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Direct Investment, Hysteresis, and Real Exchange Rate Volatility

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Recent papers by Dixit and others have put forth the argument that real exchange shocks generate a condition of hysteresis in the export entry and exit prices, and that this wedge in prices explains the persistence in the U.S. current account deficit. This article shows that the critical hysteresis bounds for exports are altered dramatically by the additional option to locate manufacturing in the United States. We develop a model that incorporates simultaneously the option to exit from a foreign country along with the option to invest in manufacturing facilities. The numerical simulations provide strong qualifications to the relationship between hysteresis in export prices and the persistence of the current account deficit. *J. Japan. Int. Econ.,* March 1996, **10**(1), pp. 12–36. School of Management, Boston University, Boston, Massachusetts 02215. © 1996 Academic Press, Inc.

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The persistence of the trade deficit of the United States has instigated a number of recent papers examining the effects of hysteresis on foreign entry into a country. In the classic Marshallian case, exit from a market occurs when price falls below the threshold where variable costs are no longer covered. Entry is triggered when price exceeds long-run average costs. Thus, even in the simple case of certainty, there exists a static hysteresis band in which neither exit nor entry occurs.

The recent treatment of hysteresis and exchange rates extends this reasoning to conditions of uncertainty in order to analyze dynamic effects of hysteresis. In the model of Dixit, prices via exchange rate fluctuations

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follow a stochastic process.[1] Exporters to a market enter during periods of overvaluation, but maintain the valuable option to withdraw if the exchange rate moves unfavorably. Since exit eradicates the value of what Dumas (1988a) has labeled perishable investments, small losses will be tolerated bacause of uncertainty over future exchange rate movements.

Curiously, the focus on trade obscures the fact that it is foreign direct investment which is responsible for hysteresis. The Dixit argument, as well as that of Baldwin and Krugman (1989), assumes that *export hysteresis* results from capital account investments in complementary assets supporting trade. However, the implications are radically different when foreign investment is used not only to support exports (e.g., through establishing distribution channels, dealer networks, and advertising) but also to shift manufacturing to the local market, i.e., the export-receiving country.

The decision to transfer production adds an important twist to the hysteresis phenomenon. Investment in local manufacturing always includes the option to shift back to an export mode if the real exchange rate should again appreciate. Production shifting between the two countries also brings about a hysteresis due to the volatility of exchange rates. Because it is costly to shut down and start up plants, it may pay to incur short-term losses and not exercise the option to shift.

The difference between the exchange rates that bound the switch and withdrawal decisions is different from the wedge in rates in the export case. We label the band in switching exchange rates as *production hysteresis*. If the production hysteresis band is not too wide, investments in overseas plants the opportunity to benefit from multinational flexibility. The investment in overseas operations generates an option value through the potential to shift production between local and foreign plants.

An indication of the importance of exchange rates is reflected in data tracking the composition of foreign investments in wholesale distribution and manufacturing in the United States. During periods of dollar overevaluation, foreign direct investments should be focused in wholesale and distribution activities in order to support exports to the United States. Subsequent to a depreciation, direct investments should flow more to establishing plants in the U.S. market.

This relationship between the change in the *composition* of foreign direct investment and the real exchange rate is graphed in Fig. 1.[2] Because of the growth of Japanese investments in the United States, it is instructive to look at the data for Japan. The trend line for Japanese investment in the

[1] See also Baldwin (1988), Baldwin and Krugman (1989), Dumas (1988a,b), Shrikhande (1988), and Kogut and Kulatilaka (1988, 1994). Dixit (1989a,b,c) reformulated the 1987 paper to cover entry under uncertainty more generally.

[2] Froot and Stein (1991) show a similar overall pattern between foreign direct investment and the real exchange rate.

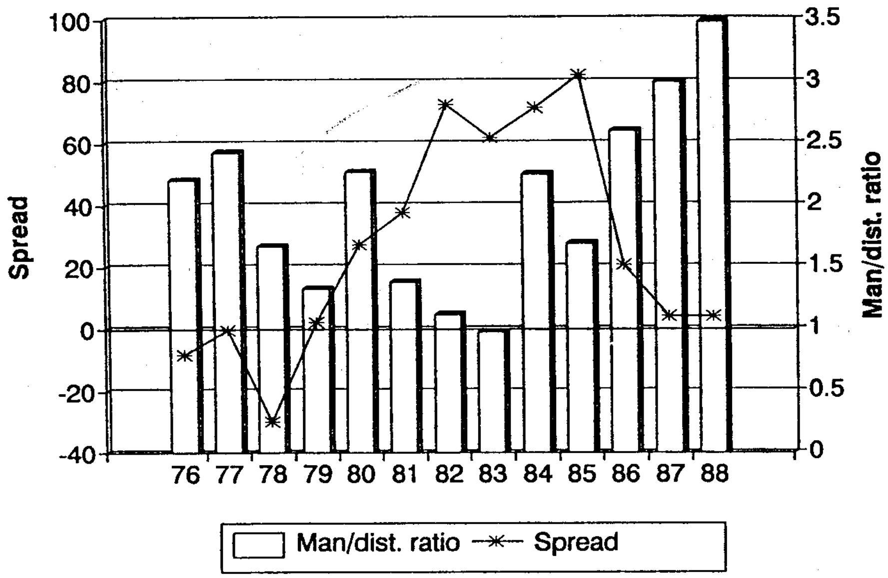

FIG. 1. Manufacturing/distribution vs spread.

United States are given for the raw number of entries in the wholesale distribution industry and in manufacturing industries in general; it can be expected that wholesale distribution investments are used to support both exports and local manufacturing sales.[3] Deviations from the equilibrium exchange rate estimates are taken from the calculations of Yoshikawa (1990). Figure 1 not only indicates an increase in the number of entries into the United States following the beginning of the Japanese yen appreciation in 1985, but also shows a change in composition of manufacturing investments relative to wholesale distribution. Data on entries for 1989 show an even more extreme profile: 23 wholesale distribution entries against 224 manufacturing entries.

The apparent relationship between exchange rates and manufacturing investments has potential implications for the trade deficit. In 1989 and 1990, the annual average Japanese manufacturing investment in the United States reached $16,312 million.[4] Between the period of 1981 and 1984, the annual average was $1703 million. The increase in Japanese manufacturing

[3] The data are drawn from published reports of the U.S. Department of Commerce, *Foreign Direct Investment in the United States*, for the years 1977 to 1988.

[4] The stock of Japanese direct investments in the United States grew from $19 to $70 billion between 1985 and 1989. Non-Japanese direct investment grew in the same time period from $165 to $331 billion. Data are from unpublished material provided by the International Trade Administration, U.S. Department of Commerce and the Ministry of Finance, Japan.

FDI in 1988 was 101%; the largest prior increase (134%) was in 1974, following the rapid devaluation of the dollar after the Smithsonian agreements.[5] Whereas some of these investments are, no doubt, complementary with trade flows, it is very likely that a portion of Japanese exports will be displaced as these new plants come on stream, thus leading to a correction in the trade account.

The flexibility to establish U.S.-based manufacturing raises important questions regarding the importance of hysteresis effects on trade deficits. Because foreign direct investment in manufacturing, in part, substitutes for imports, the trade account deficit is corrected, though the share of the home market held by foreign firms remains unaltered. Persistence of the current account deficit is an outcome of the need to serve the market until new plants come on stream. But once these plants are built, future adjustments will be more rapid, for the investment in overseas operations generates an option to shift production between local and foreign plants.[6]

The widening of the alternatives to include foreign manufacturng results in a nontrivial distinction form the simple choice between withdrawing and exporting. While hysteretic effects are still important regarding the decision to export versus other modes, they are less critical in explaining the changes in market share held by foreign companies. The analytical and simulation results indicate that moderate movements in the exchange rates induce the decision to shift manufacturing; actual withdrawal from the market occurs only in some rather extreme cases.

In the following pages, we propose a general model for evaluating the multinational flexibility to withdraw or choose the optimal manufacturing location. We first set out a partial equilibrium model which compares these two options under a set of conditions similar to those in Dixit's model.[7] By incorporating the alternative to shift manufacturing to the foreign site, the subsequent section then analyzes these choices simultaneously as a compound option. The magnitude of the option values and hysteresis bands and their sensitivity to exchange rate volatility is examined through a numerical simulation using dynamic programming.[8] The Conclusions section puts forth an alternative explanation for the persistence of the current account as arising out of the lags to set up manufacturing in the United States.

The structure of the models below reflects choices regarding the relative

[5] In more recent years, Japanese foreign direct investment has declined notably, but this decline should be seen in the context of the rapid fall in Japanese domestic capital investment.

[6] Orr (1991) recently estimated that recent FDI flows into the United States could lead to an improvement of roughly $25 billion in the U.S. trade balance, though most of this effect is estimated to occur through improved productivity of acquired operations.

[7] The modeling techniques are similar to those of Kulatilaka (1987) and Pindyck (1988).

[8] See also Baldwin (1989) for a general analysis of hysteresis in a stochastic dynamic programming framework.

importance of the factors that substantially alter the analysis of earlier treatments of hysteresis and trade. Though simple in the assumptions of partial equilibrium and competitive markets, the benefit is derived from being able to analyze the effects of changes in the characterization of the exchange rate process and investment commitments on the comparative dynamics of the compound option values and the hysteretic bands. Because it seems reasonable that the exercising of these options should be responsive to the volatility of the real exchange rate (as well as to its current level and the current operating mode), we model the operating choice along the lines of Dixit's approach.

A General Model of Multinational Production Flexibility

For expository purposes, we let Japan be the exporting country and the United States be the country of destination. Let us assume that firms are price-takers in both factor and product markets; demand is known and nonstochastic. The Japanese firms have already sunk perishable capital investments in the U.S. Market and carry excess capacity in their domestic plants in order to serve foreign markets. Having paid the entry price, $I_{\mathrm{p}}^{\mathrm{US}}$, the representative firm exports at variable cost. If it withdraws from the United States, it must pay $I_{\mathrm{p}}^{\mathrm{US}}$ again if it should wish to reenter. The subscript p represents the perishable capital that vanishes if exports should cease, superscript US indexes the target market.

The operating decision facing the firm is to choose the maximum of the net present values of the alternatives to export, withdraw, or invest in local manufacturing in the United States. This decision is determined by the cost of the inputs and incremental investments, as influenced by the current values of the state variables and expectations regarding fluctuations in future values. In our model, the state variables are the real exchange rate and the operating modes.

Before characterizing the stochastic dynamics of the real exchange rate, we develop a model covering all modes of interest to our paper. Dixit's shutdown option is a special case of this development. In this general model, we consider three modes of operations:

0. No sales in the United States.
1. Produce in Japan and export to the United States.
2. Produce in the United States and serve the U.S. market.

The dynamic problem is to value the profit stream stemming from the flexibility to choose the optimal operating mode. This choice is contingent on the previous mode of operation and the prevailing real exchange rate.

TABLE I

Mode switching from	Mode switching to 0	1	2
0		I_p^{US}	I_p^{US}
1	δ_w		δ_{JU}
2	δ_w	δ_{UJ}	

tching between modes is costly, the choice is also dependent ting mode in use at the beginning of the variable.

witching, as determined by the existing operating mode, are ending upon the necessity of new investments in manufacturing , or in the United States, I_m^{US}, or investments in perishable Given these investments, additional costs are still incurred for the complete withdrawal mode and for switching from the the American plant or from the American to the Japanese additional costs are denoted as δ_w, δ_{JU}, and δ_{UJ}. We let K_{ij} e total costs of switching between operating modes i and j.

ufacturing plants have been established in the two countries, g costs can be summarized in Table I. For instance, the decision e U.S. market by exporting incurs the cost $K_{01} = I_p^{US}$. The d profit function under the mth mode is denoted by $\Pi(\theta, m)$. ion to change the operating mode reflects both the immediate stment and those associated with any potential changes. For costs of withdrawal (δ_w), resulting from the plant shutdown, t only the exit decision but also the reentry choice. Increases itude of adjustment costs widen the hysteresis band. (In the reported later, we set δ_w to 0 for reasons of convenience, but up the effects of adjustment costs through the effects of δ_{JU}

e plant have an economic life of T. For any $t < T$, the firm tion whether to export or to withdraw from the market. When e rate realized at the beginning of time, t, is $\theta_t = \theta^k$, the value the mth mode prior to a firm acting (e.g., switching) satisfies g recursive relationship:

$$\theta^k, m, t) = \max_j \{\Pi(\theta^k, j) - K_{mj} + \rho E_t V(\theta_{t+1}, j, t+1)\}, \qquad (1)$$

e risk-free discount factor. The risk-neutral expectations condi- $= \theta^k$ are computed as

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not for the risk-adjusted discount rate, but rather for the risk-adjusted probabilities of future cash flows.[12] Having adjusted the dynamics of the stochastic variable θ to those that would prevail in a risk-neutral economy, we calculate present values of future cash flows by taking expectations using the adjusted probabilities and then discounting the cash flows at the risk-free rate.

The standard approach to such valuation problems is to solve the partial differential equation governing the value of the project to serve the U.S. market. In the case where the uncertainty follows a mean-reverting process and the underlying option is compound with switching costs at exercise, this equation cannot be solved in closed form. Instead, we explicitly lay out the equivalent dynamic programming problem and solve it numerically. A primary advantage to this formulation is that the profit maximization criteria are transparently related to the optimal operating decison. A side benefit is that the discretization provides an intuitive correspondence to important institutional aspects, such as costly recontracting and sluggish price adjustments.

We discretize the project life, T, into N periods of length Δt. At any time t, the firm observes the realization of θ_t and fixes it contractually for the period $(t, t + \Delta t)$; all decisions are made in the beginning of the period. When the contract length is within the control of the firm, the limiting continuous time case can be approximated by choosing very small values of Δt. θ is also discretized within the relevant range of fluctuations $\{\theta^1, \theta^S\}$.[13] Depending on the required precision, this range is divided into S discrete states $(\theta^1, \theta^2, \ldots, \theta^S)$, generating $S - 1$ intervals of width s.

Given the discretization of time and space, the probability, p_{ij}, that a transition from θ^i to θ^j will take place in one time interval can be approximated by lumping the probabilities of θ falling between $\theta_j - s/2$ and $\theta^j + s/2$.[14] It is important to keep in mind that p_{ij} is a pseudo probability which would prevail in a risk-neutral world. This adjustment does not assume risk neutrality. Yet, since the expectations of future cash flows are derived using the risk-neutral probabilities, the risk-free rate can be used in discounting.

Special Cases

Having specified the general model and exchange rate process, we turn to analyzing three special cases: the exporter with no flexibility, exporting with the withdrawal option, and exporting with the flexibility of production shifting.

[12] See Chapter 7 of Hull (1989) and also Pindyck (1988).

[13] The resulting state-space discretization generates a grid that is similar to that of finite difference methods used in contingent claims valuations models. See Brennan and Schwartz (1978) and Kulatilaka (1987).

[14] See the Appendix for details on the derivation of the transition probability matrix.

Pure Exporter. The conventional view of the firm's export decision is to analyze the entry decision without the withdrawal option. The value of exporting to the United States, denoted by V^x, becomes a special case of the general model, where

$$V^x(\theta^k, 1, t) = \Pi(\theta^k, 1) + \rho E_t V^x(\theta_{t+1}, 1, t+1)^{(3)} \tag{4}$$

(V^x is the value of the project to export for the fixed technology; the argument, 1, indicates that the current operating mode is exporting.) At the time $t = 0$, the exporter's decision rule is simply to invest in export entry if $V^x(\theta_0, 1, 0) > I_p^{US} + I_m^J$.

Graphically, Figs. 2a and 2b depict the benchmark case of exporting without the withdrawal or production expansion options. For purposes of illustration, we assume the special case that the single-period profit functions are linear. With known and constant demand, this linearity implies that the profit functions are Leontief, with fixed coefficients. That is, yen profits normalized by yen-dominated U.S. revenues are

$$\Pi(\theta, 1) = \alpha_1 + \beta_1 \theta. \tag{5}$$

Due to the normalization, α_1 represents the Japanese proportion of unit costs, β_1 reflects the U.S. operating margin, and θ is the unit-free real exchange rate. By construction for the export case, we let β_1 equal 1; all variable costs are incurred in Japan. Figure 1a shows one-period profits to rise and fall linearly with the exchange rates. At $\theta = 1$, net profits are positive.

Linearity in the static profit function does not lead to linearity in the dynamic valuation of the project, as shown in Fig. 1b. Due to the mean-reverting property characterizing the exchange rate diffusion process, the discounted net cash flows are not linear in θ. In order to ensure competitive entry, at PPP (i.e., $\theta = 1$) the discounted cash flows should be just sufficient to cover investment costs. For the marginal firm in this baseline case, net present value is 0.

Export versus Withdrawal. Consider now the expert decision with the withdrawal option. (This option is the Dixit (1987) and McDonald–Siegel (1985) problem.) We let δ_w be the small but finite cost incurred in withdrawing from the U.S. market. Because withdrawing is costly and due to the perishable nature of the capital investment in the United States, the value function will be sensitive to the current operating state: withdrawal or exporting. This problem is more complex than the previous one, as it

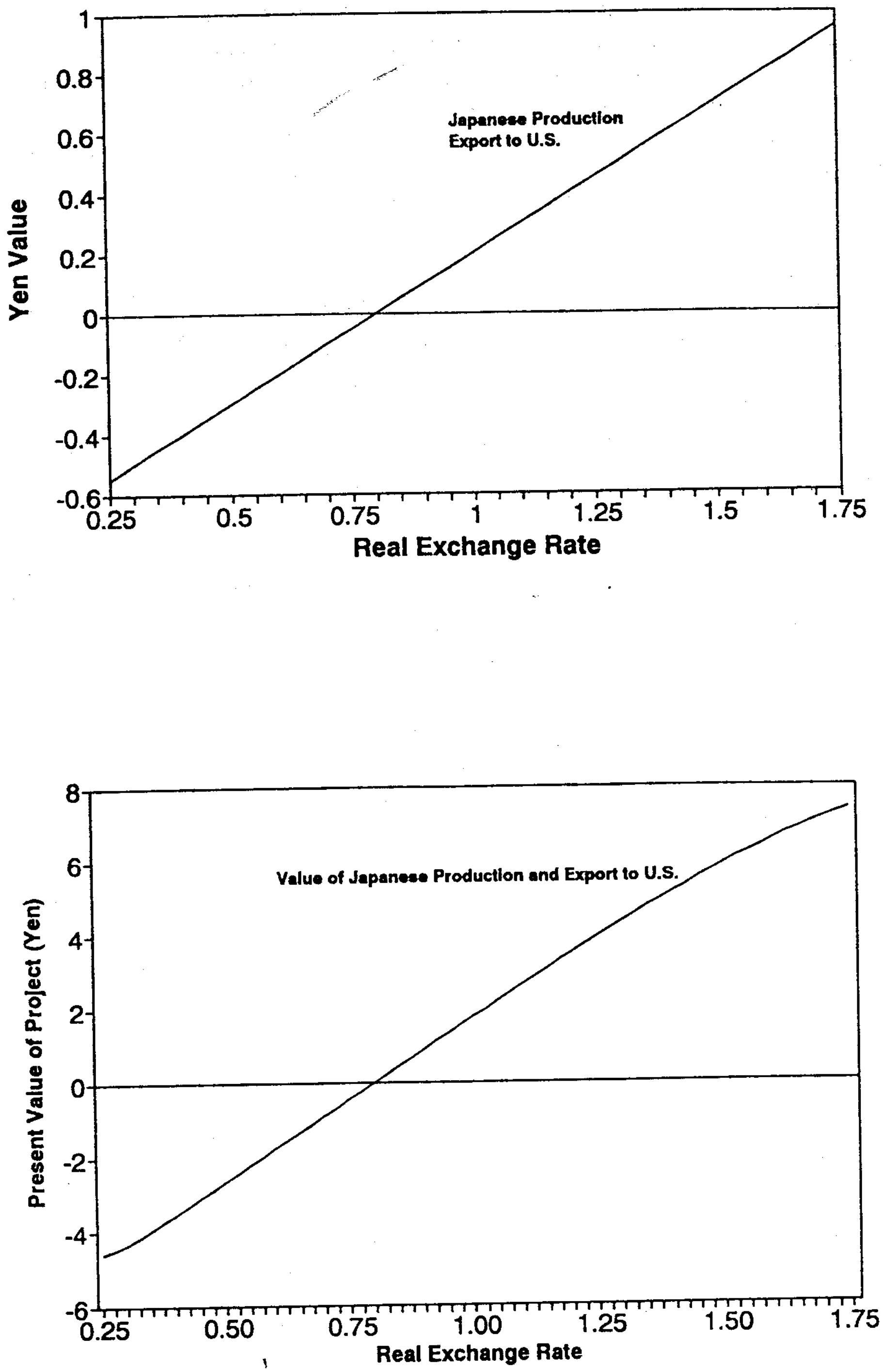


FIG. 2. (a) Single period profit functions; (b) project value with no options.

involves solving a compound option where the value function depends on the mode (export or withdraw) chosen during the previous period.[15]

Let $V^{w}(\theta, 0, t)$ and $V^{w}(\theta, 1, t)$ be the value functions when operations are withdrawn and exporting, respectively. (Note that in comparison to the fixed case, the valuation with the withdrawal option involves two state variables: the current realization of θ and the current operating mode.)

The valuations at any time $t < T$ are

$$V^{w}(\theta, 1, t) = \max\left([-\delta_{w} + \rho E_{t} V^{w}(\theta, 0, t+1)], [\Pi(\theta, 1) + \rho E_{t} V^{w}(\theta, 1, t+1)]\right) \tag{6a}$$

$$V^{w}(\theta, 0, t) = \max\left([\rho E_{t} V^{w}(\theta, 0, t+1)], [\Pi(\theta, 1) - \delta_{w} + \rho E_{t} V^{w}(\theta, 1, t+1)]\right). \tag{6b}$$

Again, working back recursively, this system can be solved for the values in the initial period, $V^{w}(\theta_0, 1, 0)$ and $V^{w}(\theta_0, 0, 0)$. At $t = 0$, the investment in exporting to the United States is made if $I_{p}^{US} + I_{m}^{J} < V^{w}(\theta, 0, 0)$. As before, to ensure competitive entry, at PPP the marginal firm must have $I_{p}^{US} + I_{m}^{J} < V^{w}(\overline{\theta}, 0, 0)$. (Replacing the term max by argmax_m in each equation gives the optimal operating mode.)

Figures 3a and 3b show how the option to withdraw from the U.S. market changes the benchline case of exporting under a rigid technology. In the one-period static formulation given in Fig. 3a, the option to withdraw truncates the profit function at the lower bound where $\pi(\theta, 1) - I_{p}^{US} = 0$. The critical values of θ for withdrawal and reentry define the band of *export* hysteresis. Parenthetically, it should be noted that the dynamic formulation includes the cost stemming from the likelihood of future reentry and withdrawal. Thus, while the flexibility to withdraw in the future increases the overall value of the project, the uncertainty causes the hysteresis band to widen.

The value of the withdrawal flexibility is given in Fig. 3b. The convexity of the value function reflects the option to withdraw for certain values of θ. As V^{w} includes the additional option to withdraw, it can never be worse than V^{x}; consequently, its graph lies always at or above the fixed technology case.

The Option to Shift Production. For values of θ to the left of the hysteresis band, the firm faces two alternatives to withdrawing from serving the

[15] See McDonald and Siegel (1985), where the shutdown option is explicitly solved for an infinitely lived project, the value of which follows a log normal process.

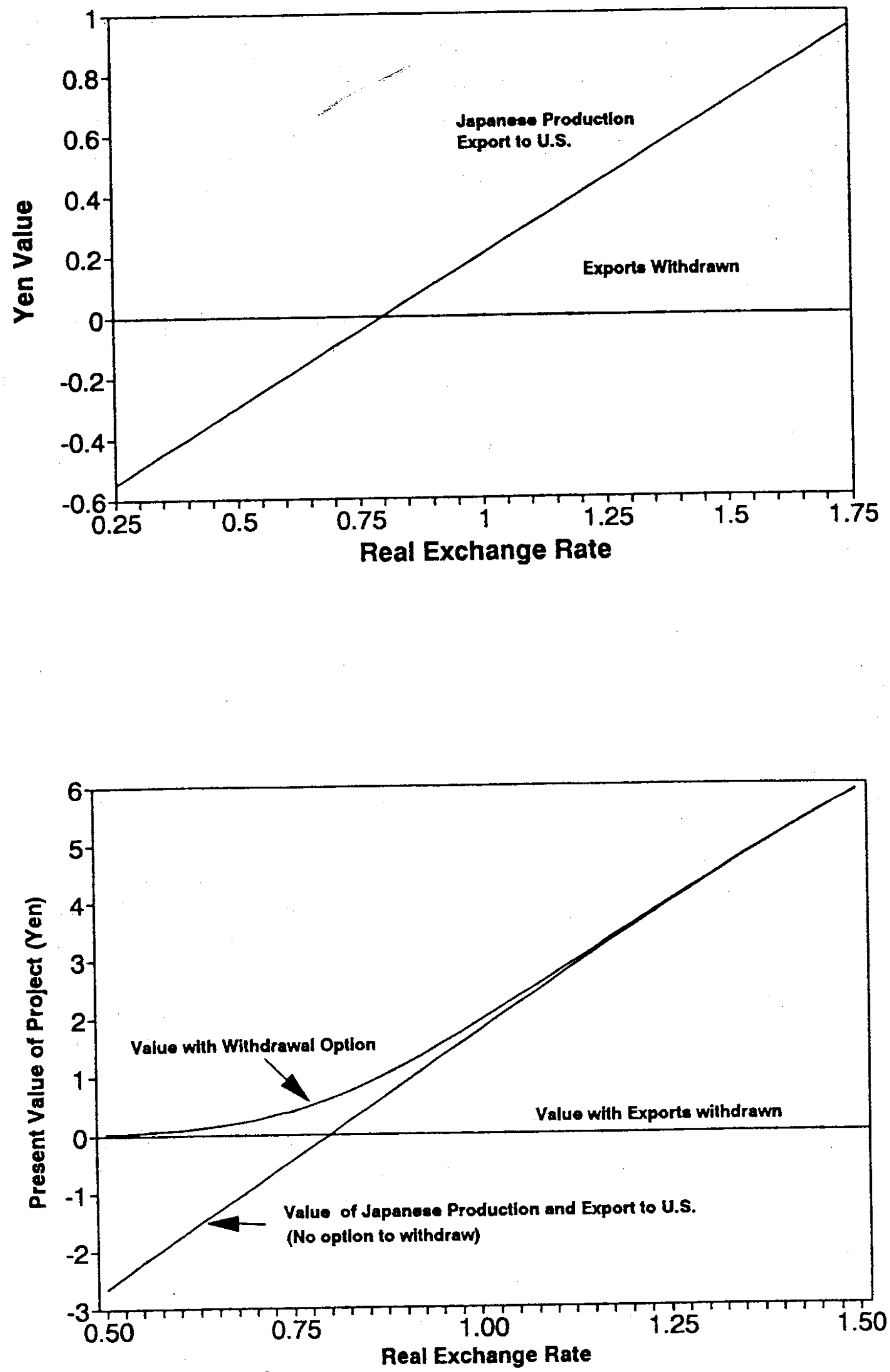


FIG. 3. (a) Single period profit functions; (b) project value with withdrawal option.

U.S. market. One is to improve productivity of current operations. At an aggregate level, increased productivity leads to shifts in the long-term PPP (or real exchange) rate. As firms and sectors vary in the potential increases in productivity, the tendency of the nominal exchange rate to revert to this newer rate implies that marginal exporters will be eliminated. In a macroeconomic setting, all exporters are competing against the real exchange rate and, hence, against each other, no matter their industry affiliation.[16] It is the heterogeneity in productivity among firms that prevents a massive switch from exporting to foreign production for all firms.

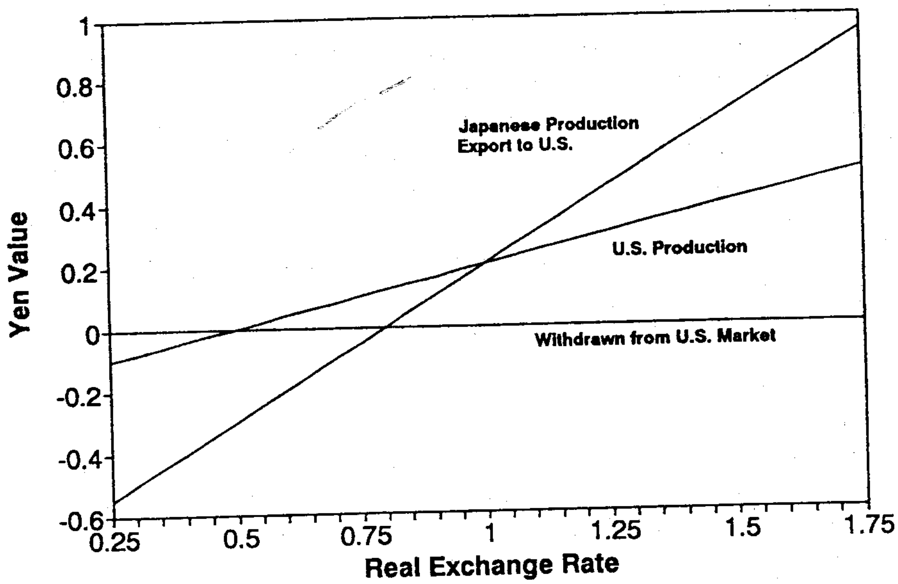
Another alternative, which would be especially appealing to the marginal exporter, is to expand production to the United States. In this case, the Japanese company invests in production facilities. To compare the export, withdrawal, and U.S. manufacturing investment options, the reasoning of Dixit's argument can be expanded. We assume that investment in production facilities is not perishable; shutdown of a plant does not eradicate the value of tangible capital equipment. Firms respond to exchange rates by considering the option of not only whether to serve the American market, but also whether to invest in the flexibility to manufacture the goods in the United States or in Japan.

The decision facing the firm is whether to invest in manufacturing plants in the United States given its previous investment in distribution and reputation, i.e., perishable capital. The export/withdrawal solution is now augmented by the option to shift production between the two plants. If the value of operating two plants with the option to shift is worth more than the additional investment cost in the United States, the project is accepted. For certain exchange rates, it is still a valid option to withdraw from serving the U.S. market.

Since the Japanese firm is already operating with an export production facility with the option to withdraw, the investment decision is to invest in the United States if $V^{\mathrm{ps}}(\theta, 1, 0) - V^{\mathrm{w}}(\theta, 1,0) > I_{\mathrm{m}}^{\mathrm{US}}$. ($V^{\mathrm{ps}}$ is the value of the project including the production shifting option.) Of course, other considerations will influence the decison, e.g., differences in technologies, host country restrictions, and tariff and transportation costs. Each of these issues complicates the model, but the fundamental results are conceptually similar to the version above.

In Fig. 4a, the one-period profit function is analyzed when the option to switch production from Japan to the United States is added to the withdrawal option case. For example, when the current production takes place in Japan, the profit function defined by max $[\pi(\theta, 1), \pi(\theta, 2) - \delta_{\mathrm{JU}}$ $\pi(\theta, 0) - \delta_{\mathrm{w}}]$ is piecewise linear in θ, where the second argument in π reflects to the modes: 0 = withdrawn, 1 = exporting, and 2 = U.S. product. The

[16] See Dornbusch *et al.* (1977).



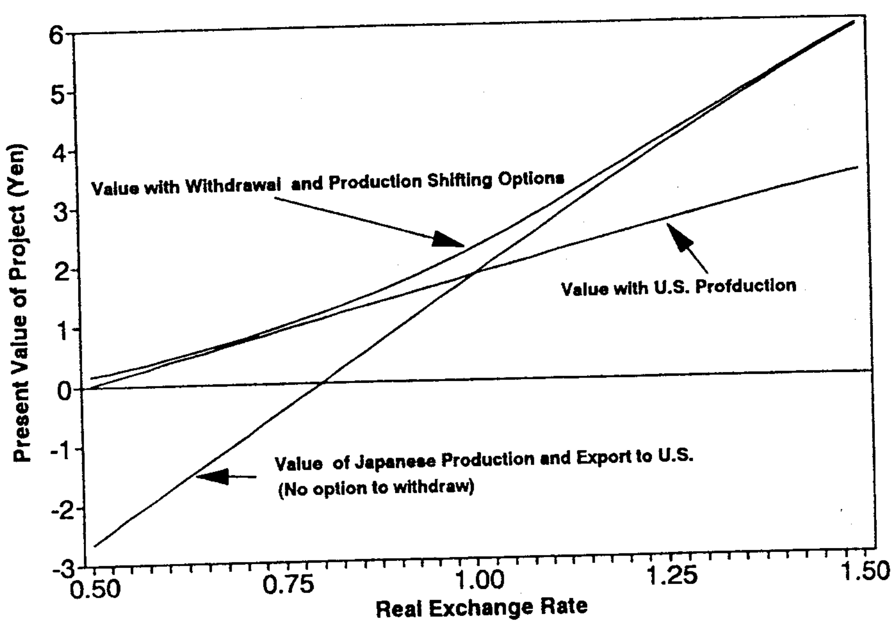


FIG. 4. (a) Single period profit functions; (b) project value with both options.

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TABLE II

Stochastic process	Profit function	Investment and switching costs
$\lambda = 0\%, 10\%$ (annual)	$\Pi(\theta, 1) = -0.8 + \theta$	$I_P^{US} = 0.2, 2.4, 24, \delta_w = 0.05$
$\sigma = 10\%, 25\%$ (annual)	$\Pi(\theta, 2) = -0.2 + 0.4\theta$	$\delta_{JU} = \delta_{UJ} = 0.05$

SIMULATIONS

To examine the relative values of the export/withdrawal and production shifting options and of their hysteresis bands, we solved for the project values and entry and exit exchange rates through a numerical analysis. The short-term profit functions are specified as earlier, i.e., linear. More complex functional specifications, such as inclusive of scale economics and carrying-costs of excess capacity, would give the same results, though dampened in magnitude.

In the simulations, time is discretized into monthly switching intervals. Such intervals are slightly shorter than suggested by discussions with U.S. plant managers but are similar to those attributed to best practice in Japanese production planning (Abegglen and Stalk, 1985). The interval durations chosen also provide a good approximation to the continuous switching case.

The parametrization of the diffusion process entails choosing values for λ and σ. For our purpose, we let the annualized λ take on values of 0 and 0.1. As mean reversion is believed to increase the value of the option, these specifications allow a comparison of mean reversion against a simple random walk with no drift.[17] We let the annual volatility, σ, take on the values of 0.1 (corresponding to Dixit's simulation assumption) and 0.25.

To evaluate the importance of hysteresis effects, we also vary the perishable capital costs. Evaluated at θ equal to 1, perishable capital costs are allowed to vary among one month, one year, and 10 years of annual profits (which correspond to multiples of 0.2, 2.4, and 24 of profits). The remaining parameter values are fixed as shown in Table II, with the costs indexed as a percentage of annual profits with PPP holding as a baseline measure. The real discount rate is set at 0.025.

Using dynamic programming, the profit values and critical exchange rates were calculated for each of the three projects: fixed technology, export/withdrawal, and production shifting.

[17] See the argument in Dixit (1989). Glen (1988) found the adjustment coefficient (λ) estimates to range from 0.04 to 0.16% on a monthly basis, with the European Monetary Countries showing the greatest reversion.

TABLE IIIa
SENSITIVITY ANALYSIS: INCREMENTAL PROJECT VALUES (IN %) WHEN CURRENTLY IN THE U.S. MARKET[a]

λ	σ	0.2	2.4	24
0.0	0.10	(a) 7.08	6.35	5.87
		(b) 12.13	12.09	12.09
0.1	0.10	(a) 0.28	0.18	0.17
		(b) 14.40	14.39	14.39
0.0	0.25	(a) 16.98	15.72	13.74
		(b) 19.58	19.16	18.89
0.10	0.25	(a) 4.87	3.87	2.84
		(b) 19.78	19.40	19.23

Note. (a) Under withdrawal option. (b) Under production shifting and withdrawal options.

[a] Values are for $\theta = 0.8$. Under this scenario, the firm is in the U.S. market either as an exporter (in case a) or as a producer (in case b).

Table III gives the *percentage* increase in the valuation of the projects with the option to withdraw and shift over the fixed technology case. [18] The option value of flexibility, of course, increases in σ. A nonintuitive result is that the lowest incremental values of production shifting occur when perishable capital is negligible. Since the cost of reentry is, in this case, low, the option to withdraw increases in value. At high extreme values of I_p^{US}, the withdrawal option tends practically to zero, whereas the production shifting option retains its value. Clearly, the incentive to withdraw or to invest in the United States will vary dramatically depending on the proportion of investment of nonretrievable capital required to enter an industry.

It is interesting that mean reversion (i.e., when $\lambda = 0.1$) decreases the project value for the simple export withdrawal case. Because reversion is to $\theta = 1.0$ and the withdrawal option is optimally exercised at $\theta = 0.8$ (ignoring hysteresis and switching costs), the effects of mean reversion on project values are dependent on the parameter choices. This ambiguity of mean reversion on project value is, nevertheless, fundamental. The value of the project falls with the distance of the critical switching point from the PPP rate, i.e., as the probability of a boundary crossing becomes less likely. (By boundary crossing, it is meant that θ has moved to cross a critical exchange rate value, where a critical rate is defined to be the point of optimal exercise of one of the options.) Consequently, as long as projects

[18] The values reported are computed at an initial value of θ equal to 0.8, the breakeven point at which variable costs are just recovered and where, by construction, the options are most in-the-money.

TABLE IIIb
INCREMENTAL PROJECT VALUES (IN %) WHEN CURRENTLY NOT IN THE U.S. MARKET[a]

		I_P^{US}		
λ	σ	0.2	2.4	24
0.0	0.10	(a) 7.10	5.22	0.14
		(b) 11.93	9.69	0.15
0.1	0.10	(a) 0.27	0.03	0.01
		(b) 14.20	11.99	0.04
0.0	0.25	(a) 16.91	14.57	4.00
		(b) 19.38	16.76	4.26
0.10	0.25	(a) 4.81	3.10	0.09
		(b) 19.58	17.00	2.79

Note. (a) Under withdrawal option. (b) Under production shifting and withdrawal options.

[a] Values are for $\theta = 0.8$. Under this scenario, the firm is *not* in the U.S. market either as an exporter (in case a) or as a producer (in case b).

differ in their production functions, the effects of mean reversion will vary across projects according to the relation between the critical switching points and the PPP value toward which θ tends.[19]

The value of flexibility is sensitive to the assumption of the initial value of θ. If we let θ at t_0 vary, the results given in Table III change substantially. To highlight the key insights, Fig. 5 graphs the incremental value of the withdraw and production shifting options; switching costs are set to zero and the exchange rate process is a random walk with no drift. Setting switching costs to zero is equivalent to eliminating hysteresis as arising from the perishable capital investment. (The effects of changing these assumptions can be gauged from Table III; switching costs and mean reversion tend to dampen the value of the export option, whereas switching costs only affects production shifting when no perishable capital has yet to be committed.)

A comparison of the sensitivity of the export-cum-withdrawal option and the export-cum-withdrawal and production-shifting options to the real exchange rate is given in Fig. 5. The graphs represent the incremental value of the two modes compared to the fixed technology export case. For the simple withdrawal option, the incremental value stems from the protection offered against an undervalued dollar by the put option to withdraw. The introduction of the additional option to shift production raises the project

[19] This result does not seem to have been anticipated in the discussion in Dixit (1989a).

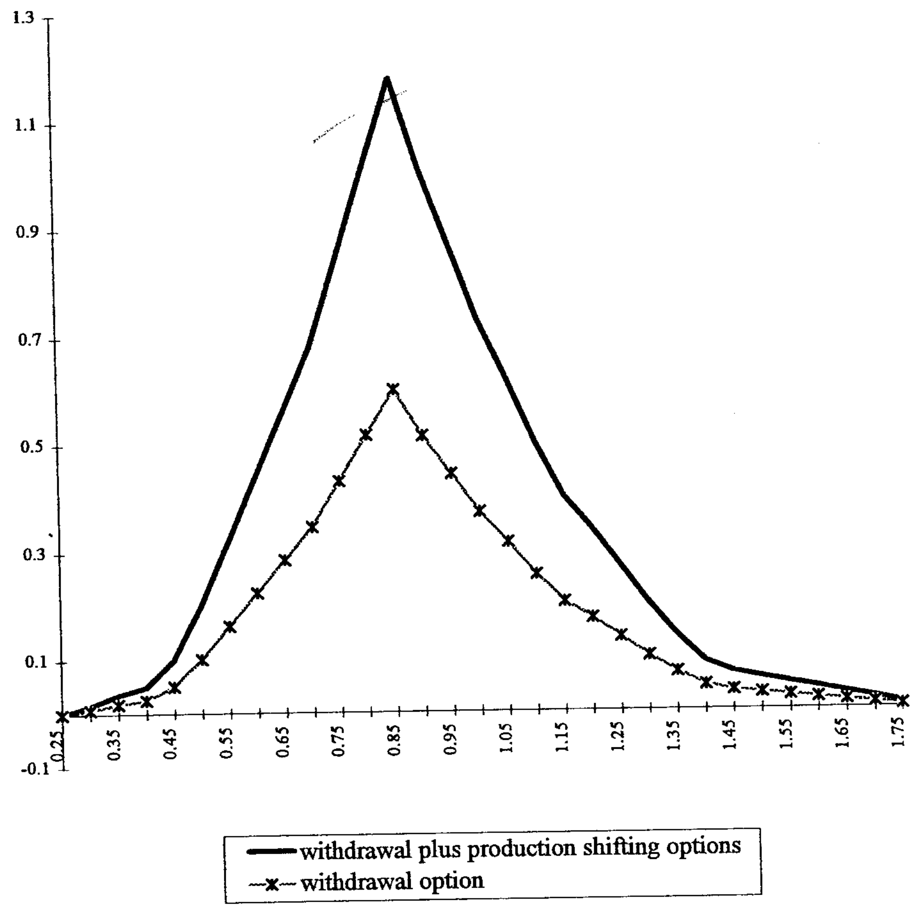

FIG. 5. Incremental option value.

value, as a moderate undervaluation of the dollar no longer leads to withdrawal, but to U.S. production.

In Fig. 5, the baseline comparison is now calculated for the case of choosing the best mode (i.e., withdrawal, Japanese production, U.S. production) at the beginning of the project selection, t_0, and then fixing this technology. Using this baseline, the incremental value reaches a peak at 0.5 and at 1.0. (These peaks correspond to the solutions for the boundary crossings implicit in the profit functions specified for withdrawal, U.S. production, and Japanese production.) The lower peak gives the value of θ where the withdrawal option should be optimally exercised, and the higher peak is where the production shifting option is worth the most and, consequently, is most likely to be exercised. Even in the absence of hysteresis,

TABLE IV
SENSITIVITY OF CRITICAL VALUES OF θ AT WHICH ENTRY/EXIT OCCURS[a]

		I_p^{US}		
λ	σ	0.2	2.4	24
0.0	0.10	(a) 0.850/0.750	0.925/0.675	1.175/0.600
		(b) 0.575/0.425	0.675/0.350	1.150/0.300
0.1	0.10	(a) 0.875/0.775	1.000/0.750	1.575/0.750
		(b) 0.550/0.400	0.600/0.225	1.750/0.125
0.0	0.25	(a) 0.875/0.725	1.000/0.600	1.325/0.400
		(b) 0.600/0.400	0.775/0.225	1.025/0.025
0.1	0.25	(a) 0.875/0.725	1.050/0.650	1.600/0.550
		(b) 0.625/0.375	0.725/0.175	1.050/NX[b]

Note. (a) Under withdrawal option. (b) Under production shifting and withdrawal options.

[a] Value pairs correspond to entry and exit values of θ, respectively.

[b] NX, no exit.

the inclusion of manufacturing in the United States clearly reduces the likelihood of withdrawal from the U.S. market.

Hysteretic effects further diminish this likelihood. In Table IV, the underlying values of θ which trigger exit and entry and which define the hysteresis bands are explicitly calculated. Immediately apparent from the table is that the option to shift production to the United States makes the likelihood of exit very improbable, even for low values of perishable capital costs. With a standard deviation of 0.1 (equal to an annual variance of only 0.01) for the random walk case, a perishable capital investment equal to one year of profits necessitates a depreciation of 88% (to 0.225 of the PPP rate) in order to induce exit if manufacturing in the United States is possible. Without the option to shift between the United States and Japan, the exit exchange rate must depreciate only 40% (to 0.60 of the PPP level).

CONCLUSIONS

There is an important implication in this shift of the withdrawal exchange rate range for the explanation of the persistence in the trade account deficit. Trade balance in the export hysteresis argument is achieved through an overshooting of the clearing rate; the exchange rate tends to, but is rarely at, the clearing value. The option to invest in manufacturing implies an eventual current account balance through the shifting of foreign production to the United States. Yet, given the magnitude of the dollar depreciation since 1985, the stickiness in clearing the trade account deficit may have less to do with withdrawal hysteresis than the lag associated with the transition from exporting to investing in the United States.

By our argument, the stickiness in the adjustment is an artifact of the current historical conditions of the buildup of foreign assets in the United States. Depending on the degree of hysteresis, future adjustments are likelier, by this argument, to be more rapid. Indeed, if U.S.-located plants were expanded to permit exporting back to the domiciles of the parent companies, the value of investing in U.S. operations would only be more attractive. Under this additional option, the profit function, illustrated in Fig. 4a, becomes V-shaped. Clearly, the implications for the current account are more dramatic, in general, when the U.S. exporter's decisions are also considered.

Of course, the speed of adjustment depends upon a number of important parameters not explicitly modeled in our paper. An important consideration, as in the model of Kydland and Prescott (1982), is the time-to-build. Clearly, the lag in the time-to-build will vary by project and industry, as well as by mode of entry (e.g., new plants versus acquisitions). Depending on the persistence of deviations from the equilibrium exchange rate, these lags will influence the attractiveness of the first-time investment in the United States. But once plants are built (or acquired) in the United States, adjustments can be expected to proceed more rapidly. In this sence, Dixit's argument may be seen to hold in the short run, but will be of relatively less empirical importance with the growth of the stock of direct investment in the United States.[20]

We have stylized our model as the building of a new plant and the subsequent shifting of production between the country locations. Another way to interpret our approach is that excess capacity is built into the plants located in Japan and the United States, with the shifting being facilitated by flexible overtime schedules. It could also be, in a more dynamic model, that the older products are shifted to the United States and new products, whose margins are less sensitive to exchange rates, are exported from Japan. These considerations, of course, would complicate the implications of our model for the current account, as they would for any partial equilibrium model.

The above model, for the sake of the analytical presentation, presented a partial equilibrium model. More broadly, the exchange rate process is driven by the conditions of the general equilibrium of the economy. Both monetary and real economic (e.g., productivity) disturbances affect the dynamics of the exchange rate process. These two sources of disturbances will differ in terms of their persistence (with monetary shocks presumably

[20] We would like to thank a referee for strengthening this point.

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ıormal distribution. In general, the transition

$$i + 0.5)s - \lambda(\overline{\theta} - \theta^i)]/\sigma\theta^i\}$$
$$- i - 0.5)s - \lambda(\overline{\theta} - \theta^i)]/\sigma\theta^i\}. \quad \text{(A3)}$$

with the end points θ^1 and θ^S. Lumping all ary, we obtain the transition probabilities

$$S - i - 0.5)s - \lambda(\overline{\theta} - \theta^i)]/\sigma\theta^i\} \quad \text{(A4)}$$

$$- S + 0.5)s - \lambda(\overline{\theta} - \theta^i)]/\sigma\theta^i\}. \quad \text{(A5)}$$

st set $\lambda = \lambda\ \Delta t$ and $\sigma = \sigma\sqrt{\Delta t}$.

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