# Technology Imports and Decision Criteria of the Schumpeterian Entrepreneur under Uncertainty

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While, suprisingly, in discussion of technology trade little attention has been focused on the behavior of the technology-importer, this paper shows that there can exist different sets of decision criteria for a Schumpeterian entrepreneur who imports foreign technology under uncertainty. A Schumpeterian entrepreneur has four sets of decision criteria: 1) the existence of potential bound for the effective gross output net of royalties; 2) the shape of randomness-indifference locus; 3) the evaluation of the magnitude of boundedness in the effective gross output net of royalties; 4) the market interest rate.

## I. Introduction

Technology transfer has been a focus of concern since the mid 1960s when foreign direct investment and the activities of multinational corporations took off. Much trade literature addresses the question of the optimal method for technology transfer. For instance, Rodriguez (1975) examines the optimal trade and licensing policies for a country which is the sole owner of the technology to produce a good. Berglas and Jones (1977) examine the issues involved in the export of technology which can be distinguished by the forms that such export takes. Krugman (1979) characterizes a "technology transfer" in terms of the increase in the number of Southern goods which can be produced only after the adoption of new Northern technology by South. McCulloch and Yellen (1982) consider the imposition of optimal royalties. Magee (1977) studies the optimal dynamic pricing of technology exports. Feenstra and Judd (1982) compare trade and licensing polices in the case of endogenous level of product variety and technology transfer. Pugel (1982) analyzes the interdependence of technology creation and in-

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ternational technology transfer in a Ricardian trade model with endogenous technological change.

In an exceptional contribution to the issue of technology import, Brecher (1982) demonstrates that the optimal level of national welfare for the home country might be lower with imported technology than without it, if the foreign country exports the technology used to produce the home exportable commodity. In a static and deterministic model, he uses a royalty payment scheme that leaves private producers indifferent to using or ignoring the technology from abroad. Findlay (1978) provides a discussion of dynamic aspects of technology transfer and foreign investment. The rate of technical change in the developing region is an increasing function of the gap between its own technology levels and that of an advanced region and of the proportion of foreign to domestic capital in the backward region.

To some extent, the recent interest in technology transfer follows Caves' (1971) observation that "as trade follows the flag, so does applied economics follow the newspaper." It is not difficult to find a wide range of reports on "technology trade" among industrialized countries. For example, according to a recent survey of the Representative of the British Chamber of Commerce in Japan, Japan's technology import from West Germany in 1984 was 3.8 times more than its technology export to West Germany in terms of items. Also, Japan's tecnology import from the U.S. was 2.9 times more than its technology export to the U.S.

Surprisingly, in discussion of technology trade little attention has been focused on the behavior of the technology recipient. This paper examines the decision criteria of a Schumpeterian entrepreneur who imports foreign technology and pays royalties and fees in terms of some fraction of realized gross output. A formal definition of the Schumpeterian entrepreneur can be derived from Schumpeter's own words. Schumpeter (1942, p. 110) wrote that "It is therefore quite wrong to say that capitalist enterprise was one, and technological progress a second, distinct factor in the observed development of output; they were essentially one and the same thing or the former was the propelling force of the latter." A characteristic of the entrepreneur provided by Schumpeter (1934, p. 66) is that "New combinations are as a rule embodied in new firms which do not arise out of the old ones but start producing beside them." Thus, in this proxy model of technological progress with dynamic internalization of R & D costs, a Schumpeterian entrepreneur runs the risk of technology imports and achieves the output augmenting efficiency from innovation or new combinations of factors of production. Therefore, we can expect a Schumpeterian entrepreneur to have different decision criteria compared with a wealthy investor. A wealthy investor might either follow the prediction of Arrow's (1974) hypotheses of risk aversion on wealth or simply be concerned about the expected value of investment.

What are the behavioral criteria of a Schumpeterian entrepreneur who imports foreign technology? What kind of relationship exists between an entrepreneur's expected efficiency and his attitude toward risk? If the market interest rate rises, does an entrepreneur reduce foreign technology imports? The purpose of this paper is to answer these questions.

The second section describes the model and analyzes 1) an entrepreneur's general attitude toward risk when production uncertainty stems from an endogenized technology import decision, and 2) the relationship between time preference and technology imports. The third section derives the decision criteria of a Schumpeterian entrepreneur who imports foreign technology under uncertainty, and then introduces an entrepreneur's partial relative risk aversion function. The final section contains concluding remarks.

## II. The Model

The key assumptions on technology imports in this model are: 1) Production uncertainty comes solely from an entrpreneur's decision about technology imports. The level of uncertainty does not depend on the level of technology imports. 2) The foreign monopoly owner exports technology and decides appropriate mark-up rates. 3) Imported foreign technology combines with the domestic factors of production to achieve efficiency results.

The Schumpeterian entrepreneur manages firms and produces capital goods. Production costs are captured at current period values. This reflects a dynamic internalization of the costs of production. The entrepreneur shows decreasing absolute risk-aversion in profits and maximizes current expected utilities of profits. He is defined as a Schumpeterian entrepreneur in the sense that the entrepreneur gets profits from introducing innovations or new combinations of factors through technology imports. Labor ($L$) is mobile and is hired at time $t$. Capital ($K$) is mobile and is purchased at time

$t$—1 for use at time $t$. There is no depreciation of capital.

Technology is defined as any kind of tangible and intangible output augmenting method. An entrepreneur agrees to pay royalties and fees for technology imports, which are contracted at time $t$—1 for use at time $t$. Royalty and fees are paid at time $t$ equal to a fraction of the firm's realized gross output in period $t$. This represents the standard way of royalty and fee payments, because in the real world, a fraction of total sales is often adopted as the royalty. Pugel (1982) has the same view. The actual payments are some base international price times mark-up rates suggested by a monopoly owner. The fraction is a convex function of the level of foreign-owned technology supplied by a monopoly owner. The convexity means the entrepreneur will not buy an unlimited amount of foreign-owned technology.

There are no entry costs. The economy is assumed to be small. Suppose there is free trade in goods. There are constant returns to scale in the expected output of the firm which is defined as stochastic constant returns to scale. Capital and labor markets are competitive.

In this model, the production uncertainty due to technology imports is introduced into the production relation (1) in the following fashion. The technology imports will be combined with domestic factors of production and augment output. However, the extent to which output is augmented will be uncertain. In practice, this kind of combinational uncertainty is one of major concerns of technology licensing.

$$X_t(s^t) = Q(K_t, L_t)\,\xi(T_t, s^t), \qquad (1)$$

where $X_t(s^t)$ = the output of commodity in period $t$ and state $s^t$,
$K_t$, $L_t$ = the amounts of capital and labor used in period $t$,
$Q(\cdot)$ = the state-independent strictly concave production function which is homogeneous of degree $1 - \alpha$ $(0 < \alpha < 1)$,
$\xi(\cdot)$ = the product augmenting efficiency function contingent upon imported technology which has a stochastic process such that $\xi(\cdot) = T_t^{\alpha} + e_t$, where $\alpha$ is a parameter and $e_t$ is an independently distributed random variable with $Ee_t = 0$;
$T_t$ = the amount of imported technology used in period $t$.

Many trade theorists have used the multiplicatively separable scalar uncertainty for analytical simplicity (e.g., Helpman and Razin 1978; Batra 1975), but this scalar uncertainty represents the influence of exogenous factors, e.g. weather, industrial strikes, etc. The innovation of this model is that the production uncertainty is linked to an endogenized technology import decision through an output augmenting efficiency function. The specification takes the form of adding a lump-sum noise contingent upon a technology import decision to the system. Suppose $\xi(\cdot) = T_t^{\alpha} + e_t$, where $e_t$ is the combinational uncertainty associated with domestic factors of production in the production process. This specification can represent the case where uncertainty does not depend on the level of technology imports, but rather on the technology import action itself.

The raondom variable $e_t$ is independently distributed with zero mean. Note that the outcome of a non-positive value of $\xi(\cdot)$ can never be imagined with technology imports, so that the event of non-positive $\xi(\cdot)$ occurs with probability zero, and has no economic meaning. Since production of a commodity requires three factors, capital, labor and foreign-owned technology, $e_t$ is degenerate if and only if $T_t = 0$. In other words, without using foreign technology, a firm displays increasing average costs with a white noise due to the given property and specification of a production function (i.e. $Q(\cdot)e$). This implies that the smaller the scale is the less average costs with uncertainty. Thus, a rational entrepreneur does not want to operate a firm under the situation of no fixed cost of investment. In this sense, production uncertainty is endogenized through a technology import decision. That specific characterization might be somewhat restrictive, but still captures the key aspect of uncertainty in many technology import decisions. For example, consider an electrical company that imports the technology of the "binary code" for manufacturing a semi-conductor chip. The action of importing the binary code generates uncertainty, but the number of related blue prints or softwares which help to increase the expected level of efficiency might leave the level of uncertainty unchanged. The entrepreneur becomes sensitive to the expected level of efficiency rather than the variance of $\xi(\cdot)$ in this environment. This case is pertinent to the specification of lump-sum production uncertainty.

A Schumpeterian entrepreneur's optimization problem is:

$$\max_{K_t, L_t, T_t} \quad EU_t[P_tQ(K_t,L_t)\xi(T_t,s^t) - W_tL_t - (R_tP_{t-1}K_t - P_tK_t) - q_tb(T_t)Q(\cdot)\xi(T_t,s^t)], \tag{2}$$

where $W_t$ = the wage rate at time $t$,
$R_t - 1$ = the market interest rate at time $t$,
$P_t$ = the price of commodity at time $t$,
$q_t$ = the international price of foreign-owned technology at time t in terms of numeraire commodity $X_t$,
$U_t(\cdot)$ = Von Neumann-Morgenstern utility function of the entrepreneur at time $t$,
$b_t$ = the mark-up rate for foreign technology at time $t$ imposed by the foreign monopoly owner,
E = expectation operator.

$$\pi = [P_tQ(K_t,L_t)\xi(T_t,s^t) - W_tL_t - (R_tP_{t-1}K_t - P_tK_t) - q_tb(T_t)Q(\cdot)\xi(T_t,s^t)]. \tag{2)'$$

$$b_t = b(T_t), \text{ where } b' > 0 \text{ and } b'' > 0. \tag{2)''$$

From (2), the first-order conditions for interior solutions are:

$$E[U_t'(\cdot)\{P_tQ_L\xi(\cdot) - W_t - q_tb(T_t)Q_L\xi_t\}] = 0 \tag{3}$$

$$E[U_t'(\cdot)\{P_tQ_K\xi(\cdot) - R_tP_{t-1} - q_tb(T_t)Q_K\xi_t + P_t\}] = 0 \tag{4}$$

$$E[U_t'(\cdot)\{P_tQ(\cdot)\alpha T_t^{\alpha-1} - q_tb(T_t)Q(\cdot)\alpha T_t^{\alpha-1} - q_tb'(T_t)Q(\cdot)\xi_t\}] = 0. \tag{5}$$

The necessary conditions (3)~(5) also are sufficient under the assumption of risk-averter and convexity of $b(T)$.

From the first-order conditions, (3)~(5), the following equations are obtained.

$$W_t = \phi\ \{P_t - q_tb(T_t)\}\ Q_L, \tag{3)'$$

$$R_tP_{t-1} - P_t = \phi\ \{P_t - q_tb(T_t)\}\ Q_K, \tag{4)'$$

$$P_t - q_tb(T_t) = \phi\, q_tb'(T_t)\alpha^{-1}T_t^{1-\alpha}, \tag{5)'$$

where $\phi = [EU_t'(\cdot)\xi(\cdot)]/EU_t'(\cdot)$. This term can be interpreted as a subjective expected efficiency, where the marginal utility of profit multiplied by the respective probabilities are used as weights.

(3)′ indicates that the equilibrium wage rate equals his expected efficiency adjusted net value of marginal product of labor, while the equilibrium rental rate of capital service equals his expected efficiency adjusted net value of marginal product of capital in (4)′. (5)′

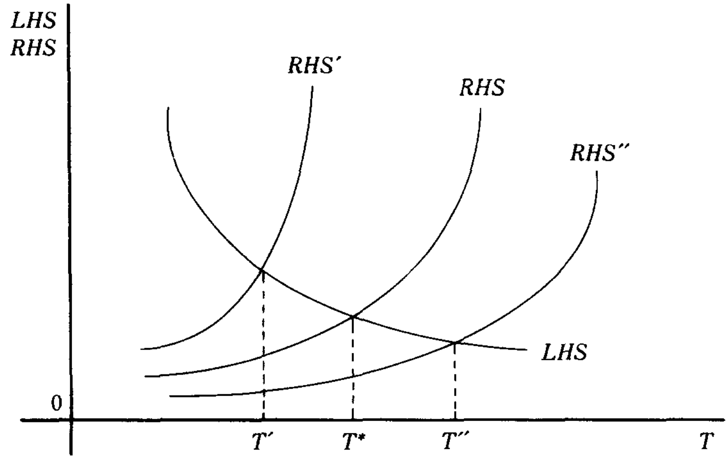


FIGURE 1
THE DETERMINATION OF EQUILIBRIUM LEVEL OF TECHNOLOGY IMPORTS

shows that when an entrepreneur imports technology under uncertainty, the net marginal revenue equals his expected efficiency adjusted value of effective marginal dilution of foreign owned technology.

The left side of equation (5)$'$($LHS$), which represents the net marginal revenue of technology imports, is a decreasing function of $T_t$. Since $b(T_t)$ is a convex function, $[P_t - q_t b(T_t)]$ decreases with increasing rate. Since $\partial\phi/\partial T > 0$ under the decreasing adjusted absolute risk-aversion in profits(see Lemma 1), $\alpha^{-1}(1 - \alpha)\ T_t^{-\alpha} > 0$, and $qb''(T_t) > 0$, it follows that the right side of (5)$'$($RHS$), which represents the entrepreneur's expected efficiency adjusted value of effective marginal dilution of foreign-owned technology, is an increasing function of $T_t$. Figure 1 shows the determination of the equilibrium level of technology imports $T^*$.

The effect of a change in scale parameter $\alpha$ on the equilibrium level of $T^*$ can be determined from (5)$'$. Since $[\partial RHS/\partial\alpha] = (\partial\phi/\partial\alpha)\ q_t b'(T_t)\alpha^{-1}T_t^{1-\alpha} - \phi q_t b'\alpha^{-2}T_t^{1-\alpha} - \phi q_t b'\alpha^{-1}T_t^{1-\alpha}\ln T_t$ can be either positive or negative, the impact of change in $\alpha$ on the equilibrium level of $T^*$ is indeterminate. This kind of indeterminacy comes from the entrepreneur's attitude toward risk. If an entrepreneur shows a decreasing adjusted absolute risk aversion in profits, his marginal expected efficency with respect to the scale parameter $\alpha$ has a positive value. Thus, $\partial\phi/\partial\alpha > 0$ works to increase the marginal cost of technology imports in $RHS$, while the increase in

$\alpha$ makes the marginal mean efficency increase and thus work to reduce the marginal cost of technology imports in *RHS*.

If an entrepreneur shows an increasing adjusted absolute risk aversion in profits, his marginal expected efficiency with respect to the scale parameter $\alpha$ has a negative value. Thus, $T^*$ fall to $T'$. Hence:

*Lemma* 1

If the entrepreneur shows a decreasing adjusted absolute risk aversion in profits, his marginal expected efficiency with respect to the scale parameter $\alpha$ has a positive value.
For proof, see Appendix.

Next, consider the entrepreneur's general attitude toward risk.

$$\text{Let } \pi = [P_tQ(K_t, L_t)\xi(T_t, s^t) - W_tL_t - R_tP_{t-1}K_t + P_tK_t - q_tb(T_t)Q(\cdot)\xi(T_t, s^t)]$$

$$\pi_t - \mathrm{E}(\pi_t) = \{P_t - q_tb(T_t)\}\, Qe_t.$$

If $U''(\cdot) < 0$, then $U'(\pi_t) \leq$ (or $>$) $U'(\mathrm{E}\pi_t)$ for $e_t \geq 0$ (or $< 0$). Therefore, $U'(\cdot)e_t \leq U'(\mathrm{E}(\cdot))e_t$ for any $e_t$. Equality holds only when $e_t = 0$.
Taking expectation both sides, $\mathrm{E}[U'(\cdot)e_t] < U'(\mathrm{E}(\cdot))\mathrm{E}e_t = 0$.
Therefore, $\{\mathrm{E}\xi(\cdot) - \phi\}$ has a positive value. This proves

*Lemma* 2

If the entrepreneur is risk-averse, then the difference between the mean efficiency and his subjective expected efficiency is always positive.

Using the first-order conditions, $(3)' \sim (5)'$ and Lemma 2, we know that if the entrepreneur is risk-averse, then the employment of capital, and labor are less than that under the case which we know the value of random variable and the value is the mean with certainty, while the employment of foreign technology is higher than that under the deterministic case. To see this, Proposition 1 is established.

*Proposition* 1

If the entrepreneur is risk-averse, the expected value of marginal benefit of technology imports is less than the expected value of marginal cost of technology imports in equilibrium.
For proof, see Appendix.

The result of Proposition 1 stems from the fact that the marginal cost of technology imports is determined by the monopoly-seller of technology and the marginal benefit of technology import is generated by an entrepreneur in the model. Thus, the level of employment of technology will be higher even under uncertainty, since the monopoly supplier of technology exercises the market power and a risk-averter entrepreneur operates the firm.

Next, a marginal impact of uncertainty on the employment of capital and labor is explored. An increase in riskiness is defined as the mean-preserving spread type of shift in the distribution function of $\xi_t$. Define $\xi_t = T_t^{\alpha} + \beta e_t$, where $\beta$ is a positive shift parameter and initially $\beta = 1$. Thus, an increase in riskiness implies an increase in $\beta$.

Suppose that there is an increase in riskiness in terms of mean preserving spread of the distribution of $\xi_t$. From (3)′ and (4)′,

$$\phi = W_t/[P_t - q_t b(T_t)]Q_L,$$

$$\phi = (R_t P_{t-1} - P_t)/[P_t - q_t b(T_t)]Q_K.$$

$$(\partial\phi/\partial\beta) = \beta \mathrm{E}[U''(\cdot)(\partial\pi/\partial\beta)\{e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')\}]\mathrm{E}U'/[\mathrm{E}U']^2 + (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U').$$

Define the coefficient of an adjusted absolute risk aversion as

$$r_\beta(\pi) = -U''(\pi)(\partial\pi/\partial\beta)/U'(\pi).$$

$$\mathrm{E}U'(\cdot)\ \{e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')\} = 0. \quad (*)$$

Let $e_t^*$ be such that $e_t^* = \mathrm{E}U'(\ )e_t/\mathrm{E}U'$.

Since $\pi - \pi^* = [P_t - q_t b(T_t)]Q(e_t - e_t^*)$,

$$\pi > (\text{or}, \leq)\ \pi^* \text{ as } e > (\text{or}, \leq)\ e^*.$$

Hence,

$$[-U''(\pi)(\partial\pi/\partial\beta)/U'(\pi)] < (\text{or}, \geq)\ [-U''(\pi^*)(\partial\pi^*/\partial\beta)/U'(\pi^*)] \text{ as}$$
$$e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U') > (\text{or}, \leq)\ 0.$$

Therefore,

$$U''(\pi)(\partial\pi/\partial\beta)[e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')] \geq (-r_\beta(\pi^*))U'(\pi)[e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')].$$

Taking expectation both sides,

$$\mathrm{E}U''(\pi)(\partial\pi/\partial\beta)[e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')] > 0 \text{ by } (*).$$

Therefore, we get that if $r_\beta(\pi)$ is decreasing in profits, then $E[U''(\cdot)(\partial\pi/\partial\beta)\{e_t - (EU'(\cdot)e_t/EU')\}] > 0$. However, if an entrepreneur is risk-averse, $EU'(\cdot)e_t < 0$ (see Lemma 2). Thus, the sign of $(\partial\phi/\partial\beta)$ is indeterminate. This is because there exists a tradeoff between a decreasing absolute risk aversion and the entrepreneur's conservatism for noise represented by $[EU'(\cdot)e_t/EU'] < 0$. If $r_\beta(\pi)$ is increasing in profits, then $(\partial\phi/\partial\beta) < 0$ so that an extrepreneur will decrease the employment of capital and labor when there is an increase in riskiness.

Consider $\pi = [P_tQ(K_t,L_t)\xi(T_t,s^t) - W_tL_t - R_tP_{t-1}K_t + P_tK_t - q_tb(T_t)Q\xi(T_t,s^t)]$

The unit cost is $a_LW_t + a_K(R_tP_{t-1} - P_t) + q_tb(T_t)$, where $a_i$ is input $i$ requirements for producing one expected unit of commodity at time $t$.

Therefore, the expected profits of the firm are

$$E\pi_t = [P_t - \{a_LW_t + a_K(R_tP_{t-1} - P_t) + q_tb(T_t)\}]EX_t.$$

Under the stochastic constant returns to scale, using (3)′ and (4)′,

$$E\pi_t = [P_t - \phi\{P_t - q_tb(T_t)\}]EX_t.$$

From Lemma 2,

$$\phi - E\xi(\cdot) < 0.$$

Therefore,

$E\pi > 0$ if $U''(\cdot) < 0$ and $T^\alpha < 1$. This proves

*Lemma* 3

If the entrepreneur is risk-averse and $T^\alpha < 1$, then expected profits and always positive.

The Lemma 3 suggests that there might exist a level of risk premium at which the entrepreneur is willing to run the risk.

Now, consider the relationship between time preference and technology imports. The analysis rests on the following Lemma 4 and Proposition 2, proven in the Appendix.

*Lemma* 4

If the entrepreneur shows a decreasing adjusted absolute risk aversion in profits, his marginal expected efficiency with respect to

the factors of production (i.e., $\partial\phi/\partial T_t$, $\partial\phi/\partial K_t$, and $\partial\phi/\partial L_t$) has positive value, respectively.
The proof is similar to the proof of Lemma 1 and is omitted.

*Proposition* 2

Suppose the entrepreneur shows a decreasing adjusted absolute risk aversion. Assume that capital and labor are complementary in the production process.

Suppose $[DAQ_{KK} - (\partial\phi/\partial K)CJ] > 0$,

where $A = \phi\{P_t - q_t b\,(T_t)\}$, $C = q_t b'(T_t)\,\alpha^{-1} T_t^{1-\alpha}$, $D = (\partial\phi/\partial T)C$
$$+\ \phi\, q_t b'' \alpha^{-1} T_t^{1-\alpha} + \phi\, q_t b' \alpha^{-1}(1-\alpha)\,T_t^{-\alpha} + q b'(T),$$
$$J = -[\phi\, q b' + (b''/b')A + (1-\alpha)T_t^{-1} A]Q_K.$$

Then, when the market interest rate increases, technology imports will decrease.

The significance of Proposition 2 is the explicit introduction of the relationship between the market interest rate and technology imports. In the existing discussion of technology imports, little attention has been focused on this fact. If the market interest rate increases, the cost of capital will increase, since more resources should be set aside for a given accumulation of capital $(R_t P_{t-1} K_t)$ at higher market interest rates. The increase in costs of capital affects the firm's net cash flow and eventually the level of technology imports, because the royalty is paid equal to a fraction of gross outputs. Thus, Proposition 2 shows that when the market interest rate increases, the entrepreneur will reduce foreign technology imports due to the increasing cost of capital. This implies that capital and technology are complementary. Usually, R & D investment is highly sensitive to the market interest rate. When the market interest rate rises, entrepreneurs might have a tendency to import foreign technology rather than making investments in their own technology. However, Proposition 2 shows that is not necessarily true.

## III. A Schumpeterian Entrepreneur's Partial Relative Risk Aversion Function

The entrepreneur's partial relative risk aversion function $r_s$ is defined as $r_s = -U''(S-c)S/U'(S-c)$, where $S = [P_tQ - q_tb(T_t)Q]\xi(\cdot)$, and $c = W_tL_t + (R_tP_{t-1}K_t - P_tK_t)$. $r_s$ is a variant of the relative risk aversion by Arrow(1974), $r_R = -U''(Y)Y/U'(Y)$, where $Y$ is total wealth. The concept of the partial relative risk aversion was first introduced by Menezes and Hanson (1970). Menezes and Hanson formulated $p(t, Y_0) = -U''(Y_0+t)t/U'(Y_0+t)$, where $Y_0$ is the individual's initial wealth, and $t$ is a random component of wealth. We know that if $Y_0 = -c$, then $p(t, Y_0)$ is identical with $r_s$. *However*, $Y_0$ cannot be equal to $-c$, since $c > 0$. Thus, a different behavior of $r_s$ is expected, compared with Menezes and Hanson's $p(t, Y_0)$. Hanson and Menezes's (1968) proposition 1 is: "Fix $Y_0$. If $p(t, Y_0)$ is non-increasing in $t$ for $t$ in some interval $(0, t_0)$ with $t_0 > 0$, then either $p(t, Y_0) = 0$ or else $Y_0 = 0$." The proposition means that for $Y_0 > 0$, if $p(t, Y_0)$ is non-increasing for $0 < t < t_0$, then $p(t, Y_0)$ is identically zero. Even though a direct comparison is not possible because the domain of $Y_0$ is different from $c$ in $r_s$, that kind of property suggested by the proposition cannot be found in $r_s$. The following proposition shows that.

*Proposition* 3

Suppose $U'(S-c) > 0$ and $U''(S-c) < 0$, where $c > 0$ and $0 < S-c < \pi_0$.

Then there exists a $\pi_0 > 0$ such that $r_s$ is non-increasing in $S$ for $c < S < \pi_0 + c$.

For proof, see Appendix.

There is a relationship between Arrow type relative risk aversion function ($r_R$) and $r_s$.$r_s$ can be rewritten as $r_s = (S/\pi)r_R$, where $r_R = -U''(\pi)\pi/U'(\pi)$ and $\pi = S - c$. Thus, we get $(dr_s/d\pi) = [(\pi + c)/\pi)](dr_R/d\pi) + (-c/\pi^2)r_R$.

The $r_R$ may increase, decrease, remain constant or be non-monotone in $\pi$. Arrow's (1974) assertion is that if both wealth and the size of the bet are increased in the same proportion, the willingness to accept the bet should decrease. His theoretical point is based on the boundedness of the utility function. It can be shown that if the utility function is to remain bounded as wealth becomes infinite, then the relative risk aversion cannot tend to a limit below one; similarly, for the utility function to be bounded from below as wealth approaches zero, the relative risk aversion cannot approach a limit above one as wealth tends to zero.

Therefore, if $r_R$ is increasing in $\pi$, then the sign of $(dr_s/d\pi)$ is indeterminate. On the other hand, if $r_R$ is decreasing in $\pi$, then $r_s$ also decreasing in $\pi$.

If $S = [P_tQ - q_tb(T_t)Q]\xi(\cdot)$ can be interpreted as a possible outcome of the effective gross output net of royalties (*EGOR*), and $r_s$ is a partial relative risk-aversion function of technology imports (*RAT*), a relationship between *EGOR* and *RAT* subject to $\partial EU_t'(\cdot)\xi(\cdot)/\partial\xi = 0$ can be found.

The exact interpretation for this relationship is an open question. However, one finding is that there exist different types of compensation between *EGOR* and the entrepreneur's risk preference when the entrepreneur's marginal utility weighted expected efficiency remains unchanged with respect to change in random variable in equilibrium.

The following theorem, proven in Appendix, demonstrates the shape of the indifference locus of the entrepreneur's marginal utility weighted expected efficiency with respect to change in the random variable in equilibrium.

*Theorem*

The entrepreneur's indifference locus of $EU'(\cdot)\xi_t$ with respect to change in the random variable $\xi_t$ is a convex function.

If $EU'(\cdot)\xi_t$ changes with respect to change in $\xi_t$ for any given equilibrium values of *K*, *L*, and *T*, then the entrepreneur will search for a new equilibrium responding to change in $\xi_t$. No response of $EU'(\cdot)\xi_t$ implies that the leve of $EU'(\cdot)\xi_t$ is a desirable one. Thus, the equilibrium will be sustained. The Theorem provides a way to determine the equilibrium combination of *EGOR* and *RAT*. The convexity of the randomness indifference locus has some meaning in this model. First, when the potential bound for *EGOR* is expected, the entrepreneur should run the high risk aversion for the larger *EGOR* to sustain a desired equilibrium. Second, the larger the *EGOR* is expected, the more the marginal risk aversion is required (see Figure 2).

On the other hand, when the prospect is optimistic so that the potential bound for *EGOR* cannot be expected, the entrepreneur should run less risk aversion for the larger *EGOR* in equilibrium (see Figure 3).

From the Theorem, we get the following corollary.

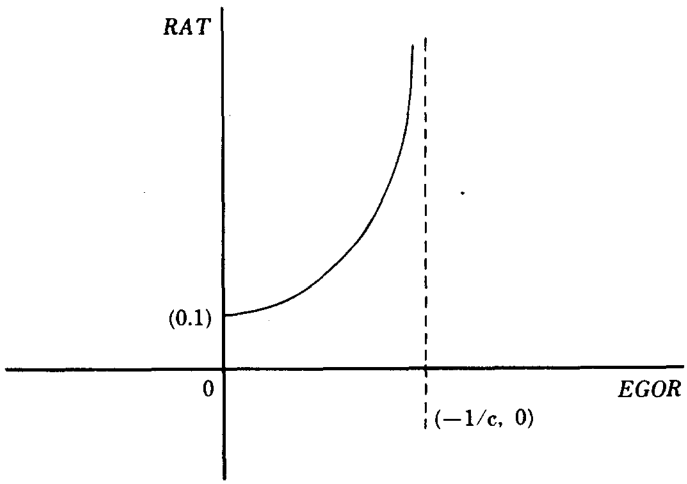


FIGURE 2
EGOR AND RAT[1]

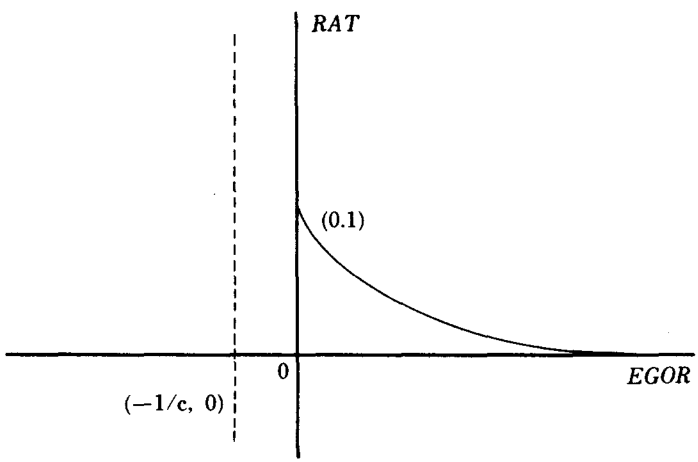


FIGURE 3
EGOR AND RAT[2]

*Corollary*

The reversal of stochastic risk preference can happen as the initial condition of *EGOR* changes.

The Corollary demonstrates that the phenomenon of risk-preference reversal can be compactly derived from an optimizing model instead of resorting to artificial examples. The phenomenon of the risk preference reversal implies that the entrepreneur's attitude toward compensations will change upon the prospect.

## IV. Concluding Remarks

This paper analyzes 1) an entrepreneur's general attitude toward risk when production uncertainty stems from an endogenized technology import decision; 2) the relationship between time preference and technology imports; 3) an entrepreneur's partial relative risk aversion function.

In the case of additive disturbance, the difference between the mean efficiency and a risk-averse entrepreneur's expected efficiency is always positive, so that the level of employment of technology will be higher even under uncertainty, since the monopoly supplier of technology exercises the market power and a risk-averter entrepreneur operates the firm. If an entrepreneur shows decreasing adjusted absolute risk aversion in profits, his marginal expected efficiency with respect to the factors of production has a positive value. When the market interest rate increases, the entrepreneur will reduce foreign technology imports due to the increased cost of capital.

An entrepreneur's partial relative risk aversion (*RAT*) function has a different property compared with Menezes and Hanson's (1970) one in the sense that it is possible for the entrepreneur's partial relative risk aversion (*RAT*) to take a positive value when *RAT* is decreasing in the effective gross output net of royalites (*EGOR*).

There exists an equilibrium combination of the effective gross output net of royalties (*EGOR*) and the risk preference. The entrepreneur's attitude toward compensations in equilibrium will be different depending on whether there exists a potential bound for *EGOR*. Thus, the reversal of risk preference can happen as the prospect of the *EGOR* changes. Therefore, the decision criteria of the Schumpeterian entrepreneur who imports foreign technology under uncertainty consist of four sets of rules of reference: 1) the existence of potential bound for the effective gross output net of royalities; 2) the shape of randomness-indifference locus; 3) the evaluation of the magnitude of boundedness in the effective gross output net of royalities; and 4) the market interest rate.

## Appendix

*Proof of Lemma* 1

$$\partial\phi/\partial\alpha = \mathrm{E}[U''(\cdot)(\partial\pi/\partial\alpha)\{e_t-(\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')\}]\mathrm{E}U'/[\mathrm{E}U']^2 + T_t^{\alpha}\, lnT_t.$$

Define the coefficient of an adjusted absolute risk aversion as

$$r_a(\pi) = -U''(\pi)(\partial\pi/\partial\alpha)/U'(\pi).$$

In addition, we know that

$$\mathrm{E}U'(\cdot)\{e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')\} = 0. \ (^*)$$

Let $e_t^*$ be such that $e_t^* = \mathrm{E}U'(\cdot)e_t/\mathrm{E}U'$.

Since $\pi - \pi^* = [P_t - q_t b(T_t)]Q(e_t - e_t^*)$,

$\pi > (\text{or}, \leq)\ \pi^*$ as $e > (\text{or}, \leq)\ e^*$.

Hence,

$[-U''(\pi)(\partial\pi/\partial\alpha)/U'(\pi)] < (\text{or}, \geq)\ [-U''(\pi^*)(\partial\pi^*/\partial\alpha)/U'(\pi^*)]$

as $e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U') > (\text{or}, \leq)\ 0$.

Therefore,

$U''(\pi)(\partial\pi/\partial\alpha)[e_t-(\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')] \geq (-r_a(\pi^*))U'(\pi)[e_t-(\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')]$.

Taking expectation both sides,

$\mathrm{E}U''(\pi)(\partial\pi/\partial\alpha)[e_t - (\mathrm{E}U'(\cdot)e_t/\mathrm{E}U')] > 0$ by (*).

Therefore, $\partial\phi/\partial\alpha > 0$.

*Proof of Proposition* 1

From (5),

$$\mathrm{E}[U_t'(\cdot)\{P_tQ(\cdot)\alpha T_t^{\alpha-1} - q_tb(T_t)Q(\cdot)\alpha T_t^{\alpha-1} - q_tb'(T_t)Q(\cdot)\xi_t\}] = 0. \ (^*)$$

Rewrite (*) as

$$\{P_tQ(\cdot)\alpha\, T_t^{\alpha-1} - q_tb(T_t)Q(\cdot)\alpha\, T_t^{\alpha-1} - q_tb'(T_t)Q(\cdot)T_t^{\alpha}\}\, \mathrm{E}U_t'(\cdot)$$
$$= q_tb'(T_t)Q\mathrm{E}U'(\cdot)e_t.$$

By Lemma 2, if the entrepreneur is risk-averse, $\mathrm{E}U'(\cdot)e_t < 0$. Thus, $\{P_tQ(\cdot)\alpha\, T_t^{\alpha-1} - q_tb(T_t)Q(\cdot)\alpha\, T_t^{\alpha-1} - q_tb'(T_t)Q(\cdot)T_t^{\alpha}\}$ $< 0$. (**)

Rewrite (**) as

$P_tQ(\cdot)\alpha\, T_t^{\alpha-1} < q_tb(T_t)Q(\cdot)\alpha\, T_t^{\alpha-1} + q_tb'(T_t)Q(\cdot)T_t^{\alpha}$, where $P_tQ(\cdot)\alpha\, T_t^{\alpha-1}$ represents the expected value of marginal benefit of technology imports and $q_tb(T_t)Q(\cdot)\alpha\, T_t^{\alpha-1} + q_tb'(T_t)Q(\cdot)T_t^{\alpha}$ indicates the expected value of marginal cost of technology imports.

*Proof of Proposition* 2

Totally differentiating equation (3)′-(5)′, we get

$$\begin{bmatrix} AQ_{LL}+(\partial\phi/\partial L)(A/\phi)Q_L & AQ_{LK}+(\partial\phi/\partial K)(A/\phi)Q_L & [\partial\phi/\partial T(A/\phi)-\phi q_tb]Q_L \\ AQ_{KL}+(\partial\phi/\partial L)(A/\phi)Q_K & AQ_{KK}+(\partial\phi/\partial K)(A/\phi)Q_K & [\partial\phi/\partial T(A/\phi)-\phi q_tb]Q_K \\ (\partial\phi/\partial L)C & (\partial\phi/\partial K)C & D \end{bmatrix}\begin{bmatrix} dL \\ dK \\ dT \end{bmatrix}$$

$$= \begin{bmatrix} 0 \\ P_{t-1} \\ 0 \end{bmatrix} dR_t \qquad (*)$$

where $A = \phi\,\{P_t - q_tb(T_t)\}$,
$C = q_tb'(T_t)\alpha^{-1}T_t^{1-\alpha}$,
$D = (\partial\phi/\partial T)C + \phi\, q_tb''\alpha^{-1}T_t^{1-\alpha} + \phi\, q_tb'\alpha^{-1}(1-\alpha)$
$T_t^{-\alpha} + qb'(T)$.

Denote the determinant of the coefficient matrix of (*) by $DET$.

$$DET = [AQ_{LL} - A(Q_{LL})^2/Q_{KK}][DAQ_{KK} - (\partial\phi/\partial K)CJ] + [AQ_{LK} - A(Q_{KK})Q_L/Q_K][J\{(\partial\phi/\partial L) - (\partial\phi/\partial K)(Q_{KL}/Q_{Kk})\} C],$$

where $J = -[\phi\, qb' + (b''/b')A + (1-\alpha)T_t^{-1}A]Q_K < 0$.

Since the state independent part of production function displays strict concavity, $[AQ_{LL} - A(Q_{LK})^2/Q_{KK}] < 0$.

If the gains due to the marginal physical product of capital exceed the loss due to the decreasing marginal physical product of capital, $[DAQ_{KK} - (\partial\phi/\partial K)CJ] > 0$.

Since the entrepreneur shows decreasing adjusted absolute risk aversion in profits, $\partial\phi/\partial T_t$, $\partial\phi/\partial K_t$, and $\partial\phi/\partial L_t$ are positive (see Lemma 4).

Hence, $DET$ has a negative value.

$$\{dT_t/dR_t\} = (-P_{t-1}/DET)[(\partial\phi/\partial K)C\{AQ_{LL}-A(Q_{LK})^2/Q_{KK}\} - \{AQ_{LK}-A(Q_{KK})Q_L/Q_K\} \{(\partial\phi/\partial L)-(\partial\phi/\partial K)(Q_{KL}/Q_{KK})\} C]$$

Therefore, $dT_t/dR_t < 0$.

*Proof of Proposition* 3

By assumption, $r_s$ is non-increasing, $U'(S-c) > 0$ and $U''(S-c) < 0$. Thus, we can choose $k > 0$ so that ther exists $\pi_0 > 0$ such that $r_s > k$ and $U'(S-c) > k$ for $c < S < \pi_0+c$.

Then, for $c < S < \pi_0 + c$

(*) $U''(S-c) < -(k/S)\ U'(S-c) < -(k^2/S)$.

Integrating (*), we get

(**) $U'(\pi_0) - U'(0) < -k^2[ln(\pi_0 + c) - lnc]$.

Since $U(\cdot)$ is strictly concave, (**) always holds for any given value of $\pi_0 > 0$.

*Proof of Theorem*

Suppose $\xi_t$ increased for any given values of $K$, $L$, and $T$.

Hence,

$dU_t'(\cdot)\xi(\cdot)/d\xi = U_t''(\cdot)[P_tQ - q_tb(T_t)Q]\xi(\cdot) + U_t'(\cdot)$.

Let $S = [P_tQ - q_tb(T_t)Q]\xi(\cdot)$.

Then, $dU_t'(\cdot)\xi(\cdot)/d\xi = U'(\cdot)(1-r_s)$,

where $r_s = -U''(\cdot)S/U'(\cdot)$.

Thus, $\xi[d^2U_t'(\cdot)\xi(\cdot)/d\xi^2] = U''(\cdot)S(1-r_s) - U'(\cdot)r_s'S$.

Therefore,

$\xi[d^2U_t'(\cdot)\xi(\cdot)/d\xi^2] = 0$ iff $r_s(1-r_s) + r_s'S = 0$

Solving for $r_s(1-r_s) + r_s'S = 0$, we get $r_s = 1/(cS + 1)$, where $c$ is a number.

Note that this solution was derived from the whole range of random variables.

$dr_s/dS = -c/(cS + 1)^2$.

$d^2r_s/dS^2 = 2c^2/(cS+1)^3 > 0$ for $r_s > 0$ and $S > 0$, which are relevant domains for economic meaning.

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