{\partial \ln P_v}\right)}{\left(-\dfrac{\partial \ln (T \times P_t)}{\partial \ln P_t}\right)}$$

$$= \frac{-(\partial \ln T / \partial \ln P_t)}{-(\partial \ln V / \partial \ln P_v)} \times \frac{-(\partial \ln \mathrm{GC} / \partial \ln P_v)}{-(\partial \ln \mathrm{GTC} / \partial \ln P_t)} \tag{16}$$

$$= \left(\frac{(\partial \ln T / \partial \ln V) \times (\partial \ln V / \partial \ln P_t)}{(\partial \ln V / \partial \ln P_t) \times (\partial \ln P_t / \partial \ln P_v)}\right) \times \left(\frac{(\partial \ln \mathrm{GC} / \partial \ln \mathrm{GTC}) \times (\partial \ln \mathrm{GTC} / \partial \ln P_v)}{(\partial \ln \mathrm{GTC} / \partial \ln P_v) \times (\partial \ln P_v / \partial \ln P_t)}\right)$$

$$= \left(\frac{\partial \ln T}{\partial \ln V} \times \frac{\partial \ln P_v}{\partial \ln P_t}\right) \times \left(\frac{\partial \ln \mathrm{GC}}{\partial \ln \mathrm{GTC}} \times \frac{\partial \ln P_t}{\partial \ln P_v}\right) = \left(\frac{(\partial \ln \mathrm{GC})/(\partial \ln \mathrm{GTC})}{(\partial \ln V)/(\partial \ln T)}\right)$$

Similar to technology stock T in Equation (10), gross product V can also be depicted as a Cobb–Douglas type function of technology stock T and change rate of TFP τ and gross production cost GC can be depicted by a function of gross technology cost GTC and change rate of TFP τ as demonstrated in Tables 3 and 4, which summarise the elasticity coefficients and contribution coefficients: φ and γ_φ as well as ξ_0 and γ_ξ of Canon printers over the period 1985–1998, respectively.

Table 3 Regression between technology stock and gross production (1985–1998)

$\ln V = \ln B_1 + \varphi_0(1 + \gamma_\varphi\tau)\ln T$

γ_φ	$\ln B_1$	φ_0	*adj.* R^2	*DW*	*AIC*
0	3.408 (18.095)	1.213 (25.372)	0.991	2.57	–20.6140
1.2	3.337 (17.498)	1.223 (25.422)	0.991	2.52	–20.6682
1.3	**3.331** **(17.446)**	**1.224** **(25.422)**	**0.991**	**2.51**	**–20.6684**
1.4	3.326 (17.393)	1.225 (25.421)	0.991	2.51	–20.6679

φ_0: initial level of the elasticity of technology stock T to gross production V; γ_φ: contribution coefficient of change rate of TFP to gross production.

From the analytical results of Tables 3 and 4 by means of AIC comparison elasticity of technology stock to gross product φ and elasticity of gross technology costs to gross production costs ξ can be developed as follows:

$$\varphi = \frac{\partial \ln V}{\partial \ln T} = 1.224(1 + 1.3\tau) \tag{17}$$

$$\xi = \frac{\partial \ln \mathrm{GC}}{\partial \ln \mathrm{GTC}} = 1.490(1 - 1.9\tau) \tag{18}$$

Applying results obtained from Equations (17) and (18), Equation (16) can be developed as follows:

$$M = \frac{\dfrac{\partial \ln \mathrm{GC}}{\partial \ln \mathrm{GTC}}}{\dfrac{\partial \ln V}{\partial \ln T}} = \frac{\xi}{\varphi} = \frac{1.490(1 - 1.9\tau)}{1.224(1 + 1.3\tau)} = \frac{1.217(1 - 1.9\tau)}{1 + 1.3\tau} \tag{19}$$

Figure 6 demonstrates trend in M over 1985–1998 by Equation (19).

Table 4 Regression between gross technology costs and gross production costs (1985–1998)

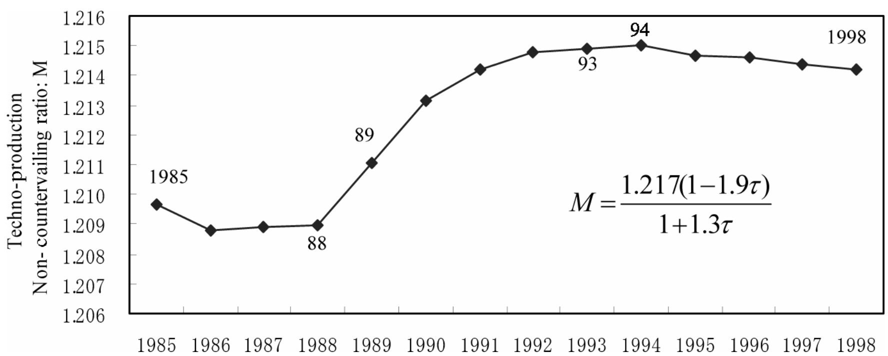
$\ln \mathrm{GC} = \ln B_2 + \xi_0(1 + \gamma_\xi\tau)^{\ln \mathrm{GTC}}$

γ_ξ	$\ln B_2$	ξ_0	*adj.* R^2	*DW*	*AIC*
0	3.688 (27.491)	1.507 (33.547)	0.989	1.86	–22.5512
–1.9	**3.785** **(28.992)**	**1.490** **(33.747)**	**0.989**	**1.88**	**–22.7165**
–2.0	3.790 (29.063)	1.488 (33.746)	0.989	1.88	–22.7159
–2.1	3.795 (29.132)	1.487 (33.745)	0.989	1.88	–22.7143

ξ_0: initial level of the elasticity of gross production cost to gross technology; γ_ξ: contribution coefficient of change rate of TFP gross production cost.

Looking at Figure 6 we note that the TP-NCR of Canon printers *M* ranged between 1.209 and 1.215 over the period examined. This demonstrates that the Canon put additional prices on marginal cost of its PT stock more than 20% higher than those on marginal cost of printers ($m_t \approx 0.2 + 1.2m_v$ [5], where m_t and m_v are mark-up ratios of technology and products in printers respectively) and there was no countervailing power in the process of technological development relative to production thus market in printers' technology development was under imperfect competition.

Figure 6 Trend in techno-production non-countervailing ratio of Canon printers (1985–1998)



While the change in the level of *M* is small as between 1.209 and 1.215 if we observe the trend in *M* carefully, we note that *M* increased rapidly (toward further monopoly) over the period 1989–1993 and it tended to decrease (toward competition) after 1994 corresponding to stagnation of LBP and increase in BJ respectively. Since Equation (19) suggests that *M* decreases as printers' technology progress τ increases as $(dM/d\tau) = -\left[3.895/(1+1.3\tau)^2\right] < 0$, these increase and decrease can be attributed to Canon's printers' technology progress efforts in respective period.

2.3.2 Relationship between change rates of TFP (τ) and technology stock (t)

Since printers' technology progress (TFP change rate) τ plays a significant role in stimulating the competitive state of technology relative to production (decrease in *M*) and increasing the elasticity of prices to technology ($\lambda^{\#}$ and λ), contribution of technology stock (*T*) to its increase should be identified.

TFP change rate τ can be developed as follows:

$$\tau = \frac{\Delta \text{TFP}}{\text{TFP}} = \left(\frac{\partial V}{\partial T} \times \frac{T}{V}\right)\frac{\Delta T}{T} = \frac{\partial \ln V}{\partial \ln T} \times \frac{\Delta T}{T} \qquad (20)$$

Applying the results of the identification of the elasticity of technology stock to gross product φ in Equation (17), τ can be depicted as follows:

$$\tau = \left(\frac{\partial V}{\partial T} \times \frac{T}{V}\right)\frac{\Delta T}{T} = \frac{\partial \ln V}{\partial \ln T} \times \frac{\Delta T}{T} = 1.224(1+1.3\tau) \times \frac{\Delta T}{T} = \frac{1.224(\Delta T/T)}{1-1.59(\Delta T/T)} \qquad (21)$$

Equation (21) suggests that the increase in technology stock $\left(\frac{\Delta T}{T}\uparrow\right)$ leads to TFP increase ($\tau\uparrow$) in Canon's printers $\left[\frac{d\tau}{d\left(\Delta T/T\right)}=\frac{1.224}{\left(1-1.591\times\Delta T/T\right)^2}>0\right]$.

2.3.3 Impact of change rate of technology on techno-production non-countervailing ratio

From Equation (19), M can be depicted as a function of τ as $M=1.217(1-1.9\tau)/(1+1.3\tau)$. In addition from Equation (21) τ can be depicted as a function of $\Delta T/T$. Therefore, M can be developed as a function of $\Delta T/T$ as follows:

$$M=\frac{1.217\left[1-1.9\left(\frac{1.224(\Delta T/T)}{1-1.591(\Delta T/T)}\right)\right]}{\left[1+1.3\left(\frac{1.224(\Delta T/T)}{1-1.591(\Delta T/T)}\right)\right]}=1.217-4.350(\Delta T/T) \tag{22}$$

Equation (22) suggests that in case, when change rate of technology stock $(\Delta T/T)$ is in the range of $0<(\Delta T/T)<(1.217/4.350)=0.280$, increase in technology stock reduces the TP-NCR M in Canon printers development demonstrating the stimulation of the competitive circumstances in technology development towards the similar level to competitive circumstances in production.

2.3.4 Elasticity of Canon PT to technology competition (ϕ)

Elasticity of Canon printers' technology to technology competition ϕ can be developed as follows:

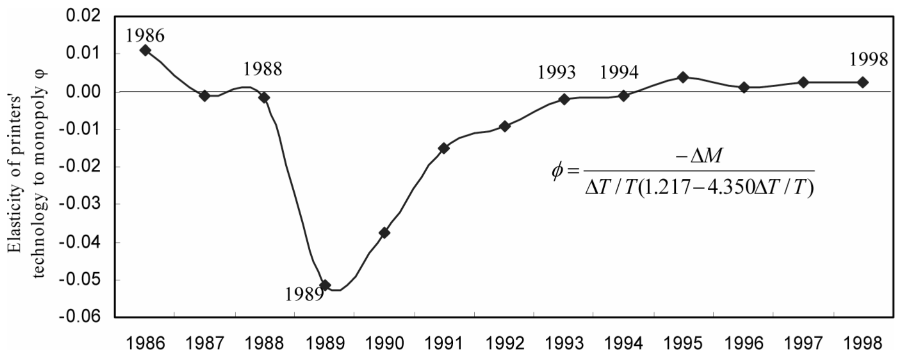
$$\phi=-\frac{\partial\ln M}{\partial\ln T}=-\left(\frac{\Delta M/M}{\Delta T/T}\right)=-\frac{\Delta M}{M(\Delta T/T)} \tag{23}$$

Since $M = 1.217 - 4.350(\Delta T/T)$ as depicted in Equation (22), ϕ can be developed as:

$$\phi=\frac{-\Delta M}{\Delta T/T[1.217-4.350(\Delta T/T)]} \tag{24}$$

Applying the results of the analysis obtained from the analysis of (Section 2.3.3) M decreases in response to increase in technology stock T leading to improvement of technology competitive circumstances relative to those of production and it can be expected that M will tend to 1 under perfect competition in which technology is in the similar competitive condition as that of production and ϕ increases its positive value accordingly. Figure 7 demonstrates the trend in elasticity of Canon PT to technology competition ϕ over the period 1986–1998.

Figure 7 Trends in elasticity of Canon printers' technology to technology competition (1986–1998)



Looking at Figure 7 we note that over the period 1986–1988 (rapid increase in LBP) and 1994–1998 (rapid increase in BJ) the elasticity of Canon PT to technology competition ϕ demonstrates positive, which indicates that M decreased in response to increase in technology stock T and market structure of PT tended to competitive state relative to that of production. Contrary to these periods ϕ demonstrates negative over the period of 1989–1993 (stagnation of LBP), which indicates that M increased in response to increase in technology stock T and monopolistic market structure of PT relative to that of production tend to be strengthened.

These observations suggest that while the elasticity of Canon printers' technology to technology competition demonstrates positive and increase in technology stock induced technology competition during the rapid increase in production by means of the emergence of the new innovation, this elasticity demonstrates negative without such increase in production resulting in technology non-competitive structure relative to that of production. Analyses in Section 2.2 suggest that these periods correspond to the periods of active technology development (rapid increase in LBP and BJ) and stagnation in this development (stagnation of LBP), respectively; thus analyses in Sections 2.2 and 2.3 demonstrate the second hypothesis that technological development lead to improvement of competitive circumstances in Canon PT.

2.4 Measurement of functionality development – a case of Canon printers

Given that diffusion velocity of technology a does not change remarkably from Equation (6), functionality development FD can be approximated as follows:

$$\text{FD} \approx \frac{2}{1+(1/aT)\left(1/\lambda-\phi\right)} \tag{6a'}$$

Substituting the results of the empirical analyses obtained by Equations (15) and (24) for λ and ϕ in Equation (6a'), FD can be computed as illustrated in Figure 8, which demonstrates that functionality development in Canon printers continued to increase over the whole period examined, which can largely be attributed to the increase in technology stock T.

Figure 8 Trends in degree of functionality development in Canon printers with and without the influence of technology competition (1986–1998)

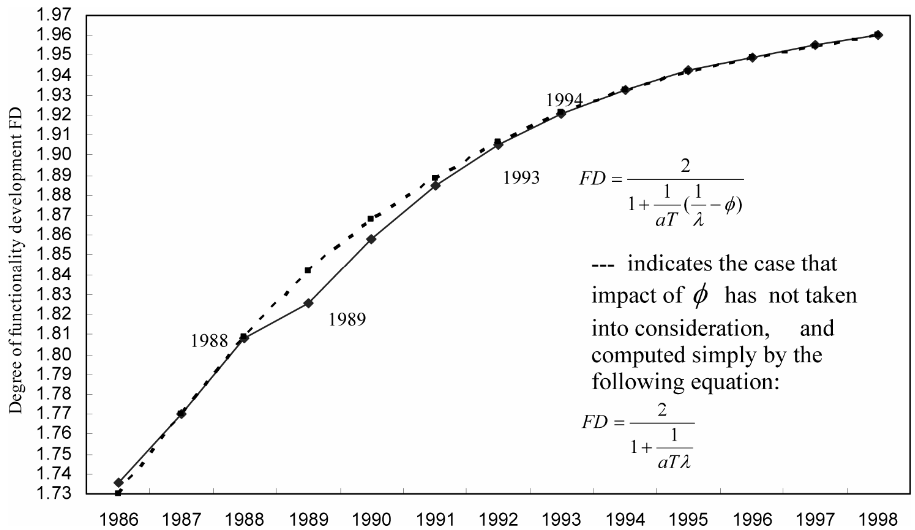


Figure 8 suggests that over the period 1986–1988 and 1994–1998 there was no substantial influence of technology structure in competition relative to production (effect of elasticity of Canon PT to technology competition ϕ) on degree of Canon printers functionality development, and over the period 1989–1993 higher functionality development could have been expected without influence of monopoly in other words functionality development was decreased by the monopolistic structure in technology relative to production.

However, the effect of the monopoly was not so significant, which implies that there should be a limit of the inducement of functionality development by means of the improvement of competitive circumstances within the supply of side efforts.

These observations do not correspond to the third hypothesis that the improvement of competitive circumstances contributed to the functionality development in Canon printers development. This miscorrespondence urges us to analyse the dynamism beyond supply side efforts.

3 Dynamism of countervailing power between supply and demand markets in printers development (Demonstration of the Hypothesis of Demand Side)

3.1 Impact of functionality development on induction of supply and demand – a case of Canon printers

3.1.1 Printers functionality development and inducement of PC*s demand*

Development of printers induces the demand of PCs (Watanabe and Ane, 2004) and FD of printers accelerates such inducement; therefore, the relationship between them can be depicted as follows:

$$\ln \mathrm{PC}_t = \ln C_1 + \kappa_0 (1 + \delta_\kappa \mathrm{FD}^n) \ln V_{t-1} + b \times D \tag{25}$$

where: PC_t shipment of PCs at time t; C_t: scale factor; κ_0: initial level of elasticity of sales of printers to shipment of PCs; FD: functionality development of printers; V_{t-1}: sales of printers at time $t-1$; and D: dummy variables, 1996–1998 = 1, and other years = 0.

By Equation (25), regression between sales of Canon printers and their customers represented by shipment of PCs can be computed and the result of the computation over the period 1986–1998 is demonstrated in Table 5.

Table 5 Regression between sales of Canon printers and shipment of PC*s* (1986–1998)

n [6]	δ_κ	$\ln C_1$	κ_0	B	*adj.* R^2	*DW*	*AIC*
	0	–7.933 (–37.916)	7.707 (81.092)	–0.075 (–3.796)	0.998	1.19	–43.730
2	0.003	–8.192 (–61.052)	7.780 (128.368)	–0.060 (–4.780)	0.999	1.49	–64.213
	0.004	**–8.276** **(–63.027)**	**7.802** **(131.812)**	**–0.055** **(–4.505)**	**0.999**	**1.81**	**–64.848**
	0.005	–8.359 (–57.935)	7.824 (120.535)	–0.050 (–3.760)	0.999	2.05	–62.703

By means of the identification of the statistically most significant values Equation (25) can be identified as follows:

$$\ln \mathrm{PC}_t = -8.276 + 7.802(1+0.004\mathrm{FD}^2)\ln V_{t-1} - 0.055D \tag{25'}$$

3.1.2 PC*s demand increase and inducement of printers development*

Furthermore, increase in PCs demand induces further development of printers (Watanabe and Ane, 2004) thus the following regression can be depicted:

$$\ln V_t = \ln C_2 + \upsilon \ln \mathrm{PC}_{t-1} \tag{26}$$

where V_t: sales of printers at time t; C_2 : scale factor; υ: elasticity of shipment of PC to sales of printers and PC_{t-1}: shipment of PCs at time $t-1$.

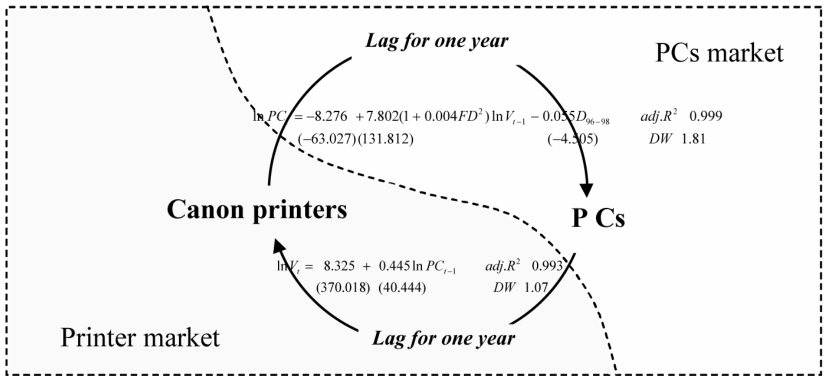
Similarly, Tables 5 and 6 demonstrates the result of the regression analysis between shipment of PCs and sales of Canon printers over the period of 1986–1998.

Table 6 Regression between shipment of PCs and sales of printers (1986–1998)[7]

$\ln C_2$	υ	*adj.* R^2	*DW*
8.325 (370.018)	0.445 (40.444)	0.993	1.07

Basis of the foregoing analysis supply and demand virtuous cycle between Canon printers and PCs can be developed in Figure 9.

Figure 9 Virtuous cycle between Canon printers and PC (1986–1998)



This demonstrates the first and second demand side hypothesis that functionality development of Canon printers increased in PCs demand and increase in PCs demand induced further development of printers.

3.2 Contribution to prices decrease from both supply and demand sides - a case of Canon printers and Japan's PCs

3.2.1 Influence of a virtuous cycle of supply and demand, technology competition on prices of printers

As a consequence of a virtuous cycle between supply and demand of printers and PCs prices of printers demonstrate a dramatic decrease as observed in Figure 1. Furthermore these prices are influenced by competitive state of technology structure relative to production (M). Therefore, taking into account of the trend in TP-NCR as illustrated in Figure 6 the regression between them can be depicted as follows:

$$\ln P_{\mathrm{vr}} = \ln C_3 + \theta_0 (1 + D_1 \delta_{\theta 1} M + D_2 \delta_{\theta 2} M + D_3 \delta_{\theta 3} M) \ln \mathrm{CV} + b_3 \ln \mathrm{CPC} + b_4 \times D_4 \qquad (27)$$

where P_{vr}: fixed price of printers; C_3 scale factor; θ_0: initial level of elasticity of cumulative sales to price of printers; $\delta_{\theta i}$ ($i = 1$~3): contribution coefficient of TP-NCR; CV: cumulative sales of printers (at 1995 fixed prices); CPC: cumulative shipment of PCs (million sets); dummy variables: D_1: 1986–1988 = 1; D_2: 1989–1993 = 1; D_3: 1994–1998 = 1; D_4: 1996 = 1 and other years = 0.

Results of the regression analysis over the period 1986–1998 by Equation (27) are summarised in Table 7.

Table 7 Regression between cumulative sales of printers, cumulative shipment of pcs and price of printers (1986–1998)[8]

	$\ln C_3$	θ_0	b_3	b_4	$adj.\ R^2$	DW	AIC
$\delta(\delta_{\theta 1}, \delta_{\theta 2}, \delta_{\theta 3})=0$	4.264 (12.292)	−0.183 (−4.662)	−0.249 (−10.154)	0.012 (1.751)	0.999	1.69	−89.274
$\delta_{\theta 1} = -0.102$ $\delta_{\theta 2} = -0.089$ $\delta_{\theta 3} = -0.091$	**4.109 (16.173)**	**−0.158 (−5.162)**	**−0.273 (−15.543)**	**0.015 (2.383)**	**0.999**	**2.52**	**−91.201**

Looking at Table 7, we note that increase in cumulative sales of Canon printers (CV) and shipment of PCs (CPC) contributed prices decrease in printers and the virtuous cycle between supply and demand sides observed in Section 3.1 contributed greatly to decrease in prices of Canon printers and influence of competitive state of technology structure relative to production (*M*) on prices of printers can not be overlooked. While over the period 1986–1988 (rapid increase in LBP) and 1994–1998 (rapid increase in BJ), increase in competition (decrease in *M*) accelerated prices decrease in Canon printers over the period 1989–1993 (stagnation of LBP) when *M* increased demonstrating monopolistic state resulted in increase in prices of Canon printers.

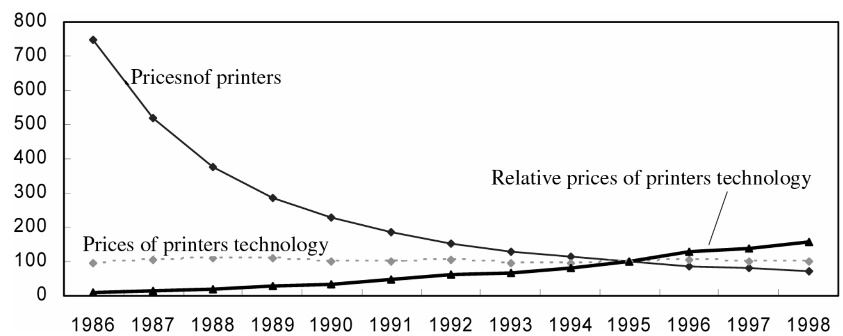
These observations demonstrate the third demand side hypothesis that improvement of competitive circumstances decreased in prices of printers.

3.2.2 Influence of demand of printers and PC, technology competition on relative prices of PT

3.2.2.1 Trend in relative prices of PT

Figure 10 demonstrates the trend in relative prices of Canon PT over the period of 1986–1998, and a comparison of this trend with trends in prices of printers and prices of PT.

Figure 10 Trends in fixed prices of printers, prices of PT and relative prices of printers' technology (1986–1998)–Index: 1995 = 100



From Figure 10 we note that while the prices of PT maintained almost the same level over the period examined prices of printers have shown dramatic decrease, which leading to the relative prices of PT continued as slightly increased.

3.2.2.2 Implications of increasing trend in relative prices of PT

Increasing trend in relative prices of PT provides as the following significant postulates:

1 Whether price elasticity of technology $\left[\lambda = -\left(\partial \ln T / \partial \ln P\right)\right]$ functioned or not.

Since λ maintains positive (Figure 5) increasing trend in relative prices of technology should react to decrease in technology stock. Nevertheless technology stock maintains increasing trend, which suggests that other mechanism rather than λ strongly functioned in inducing technology stock.

2 Whether elasticity of competition to relative prices of technology $[\gamma = \partial \ln P / \partial \ln M]$ functioned or not.

Since γ demonstrates negative over the, whole period examined except 1995–1998 (when M demonstrated decreasing trend) as illustrated in Figure 11 increasing trend of relative prices of technology suggests that the mechanism of γ did not function as anticipated (see footnote 10).

3 How marginal productivity of technology ($\partial V/\partial T$) which is a ratio of P and M (P/M) and a source of functionality development $[\mathrm{FD} = 1/1 - (\partial V/\partial T)/aV]$ can be maintained. Figure 12 illustrates trend in marginal productivity of technology over the period 1986–1998.

While Figure 12 demonstrates that the marginal productivity of Canon PT continued to increase this can simply be attributed to successive increase in P as demonstrated in Figure 10 not to substantial decrease in M. However, in a competitive circumstance, where both P and M decrease optimal balance between decreases in P and M should be constructed[9].

Figure 11 Trends in elasticity of competition to relative prices of technology (1986–1998)

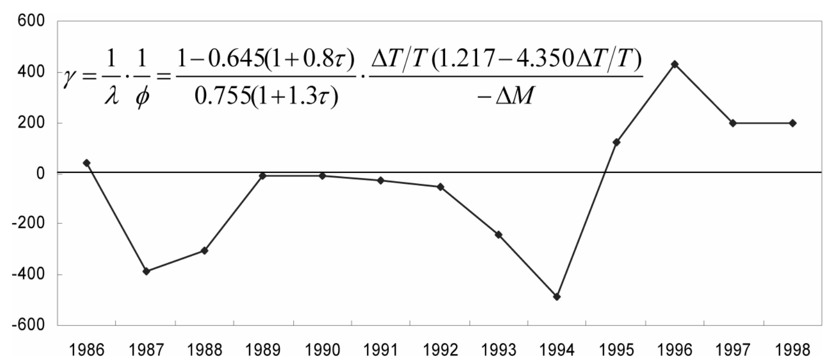
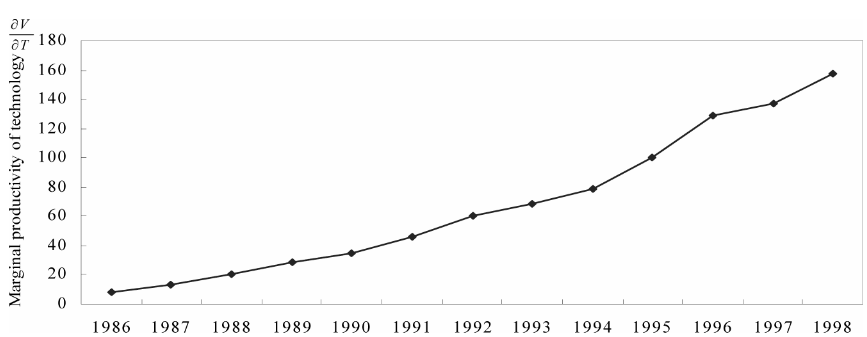


Figure 12 Trend in marginal productivity of technology in Canon printers (1986–1998) – Index: 1995=100.



3.2.2.3 Governing factors of prices of PT

Similar to two factors learning effects with technology competition effect as depicted in Equation (27) to which both cumulative sales of printers (CV) with technology competition effect and cumulative shipment of PCs (CPC) contributed to decrease in prices of printers and printers' technology prices function can be depicted by the following equation:

$$\ln P_{\mathrm{tr}} = \ln C_4 + \pi_0 (1 + D_1\delta_{\pi 1}M + D_2\delta_{\pi 2}M + D_3\delta_{\pi 3}M) \ln \mathrm{CV} + b_5 \ln \mathrm{CPC} + b_6 \times D_4 \quad (28)$$

where P_{tr}: fixed price of PT; C_4: scale factor; π_0: initial level of elasticity of cumulative sales to the price of printers' technology; $\delta_{\pi i}$ ($i = 1{\sim}3$): contribution coefficient of TP-NCR; CV: cumulative sales of printers (at 1995 fixed prices); CPC: cumulative shipment of PCs (million sets); dummy variables: D_1: 1986–88 = 1; D_2: 1989–93 = 1; D_3: 1994–1998 = 1; D_4: 1996 = 1, and other years = 0.

Results of the regression analysis by Equation (28) over the period 1986–1998 are summarised in Table 8.

Table 8 Regression between cumulative sales of printers, cumulative shipment of pc and prices of PT (1986–1998)

	ln C_4	π_0	b_5	b_6	*adj.* R^2	*DW*	*AIC*
$\delta(\delta_{\pi 1}, \delta_{\pi 2}, \delta_{\pi 3}) = 0$	3.877	0.565	−1.248	−0.085	0.999	2.14	−45.597
	(−2.084)	(2.684)	(−9.480)	(−2.295)			
$\delta_{\pi 1} = -0.083$ $\delta_{\pi 1} = -0.091$ $\delta_{\pi 1} = -0.100$	**3.025** **(−2.366)**	**0.690** **(4.230)**	**−0.366** **(−4.295)**	**−0.077** **(−2.263)**	**0.992**	**2.63**	**−47.997**

From Table 8 we note that similar to the case of prices of printers cumulative shipment of PCs (CPC) contributed to decrease in prices of PT. However, contrary to the case of prices of printers cumulative sales of Canon printers (CV) reacted to increase in prices of PT.

In addition, the results of this analysis show that monopolistic state of technology relative to production (*M* increase) reacted to decrease prices of PT, while the competitive state (*M* decrease) increased them. These results can be interpreted as follows:

1 In a market under monopoly structure (1989–1993) Canon was able to secure resources of R&D selective way so that it can develop an idealistic new technology with the highest productivity, which resulted in decrease in prices of PT.

2 In a market under competition structure (1986–1988 and 1994–1998) in order to win the race with other competitors Canon endeavoured to take every effort for advancement and differentiation of its technology, which resulted in increase in prices of PT.

3 Trend in TP-NCR of Canon printers as demonstrated in Figure 6 suggests that the Canon put higher additional prices on its marginal cost of PT in the period of monopoly structure, when lower technology prices can be expected than the period of competition structure thereby it stabilised its prices of PT over the period examined as demonstrated in Figure 10.

As far as the PT prices (not printers prices) are concerned these observations and interpretations do not correspond to the third demand side hypothesis that improvement of competitive circumstances decreased in prices of printers.

3.2.2.4 Governing factors of relative prices of PT

Utilising Equations (27) and (28), relative prices of printers' technology can be developed as follows:

$$\ln P \approx \ln P_{\text{tr}} - \ln P_{\text{vr}}$$

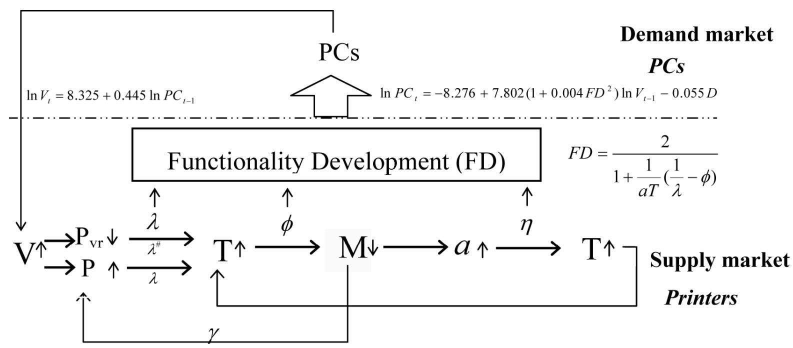
$$= -1.084 + 0.848\,(1 - 0.086\text{D}_1 M - 0.091\text{D}_2 M - 0.107\text{D}_3\, M)\ln \text{CV} - 0.093 \ln \text{CPC} - 0.097\text{D}_4 \qquad (29)$$

Equation (29) demonstrates the similar structure as Equation (28) depicting PT prices and suggests that while PCs demand (CPC) increase contributed to decrease in relative prices of PT increase in demand of printers (CV) and activation of competitive circumstances of printers supply (decrease in *M*) reacted to increase in relative prices of the PT.

3.3 The role of techno-countervailing power

By integrating the major results of the analyses of both supply and demand sides Figure 13 illustrates techno-production dynamism between supply and demand markets in Canon's printers development over the period 1986–1998.

Figure 13 Techno-Production dynamism between supply and demand market – *a case of Canon's printers development* (1986–1998)



$$\ln P_{vr} = 4.109 - 0.158(1 - 0.102 D_1 M - 0.089 D_2 M - 0.091 D_3 M)\ln CV - 0.273 \ln CPC + 0.015 \cdot D_4$$

$$\ln P = -1.084 + 0.848(1 - 0.086 D_1 M - 0.091 D_2 M - 0.107 D_3 M)\ln CV - 0.093 \ln CPC - 0.097 \cdot D_4$$

$$\lambda^{\#} = -\frac{\partial \ln T}{\partial \ln P_{vr}} = 1.171\frac{(1+1.3\tau)}{(1+0.8\tau)}$$

$$\lambda = -\frac{\partial \ln T}{\partial \ln P} = \frac{0.755(1+1.3\tau)}{1-0.645(1+0.8\tau)}$$

$$\phi = -\frac{\partial \ln M}{\partial \ln T} = \frac{-\Delta M}{\Delta T/T(1.217 - 4.350\,\Delta T/T)}$$

$$\gamma = \frac{\partial \ln P}{\partial \ln M} = \frac{1}{\lambda}\cdot\frac{1}{\phi}$$

$$M = \frac{1.217(1-0.9\tau)}{1+1.3\tau} = 1.217 - 4.350\,\Delta T/T$$

$$\tau = \frac{\Delta TFP}{TFP} = \frac{1.224\,\Delta T/T}{1-1.591\,\Delta T/T}$$

Figure 13 suggests that the prime locomotive of the dynamism is initiated by products market rather than the technology market, while technological progress plays the key role in developing printers market.

Main stream of the dynamism can be traced as follows:

1. Dramatic decrease in printers prices (prices of products: P_{vr}) induced vigorous technological development leading to increase in price elasticity of technology stock ($\lambda^{\#}$) as well as technology stock (T) which significantly contributed to the functionality development (FD) in printers.
2. Significant increase in this functionality development induced PCs demand, which induced further development of printers, while contributing simultaneously to further decrease in printers prices.
3. In the course of this dynamism in products market competitive circumstances were improved, which reacted to further accerelate this dynamism. Thus, a virtuous cycle between price decrease, technological development, functionality development as well as improvement of competitive circumstances in printers supply market and subsequent increase in printers demand in the demand market as a consequence of the increase in PCs demand were constructed.
4. Contrary to such an activated virtuous cycle in products market, technology market was far behind the activated virtuous cycle in the products market.
5. Consequently, relative prices of PT (P) continued to slight increase which, with a positive value of elasticity of relative prices to PT (λ) reacted to impede increase in technology stock.
6. In addition, a vicious cycle between increase in printers production, relative prices of PT and competitive state of technology relative to production can not be overlooked.

4 Conclusion

In light of the increasing significance of the optimal co-evolution between competition and monopoly for significant technological innovation in a mega-competition, while facing an increasing constraints in R&D funding this paper attempted to demonstrate this postulate by analysing the interacting dynamism between technological development and production in the printer market as well as subsequent demand increase in the personal computer market driven by new functionality development of printers. On the basis of an empirical analysis of Canon printers and Japan's personal computers the significant role of techno-countervailing power between supply and demand in inducing and disseminating new functionality was demonstrated.

Noteworthy findings obtained include:

1. Rapid decrease in prices of Canon printers induced its technological development the level of price elasticity to PT decreased without rapid increase in printers production by means of the emergence of the new technology and technological development leveraged to improve competitive circumstances in Canon PT.

However, there was no substantial countervailing power in the process of technological development relative to production thus market in PT development was under imperfect competition. Therefore, there should be a certain limit of the inducement of functionality development by means of the improvement of competitive circumstances within the supply side efforts

2 Functionality development of Canon printers increased in PCs demand in the demand market and this increase induced further development of printers in the supply market, while improvement of competitive circumstances in printers development decreased in prices of printers this was not the case in PT prices and this can be attributed to the indigenous nature of technology development that while a firm can secure resources of R&D selective way so that it can develop an idealistic new technology with the highest productivity in the monopoly market it is urged to endeavour to take every effort for advancement and differentiation of its technology in order to win the race with other competitors in the competitive market.

These findings lead to the following policy implications:

1 Given the sustainable increase in qualified technology is indespensable for maintaining a virtuous cycle between price decrease, technologyical development, functionality development and improvement of competitive circumstances initiated by products market restructuring of the technology market should be targetted for the next generation printers development.

2 In addition, given that increase in technology stock and marginal productivity of technology are essential for constructing this virtuous cycle and sustainability of the functional development, quantitative increase and qualitative improvement of technology stock should be satisfied simultaneously.

3 Furthermore, considering that sustainability of marginal productivity of technology demands on the optimal balance between relative prices of technology and competitive state in technology structure and that there remains certain limit in maintaining this optimal balance within the supply market techno-countervailing power between supply and demand markets leading to satisfy and stimulate the above conditions is essential.

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Notes

[1]When a is constant, $1/\eta = 0$ in Equation (6). λ, ϕ and η are defined as the relationship elasticity between P, T, M and a respectively.

[2]In general stable stations RDEF can be approximated as $\text{RDEF} \approx \text{WPI}$.

[3]The AIC can be generally calculated by the following equation: AIC = n ln(RSS/n) + 2K where n: number of observations; RSS: residual sums of square; and K: number of parameters in the model.

[4] # indicates that elasticity of printers prices to technology is different from elasticity of relative prices of PT to technology (λ).

[5] $M = \frac{1+m_t}{1+m_v} \approx 1.2 \qquad m_t \approx 0.2 + 1.2m_v$

[6]The value n is identified by a heuristic approach which determines most statistically significant value.

[7]Based on Equations (25) and (26) the role of functionality development on sales of Canon printers are focused and the relationship between printers and PCs are demonstrated by means of separate equations by examining two-stage least squares as depicted as follows:

$\ln V_t = 8.123 + 0.511 \ln PC$ adj.R^2 0.994
(428.89)(44.96)

The result is similar to the results of separate equations as summarised in Table 6, which demonstrates that the analysis by separate equations can be considered reasonable.

[8]Although freedom of the analytical results of Tables 7 and 8 is 9, we have checked the results again regarding lnCPC as constant term by heuristic approach and got similar significant results to those shown in Table 7 and 8 this proved that the results of Table 7 and 8 are statistically significant in spite of their a little low level of freedom.

[9]This optimal balance is equivalent to $\gamma = (\partial \ln P/\partial \ln M) > 1$ which implies $[d/dt\,(\partial V/\partial T)]/(\partial V/\partial T) > 0$ (marginal productivity of technology continues to increase) as $[d/dt\,(\partial V/\partial T)]/(\partial V/\partial T) = (\Delta P/P) - (\Delta M/M)$ and $\gamma = (\partial \ln P/\partial \ln M) = [(\Delta P/P)/(\Delta M/M)] > 1$ leads $(\Delta P/P) > (\Delta M/M)$.

[10]Under the perfect competition, since the prices are eternal to any changes in production factors, these differentiations are 0.

[11] $\gamma = \partial \ln P/\partial \ln M$ indicates elasticity of competition to prices of technology: technology competition relative to production competition induces price decrease. Since $\gamma = (1/\lambda) \times (1/\phi)$, γ reduces as λ and ϕ increase thus there exists certain self constraints in this feedback cycle.

Appendix:

Appendix A1: Explanation of the development of relative prices of PT

Gross product of a firm can be depicted as follows:

$$V = F\,(X, T)$$

where V: gross product (GDP); X: labour (L) and capital (K); and T: technology stock.

Profit of a firm π is considered as gross income (gross product cost) except for labour, capital and technology costs as follows:

$$\pi = \text{GC} - \sum_{X=L,K} \text{GXC-GTC}$$

where given that P_v: current price of product and P_t : current price of technology, GC: gross product cost (current price) $=P_v \times V$; GXC: = GLC + GCC: labour and capital cost (current price); and GTC: technological cost (current price) $=P_t \times T$.

Taking differentiation of GC by T, marginal revenue of technology stock (MR) can be depicted as:

$$\text{MR} = \frac{\partial \text{GC}}{\partial T} = \frac{\partial (P_v \times V)}{\partial T} = P_v \frac{\partial V}{\partial T} + V \frac{\partial P_v^{10}}{\partial T} = P_v \frac{\partial V}{\partial T}\left(1 - \frac{1}{\varepsilon_v}\right)$$

where $\varepsilon_v = -\frac{\partial \ln V}{\partial \ln P_v}$ (elasticity of prices of printers to gross product).

Similarly, taking differentiation of gross technology cost GTC by technology stock T, marginal cost of technology stock MC can be depicted as follows:

$$\text{MR} = \frac{\partial \text{GTC}}{\partial T} = \frac{\partial (P_t \times T)}{\partial T} = P_t + T\frac{\partial P_t}{\partial T} = P_t\left(1 + \frac{T}{P_t} \times \frac{\partial P_t}{\partial T}\right) = P_t\left(1 - \frac{1}{\varepsilon_t}\right)$$

where $\varepsilon_t = -(\partial \ln T / \partial \ln P_t)$ (elasticity of prices of PT to technology stock).

Since marginal income is equal to marginal cost, the following equation can be obtained:

$$P_v \frac{\partial V}{\partial T}\left(1 - \frac{1}{\varepsilon_v}\right) = P_t\left(1 - \frac{1}{\varepsilon_t}\right)$$

$$\frac{\partial V}{\partial T} = \frac{P_t}{P_v} \times \frac{1 - (1/\varepsilon_t)}{1 - (1/\varepsilon_v)} \equiv P\frac{1 - (1/\varepsilon_t)}{1 - (1/\varepsilon_v)}$$

where $P = P_t / P_v$: relative prices of technology.

Appendix A2: Explanation of cobb – douglas type function of fixed prices and TFP change rate

Fixed prices of PT is expressed as $P_{tr} = P_t$/RDEF,

where P_t: current prices of PT, and *RDEF*: R&D deflator.

$$\frac{P_t}{P_v} = P = M \times \frac{\partial V}{\partial T}, P_t = M \times \frac{\partial V}{\partial T} \times P_v$$

Therefore, under competitive state,

$$\text{GTC} = P_t \times T, \qquad P_t = \frac{\text{GTC}}{T}$$

$\partial \text{GTC} / \partial P_t = T$ (Shappard's lemma)

where GTC: gross cost of technology (≈ R current R&D investment).

Under no competitive condition, if it will change in the bias of b in Equation 2,

$$P_t = b \times \frac{\text{GTC}}{T}$$

GTC = $P_t \times T/b$

On the basis of Equations (3) and (4),

$$\frac{\partial \text{GTC}}{\partial P_t} \times \frac{P_t}{\text{GTC}} = \frac{\partial \ln \text{GTC}}{\partial \ln P_t} = T \times \frac{P_t}{\text{GTC}} = b$$

$$\frac{\partial \ln P_t \times T/b}{\partial \ln P_t} = \frac{\partial \ln T}{\partial \ln P_t} + 1 = b, \qquad \frac{\partial \ln T}{\partial \ln P_t} = b - 1$$

$$\ln T = a + (b-1)\ln P_t = a + b'\ln P_t = a + b'\ln\left(M \times \frac{\partial V}{\partial T}\right) P_v$$

where a: constant; and $b' = b - 1$.

Therefore,

$$T = A_1 P_t^{b'} \qquad (A_1 = e^a)$$

$$= A_1 (P_{\text{tr}} \text{RDEF})^{b'} \equiv A_1 P_{\text{tr}}^{\mu}$$

where $\mu = b'\left(1 + \frac{\ln \text{RDEF}}{\ln P_{\text{tr}}}\right) \equiv \mu_0 (1 + \gamma_\mu \tau) \approx \mu_0 (1 + \gamma_\mu \tau) \approx \mu_0 e^{\gamma_\mu \tau}$;

and $b \equiv \mu_0, \frac{\ln \text{RDEF}}{\ln P_{\text{tr}}} \equiv \gamma_\mu \tau$

Then, $T = A_1 P_{\text{tr}}^{\mu_0 e^{\gamma_\mu \tau}}$

Table A1 Trends in fixed prices fixed prices of technology and relative prices of technology of Canon printers (1986–1998) – 1995 = 100

	P_{vr} *(fixed prices)*	P_{tr} *(fixed prices of technology)*	P^a *(relative prices of technology)*	*WPI (whole sales price index)*	*RDEF (R&D deflator)*
1986	746.83	93.41	7.86	142.40	89.54
1987	519.08	105.39	13.54	133.63	89.17
1988	347.73	108.13	20.53	127.50	90.77
1989	287.91	109.31	28.31	126.25	94.20
1990	230.44	100.24	34.30	123.30	97.27
1991	185.97	101.95	46.44	116.93	99.10
1992	151.59	104.13	60.53	113.09	99.70
1993	130.70	97.48	68.56	108.09	99.40
1994	114.12	94.36	78.95	104.32	99.65
1995	100.00	100.00	100.00	100.00	100.00
1996	86.71	105.75	129.31	95.19	100.98
1997	79.28	98.28	137.27	92.10	102.03
1998	70.41	99.38	157.55	90.17	100.70

[a] $P = \frac{P_t}{P_v} = \frac{P_{\text{tr}} \times \text{RDER}}{P_{\text{vr}} \times \text{WPI}}$

Table A2 Development trajectory of Canon printers (1971–1999) – 1995 fixed prices[d]

	R&D expenditure (*¥100 millions at 1995 fixed prices*)	*Technology stock*[a] (*¥100 millions at 1995 fixed prices*)	*Sales of printer (\ 100 mil.)*						*Prices of printers* (*¥10 thos. at 1995 fixed prices*)
			Current prices				*1995 fixed prices*		
			LLBP[b]	*LBP*	*B J*	*Total*	*Total*	*Cumulative sales*	
1971	0.3	–	–	–	–	–	–	–	–
1972	0.4	–	–	–	–	–	–	–	–
1973	0.5	–	–	–	–	–	–	–	–
1974	0.6	–	–	–	–	–	–	–	–
1975	0.84	2.000	–	–	–	–	–	–	–
1976	1.27	2.266	3[c]	–	–	–	–	–	–
1977	1.49	2.614	3[c]	–	–	–	–	–	–
1978	1.87	3.039	5[c]	–	–	–	–	–	–
1979	2.02	3.672	9	–	–	9	5	12	–
1980	2.25	4.692	11	–	–	11	6	18	–
1981	2.51	5.866	18	–	–	18	11	29	–
1982	3.13	7.342	26	–	–	26	15	44	–
1983	3.99	8.868	28	–	–	28	17	63	–
1984	5.23	10.521	45	111	–	156	96	159	–
1985	6.68	12.324	60	418	–	478	302	465	76.346
1986	7.82	14.625	80	673	–	753	529	1046	47.051
1987	8.75	17.632	102	1078	–	1180	883	1998	32.702
1988	10.91	21.681	125	1535	–	1660	1302	3396	23.608
1989	12.42	26.910	149	2064	–	2213	1753	5183	18.139
1990	13.88	32.924	172	2251	146	2569	2084	7390	14.517
1991	15.54	39.466	191	2434	628	3253	2782	10574	11.716
1992	16.45	47.729	207	2609	1238	4054	3585	14518	9.550
1993	17.61	56.952	220	2774	1357	4351	4025	19215	8.234
1994	21.17	67.015	230	2927	1647	4804	4605	24516	7.189
1995	23.10	78.065	0	3067	2734	5801	5801	31378	6.300
1996	28.32	89.284	0	3194	3924	7118	7478	40437	5.463
1997	32.25	100.907	0	3322	3967	7289	7914	49709	4.995
1998	35.25	115.321	0	3618	4543	8161	9058	59833	4.436
1999	37.14	130.694	0	3453	4012	7465	8820	72565	

[a]Given total R&D expenditure of 3 types of printers at time t R_t, technology stock of printers technologies at time t can be measured by the following equation (Griliches, 1979 ; Watanabe, 1999 ; Watanabe, et al., 2006):

$$T_t = R_{t-4} + (1-0.067)T_{t-1}$$

where lead time between R&D and commercialization; 4 years; rate of obsolescence of printers technologies: 6.7% p.a. (average life time: 15 years); and T_0 = 2.0 (technology stock in 1975: Yen 100 mils. at 1995 fixed prices).

[b]Semiconductor laser.

[c]Gasification type of laser.

[d]R&D expenditure was deflated by using R&D deflator while sales and prices of printers were deflated by using WPI of electrical machinery equipments.

Sources: Canon Story (2001), Watanabe, Matsumoto et al. (2001), Watanabe, Tsuji et al. (2001).