Technology Selection and Commitment in New Product Development: The Role of Uncertainty and Design Flexibility

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APPENDIX

We now consider the case when the firm choosing a proven technology does not launch a follow-up product with the prospective technology because it is not economically viable (as when the inequality in section 2.1 is not satisfied). Under these conditions, the profit term from choosing the proven technology using the parallel path design approach is given by:

$\pi_n^{pv,PP}(v_n) = G_{pv} - C_{dev} - C(T_n)$. Similarly, the

profit from choosing proven technology (pv) at T_n using the sufficient design (SD) approach

$\pi_n^{pv,SD}(v_n) = \overline{G_{pv}} - \overline{C}_{dev}$

The profit from choosing the prospective technology remains unchanged.

We can analyze the consideration region for the prospective technology in a manner similar to that of section 3.1.

$$\pi_0^{pv}(v_0) = G_{pv} - C_{dev}$$

$$\pi_0^{ps}(v_0) = G_{pv} - C_{dev} - G_{pv}F(T_{dev})\beta - C_{dev}\gamma + v_0\left(G_{ps} - G_{pv} + C_{dev}\gamma + G_{pv}F(T_{dev})\beta\right)$$

Comparing the profit expressions above, a necessary condition for the firm to not reject the prospective technology outright is obtained by setting $\pi_0^{ps}(v_0) \geq \pi_0^{pv}(v_0)$ or if:

$$v_0 \geq v_{thr} = \frac{C_{dev}\gamma + G_{pv}F(T_{dev})\beta}{(G_{ps} - G_{pv}) + C_{dev}\gamma + G_{pv}F(T_{dev})\beta}$$

The above expression looks quite similar to (9) in the body of the paper, except for a few changes in the denominator. The relationship of the threshold value to the gross profit terms and the coefficient of reversion terms remains the same. However, the threshold value is monotone increasing in $F(T_0)$ and C_{dev} whenever $G_{ps} > G_{pv}$. In other words, the more expensive the development process and the more frontloaded the customer demand, the smaller the region of consideration of the prospective technology.

Characterizing the Convergence for a Risk-Averse Firm

We now characterize the convergence process under the parallel path approach for a risk-averse firm that seeks to maximize the certainty equivalent of profits. We compare the paths of deliberation of the risk-neutral firm and the risk-averse firm, and derive insights into the definition process under risk aversion.

We assume that the firm has an absolute risk aversion of the quadratic form, i.e., we assume that the payoff of w to the firm is of the form of $U(w)=-(a-w)^2$ (Pratt, Raiffa and Schlaifer 1995). The profits to the firm are $-F+Ax$, where F represents the costs that are independent of the viability of the prospective technology, and x represents the viability of the prospective technology. The certainty equivalent of the profits to the firm can be calculated using the relationship: $U(C)=\int U(x)f(x)dx$, where C represents the certainty equivalent, f(x) is the pdf of the Beta distribution, and U(x) represents the utility from an uncertain payoff of x.

$\Rightarrow -(a-C)^2=\int_0^1 -[a-\Pi(x)]^2 f(x)dx$, where a=-F+A, since that's the highest payoff possible, $\Pi(x)=-F+Ax$ and the pdf f(x) is given by $f(x)=\frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}x^{\alpha-1}(1-x)^{\beta-1}$.

The certainty equivalent of profits is therefore given by:

$$-(-F+A-C)^2=\int_0^1 -[-F+A+F-Ax]^2\frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}x^{\alpha-1}(1-x)^{\beta-1}dx$$

$$(-F+A-C)^2=\int_0^1 A^2[1-x]^2\frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)}x^{\alpha-1}(1-x)^{\beta-1}dx$$

$$\Rightarrow (-F+A-C)^2=\frac{\Gamma(\beta+2)\Gamma(\alpha+\beta)}{\Gamma(\beta)\Gamma(\alpha+\beta+2)}\int_0^1 A^2\,\frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha)\Gamma(\beta+2)}x^{\alpha-1}(1-x)^{\beta+1}dx$$

$$\Rightarrow -F+A-C=A\sqrt{\frac{\beta(\beta+1)}{(\alpha+\beta)(\alpha+\beta+1)}};C=-F+A[1-\sqrt{\frac{\beta(\beta+1)}{(\alpha+\beta)(\alpha+\beta+1)}}]$$

It can be easily seen that C is less than the expected value of profits, $-F+A\frac{\alpha}{\alpha+\beta}$, which shows that the risk-averse firm values the profits to be less than the expected value, owing to the uncertainty associated with the profit. If the firm seeks to maximize the certainty equivalent of profits, it follows a procedure that is similar to the one described in the parallel path approach for the expected value of profits, i.e., it deliberates until the value obtained from new information is less than the cost of delay from the deliberation. Result 4 summarizes our findings for the effect of risk aversion.

Result 4

(i) If the viability of the prospective technology is above a certain critical value, the firm will terminate the development of the product based on the proven technology *earlier* than the risk-neutral firm.

(ii) If the viability of the prospective technology is below a critical value, the firm will terminate the development of the product based on the prospective technology *later* than the risk-neutral firm.

Proof

The proof of Result 4 is based on a comparison of the net change in profit ($\Delta\Pi$) from the certainty equivalent case with that of $\Delta\Pi$ in the expected profit case. To simplify the exposition of the proof, we label $\Delta\Pi$ in the certainty equivalent as $\Delta\Pi_c$ and that in the expected value case as $\Delta\Pi_e$.

(i) To prove the first part of the result, we note that

$$\Delta\Pi_c = F^{ps,PP} - F^{pv,PP} + \mu_n^{+} A^{ps,PP} - \mu_n A^{pv,PP} - [C(T_{n+1}) - C(T_n)]$$

$$= -\Delta F^{PP} - [C(T_{n+1}) - C(T_n)] + \left(\mu_n^{+} - \mu_n\right) \; A^{pv,PP} + \mu_n^{+}\left(\Delta A^{PP}\right)$$

where $\mu_n = 1 - \sqrt{\dfrac{\beta(\beta+1)}{(\alpha+\beta)(\alpha+\beta+1)}}$ and $\mu_n^{+} = 1 - \sqrt{\dfrac{\beta(\beta+1)}{(\alpha+\beta+1)(\alpha+\beta+2)}}$

To prove the result, we need to show that $\Delta\Pi_c \leq \Delta\Pi_e$ when the mean viability of the new technology is above a certain threshold value. From section 4, the value of $\Delta\Pi_e$ is given by $\Delta\Pi_e = -\Delta F^{PP} - [C(T_{n+1}) - C(T_n)] + \left(\nu_n^{+} - \nu_n\right) \; A^{pv,PP} + \nu_n^{+}\left(\Delta A^{PP}\right)$. If the relationship $\Delta\Pi_c \leq \Delta\Pi_e$ is satisfied, it follows that the risk-averse firm will always converge before the risk-neutral firm, as the termination condition will be reached earlier. Comparing the expressions of $\Delta\Pi_c$ and $\Delta\Pi_e$, we can see that $\Delta\Pi_c \leq \Delta\Pi_e$ iff

$[\left(\mu_n^{+} - \mu_n\right) - (\nu_n^{+} - \nu_n)] \; A^{pv,PP} + (\mu_n^{+} - \nu_n^{+})\left(\Delta A^{PP}\right) \leq 0$.

Now note that the value of μ_n^{+} is always lower than ν_n^{+}, as the certainty equivalent of profit when the payoff is uncertain is always lower than the expected value of profit, therefore, the second term is always negative. The first term is equal to zero when the following condition is satisfied:

$\frac{4(b+1)(2b-a)}{(a+2)^2} = \frac{b^2}{a(a+1)^2}$; where b = β + n - S_n , a = α + β + n, S_n is the number of positive pieces of information, and n is the total number of pieces of information.

Also, since μ_n^+ and μ_n are *strictly increasing* in β+n-S_n, a higher ratio of α+S_n to β+n-S_n than that described in the above condition will cause the inequality of $\Delta\Pi_c \le \Delta\Pi_e$ to hold strictly. Therefore, when the mean viability of the prospective technology is above a certain critical value where α+S_n and β+n-S_n are described by the above equation, the risk-averse firm defines earlier than the risk-neutral firm.

(ii) The proof of part (ii) is very similar to part (i). For the firm to choose the proven technology while deliberating on the prospective technology, we have to show that if the mean viability is below a certain critical value, then $\Delta\Pi_c \ge \Delta\Pi_e$. This implies that the termination condition for the certainty equivalent case will be reached only after that in the expected value case, and the risk-averse firm will deliberate further. From Result 3,

$$\Delta\Pi_c = F^{pv,PP} - F^{ps,PP} + \mu_n^- A^{pv,PP} - \mu_n A^{ps,PP} - [C(T_{n+1}) - C(T_n)]$$

$$= \Delta F^{PP} - [C(T_{n+1}) - C(T_n)] + \left(\mu_n^- - \mu_n\right) \ A^{ps,PP} - \mu_n^- \left(\Delta A^{PP}\right)$$

For the condition $\Delta\Pi_c \ge \Delta\Pi_e$ to hold, the following condition has to be satisfied:

$[\left(\mu_n^- - \mu_n\right)$-$(v_n^- - v_n)]\ A^{pv,PP} - (\mu_n^- - v_n^-)\left(\Delta A^{PP}\right) \ge 0$. The second term is always strictly greater than zero. For the first term to be greater than zero, using a procedure similar to part (i), we can show that if the mean viability of the prospective technology is below a certain value, the inequality is strictly satisfied, and since the termination condition for the expected value is stronger, the risk-averse firm will deliberate further than the risk-neutral firm.