

Learning Process and Export Adjustment : Simulations of Dynamic Models in the Japanese Case

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ABSTRACT

By introducing the Bayesian learning process, this paper formalizes, within the standard optimization framework, persistent errors in exchange rate expectations often reported in survey data. The model predicts that when a switch in exchange rate adjustment is anticipated with non-zero probability, expectations should be ex-post biased even if agents form their expectations ex-ante rationally. To quantify the learning effect, the following two dynamic models are simulated in the case of Japanese machinery export; In the adjustment cost model, export quantity choice is persistently affected by exporter's initial belief during the learning process. In the customer market model, one hypothetical learning path, which is constructed from historical episodes, explains nearly ten percent of price changes caused by forecast errors.

Keywords :

exchange rate uncertainty ; Bayesian learning ; export adjustment ; pass-through

1. Introduction

In the standard optimization framework of economics, agents are supposed to form their expectations rationally. Expectations of exchange rates, however, deviate from the rational expectations, as has been reported in many survey studies. For example, during the drastic yen exchange rate changes in the 1980s after the Oil Shocks as shown in Figure 1, survey data some of which are summarized in Figure 2 indicate how seriously and persistently the exchange rate expectations actually held by economic agents behaved in a biased direction. Investigations of various survey data, including Frankel and Froot (1987) and Ito (1990), strongly reject the rational expectation hypothesis, in the sense of the unbiasedness and orthogonality, for exchange rate expectations.

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FIGURE 1 EXCHANGE RATE

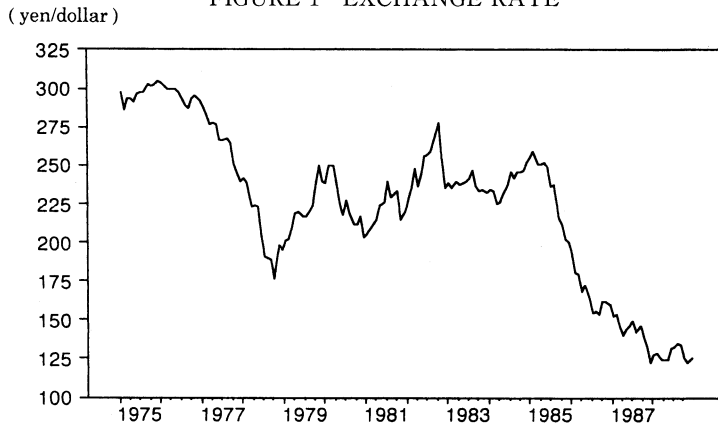
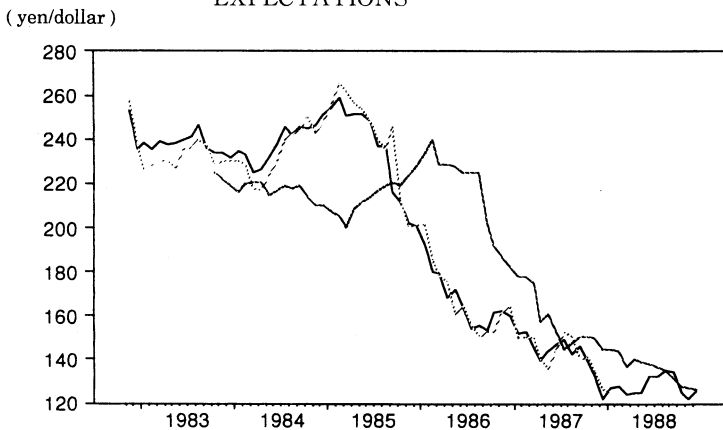


FIGURE 2 SURVEY DATA OF EXCHANGE RATE EXPECTATIONS



(NOTE) The thick line corresponds to actual current exchange rates. The dotted line is one-month ahead expectation from MMS data and the distanced dashed line is 12-month ahead expectation from *Economist data*.

Although we could explore the effect of expectations on current export prices by exploiting accumulated results of survey studies as Tomiura (1992a) tried, the reliance on others' survey data has a problem in that no formal explanation has yet been given to the generation mechanism of observed persistent forecast errors. By considering the learning process, this paper extends the analysis of export dynamics so that persistent forecast errors could, at least partly, be consistent with the optimization framework of economics. The magnitude of the learning effect will also be examined by simulations of dynamic models in the case of Japanese machinery exports. The models which will be simulated with learning effect are the asymmetric adjustment cost model of export quantity choice and the customer market model of export pricing.

The rest of this paper has three sections. Section 2 formalizes the learning process of an

exporting firm. Section 3 reports results from simulations in the case of Japanese exports. Section 4 concludes.

2. Theory

2.1. Previous results

Expectations held by rational agents may be ex-post on average biased because of the anticipation of uncertain future switches. Speculative attack models, which originated in Salant and Henderson (1978) and whose stochastic version was examined by Flood and Garber (1984), study the effects of market anticipation of future regime collapse. These speculative attack models have revived in the context of target-zone policy (for example, Krugman and Rotemberg (1990)). Their empirical applications include Smith and Smith (1990), which identifies the speculative portion in actual British exchange rate changes in the 1920s.¹⁾

By introducing the learning process, Lewis (1988) provides alternative interpretation to the seemingly “irrational” expectations. She concludes that systematic expectation errors during a learning process is “rational” conditional on the available information and on the agent’s belief. Lewis (1989) attributes around half of the prediction errors in the U.S. dollar exchange rate in the early 1980s to the learning effect. The learning model differs from the speculative attack models in that expectation errors persist even after a switch because agents are not convinced of the switch which is not directly observable.

2.2. A Model of Bayesian Learning

Before studying the corporate export dynamics, we have to introduce a model of exchange rate determination. To concentrate on the learning effect, consider the following simple model :

$$s_t = \phi' x_t + m_t + \phi_1 \{E_t(s_{t+1}) - s_t\} \quad (1)$$

where the logarithm of exchange rate is expressed by s , m is the policy variable which is assumed to be unobservable by exporting firms and x denotes other exogenous variables affecting the exchange rate determination. E_t stands for the mathematical expectation operator conditional on all available information at time t . ϕ_1 is the semi-elasticity.

Suppose that m takes either of the following two possible values :

$$\begin{aligned} m_t &= m^0 + \varepsilon_{0t} && \text{with probability } \pi_{0t} \\ &= m^1 + \varepsilon_{1t} && \text{with probability } \pi_{1t} \end{aligned}$$

where ε_{it} is a random variable i.i.d. distributed to normal with mean zero and variance σ^2 . Assume $m^1 > m^0 = 0$ without loss of generality and naturally $\pi_{0t} + \pi_{1t} = 1$ for all t .

By solving forward, (1) reduces to

1) Ito (1990) refers to the possibility of “Peso problem” in discussing the failure of the rationality test in his survey data study.

$$s_t = (1 - \theta) \sum_j \theta^j \phi'_0 E_t x_{t+j} + (1 - \theta) m_t + (1 - \theta) \sum_j \theta^j E_t m_{t+j} \quad (2)$$

where $\theta = \phi_1 / (1 + \phi_1)$ ($0 < \theta < 1$).

Since $E_t m_{t+j} = m^1 \pi_{1,t}$ for all $j > 0$, we obtain

$$s_t = {}_t X_t + (1 - \theta) m_t + \theta m^1 \pi_{1,t} \quad (3)$$

where ${}_t X_t = (1 - \theta) \sum_j \theta^j \phi'_0 E_t x_{t+j}$. The exchange rate determination is thus affected by insufficient confidence through π .

The probability of each state $(\pi_{0,t}, \pi_{1,t})$ is updated over time by the following Bayes' rule, given the prior belief $(\pi_{0,0}, \pi_{1,0})$ which may be possibly affected by the earlier history of policy interventions:

$$\pi_{1,t} = \frac{\pi_{1,t-1} f(m_t | m^1)}{\pi_{1,t-1} f(m_t | m^1) + \pi_{0,t-1} f(m_t | m^0)} \quad (4)$$

where f is the probability density function.

Then, the expectation bias is given by

$$E_t s_{t+1} - s_{t+1} = \{ {}_t X_{t+1} + (1 - \theta) E_t m_{t+1} + \theta m^1 E_t \pi_{1,t+1} \} - \{ X_{t+1} + (1 - \theta) m_{t+1} + \theta m^1 \pi_{1,t+1} \}.$$

Assume that the only uncertainty is from policy switches (${}_t X_{t+1} = X_{t+1}$) for simplification. Then, by taking conditional expectations on $m_t = m^0$, the forecast error if no depreciation policy is taken, denoted by η , is given as follows:

$$\eta_t = E_t [E_t s_{t+1} - s_{t+1} | m^0] = m^1 (\pi_{1,t} - \theta \pi_{1,t+1}) > 0 \quad (5)$$

The above inequality follows from $m_1 > 0, 0 < \theta < 1$, and $\pi_{1,t+1} < \pi_{1,t}$ under $m_t = m^0$.

This demonstrates that exchange rate expectations during the currency appreciation period are ex-post systematically biased toward the depreciation when the true policy in the sample period is appreciation-oriented (m^0), because agents ex-ante anticipate policy switch to $m^1 (> m^0)$ with positive probability $\pi_{1,t}$.

Therefore, since assessed subjective probability of switch ($\pi_{1,t}$) is revised only gradually over time through the Bayesian learning process (4), exchange rate expectations held by rational exporters are persistently biased almost all the time.

To see the behavior of exchange rate forecast error (η_t), differentiate (5) with respect to the size of expected reversal (m^1) and to the initial belief ($\pi_{1,0}$);

$$\text{sign}(\partial \eta_t / \partial m^1) = \text{sign}(\pi_{1,t} - \theta \pi_{1,t+1}) > 0 \quad (6)$$

$$\text{sign}(\partial \eta_t / \partial \pi_{1,0}) = \text{sign}(\partial \pi_{1,t} / \partial \pi_{1,0} - \theta \partial \pi_{1,t+1} / \partial \pi_{1,0}) > 0 \quad (7)$$

which implies that the prediction error toward currency depreciation during an appreciation

process is wider as the expected size of reversal is greater or as the initially assessed probability of reversal is higher.

Combining this result with dynamic export pricing models, such as the customer market model, should provide the following implication : If the demand to export can be characterized by sluggish customer flows where the history of price changes has a persistent impact on future customer stock, then the exchange rate forecast error at one point in time has a long-lasting effect on pricing decisions of exporters. Put another way, as long as pricing decision has investment-like aspect, the export price cut is more drastic, for example, when exporting firms have not yet learned the fundamental or policy change during the early stage of currency appreciation process (e.g. 1986 after the Plaza-G5 Accord in 1985).

In other words, the export pricing which seems to be “irrational” from the viewpoint of ex-post observers (econometricians) could partly be “ex-ante rational” because, in forming exchange rate expectations, exporters take account of the possibility of a future switch which does not materialize at last. The deviation from the “ex-ante rational” export price from the “ex-post rational” one is determined by the Bayesian learning process which in turn depends on the initial beliefs held by firms (possibly influenced by earlier history of policy interventions).

This learning model also yields valuable insights to the exporter’s different responses to permanent and to temporary exchange rate changes, as Krugman (1987) points out. During currency appreciation process, an exporter should cut their export price more drastically if she regards this appreciation as only temporary, not as permanent. This behavior is interpreted in this model as follows : if the current appreciation is anticipated to be temporary, then, the assessed probability of switch to depreciation in the next period should be high and this leads to expected exchange rate biased towards depreciation, which results in a lower export price. Thus, this model provides a clue to examine the effect of anticipated persistence of exchange rate adjustment process on export pricing decisions.

3. Simulation studies in the case of Japanese exports

This section reports the results of simulations of dynamic models where the learning process must play a critical role. The parameters are adapted from the case of Japanese machinery export. Two theoretical models which will be simulated are the asymmetric adjustment cost model of export quantity choice and the customer market model of export pricing. Although formal derivations should be sought in my companion papers (Tomura (1992a,b)), the brief descriptions of the two models in this section will later be supplemented by Appendix C.

3.1. Effects of learning on export quantity adjustment

An exporter is supposed to face costly adjustment in changing her export quantity level as the exchange rate changes. The adjustment decision, however, must be seriously affected by her expectations of future exchange rates. Therefore, the export quantity choice is a good example to test the relevancy of the learning story. In the following, a dynamic export model with

asymmetric adjustment costs under exchange rate changes following a two-state Markov process will be simulated with parameters from Japanese machinery exports. See Appendix C-1 for the structure of the theoretical model.

Suppose that expanding export quantity is costly while shrinking it bears no costs. This realistic assumption of asymmetric adjustment costs simplifies the problem for us. Let me denote the export expansion costs by b and marginal production costs by c . Next, assume that the exchange rate change is the sole uncertainty in the model and follows a two-state Markov process.²⁾

Then, if the exchange rate is at the depreciated level ($e = e^*$), by the model formally explained in the Appendix C, the export quantity level chosen by an exporter is given by

$$q = \alpha \left(\frac{c + b}{e} \right)^{-\theta} \quad (8)$$

where I assume log-linear export demand function with elasticity θ and α is a positive constant. Thus, the export quantity choice in a currency depreciation period degenerates to the simple static or myopic optimization.

On the other hand, when the exchange rate is at the appreciated level ($e = \underline{e}$), one unit of export reduction today will raise the cost by “ b ” in the next period (discounted at the rate δ) if the exchange rate reverts to the depreciated level (occurring with the probability λ). Then, again as will be derived in Appendix C, the export quantity q during the currency appreciation phase chosen by the firm i ($i = 1, 2, \dots, N$) at time t is given by

$$q_{it} = \alpha \left(\frac{c - \delta \lambda_t b_{it}}{e_t} \right)^{-\theta} \quad (9)$$

No private information in expectations ($\lambda_{it} = \lambda_t$ for all i) is assumed so that we can concentrate on the dynamics of learning. The relation (9) confirms the natural results such as larger export quantity for lower production costs (c), and for more depreciated exchange rate (e), *ceteris paribus*. This, however, also demonstrates that firms with higher expected costs of future export expansion ($\delta \lambda b$) keep their export quantity level higher during the currency appreciation phase, *ceteris paribus*. This realistic prediction, which is brought about by the two-state Markov assumption, implies that higher expectations of future currency depreciation (λ) makes exporters keep their export quantity level higher for a given magnitude of currency appreciation.

The expectations held by exporting firms often change quickly over time especially during drastic exchange rate adjustment process.³⁾ This dynamic changes in expectations (λ_t) cannot leave export decisions untouched. In what follows, I report results from two experiments.

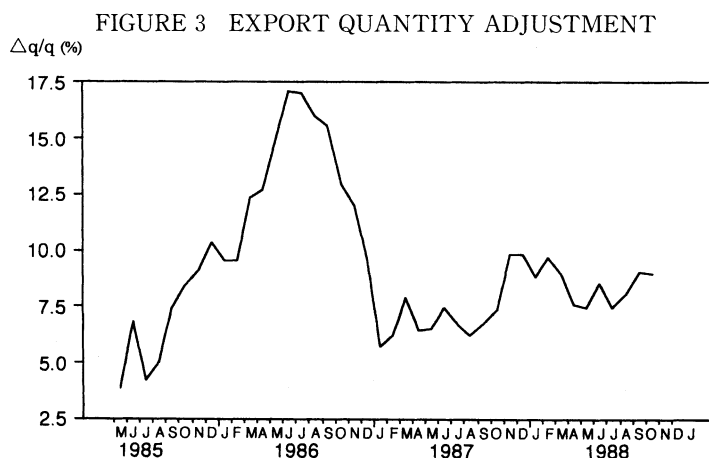
First, to obtain information about the effects of expectations on export decisions during

2) Engel and Hamilton (1990) estimate exchange rate models allowing switches and conclude that “long swing” model dominates random walk model in explaining actual exchange rate changes.

3) Frank (1988) interprets the similar observation from a different perspective. He focuses on another aspect of sunk entry cost : as a reflection of belief held by a firm. If a firm sunk larger cost on entry, then, his anticipation about profitability should be higher and hence the firm stays in the market longer.

exchange rate appreciation, the comparison of the relation of export quantity and exchange rate during the currency depreciation phase, (8), with that during the appreciation phase, (9), is useful. The intuition behind this comparison is that the export quantity choice during the currency depreciation is independent of dynamically changing expectations, as shown in (8). Then, we can infer the effect of expectations (λ_t) by comparing the actual export quantity level during currency appreciation with the export quantity level obtained by extrapolating, into the currency appreciation periods, the relation (8) which is estimated for the currency depreciation period.

Figure 3 illustrates the case in Japanese machinery exports during the yen appreciation after 1985. Here, I define the rate as the percentage deviation of actual export quantity from the level which is obtained from (8) with parameters estimated for the preceding yen depreciating period (1979:11-1985:1).⁴⁾ At the peak (mid-1986) which is about one year after the exchange rate adjustment process began, thus defined rate is as high as 17%.⁵⁾



(NOTE)

$$\Delta q/q (\%) = (\text{actual export} / \text{estimated export}) - 1$$

The "estimated export" is obtained by extrapolating (8) estimated over 1979:11-1985:1.

Although the estimation procedure is far from perfect, this magnitude of deviation suggests that the role of learning is not at all negligible. Since the export adjustment costs themselves are not supposed to be drastically changing monthly under stable inflation as in the 1980s, the quick changes in Figure 3 should be mainly due to the dynamic changes in expectations during the

4) I conduct a linear regression of $\log q$ on constant term, and $\log c/e$ from 1979:11 to 1985:1, assuming b/c stable. Then, I calculate the "estimated" export quantity with estimated coefficients in this regression combined with actual e and c from 1985:2 to 1988:12. See Appendix A for details of the data involved.

5) The export quantity during yen appreciation phase is "too large" in that it is larger than that for the same yen rate during depreciation phase. This finding is puzzling since the effect of entry costs must be stronger on entry during depreciation phase than on exit during appreciation phase. We should interpret the estimates with reserve because production technology and/or preference, which we assume constant, may happen to change before and after the yen appreciation. Especially, productivity growth may not be negligible for the Japanese machinery industry.

learning process. Figure 3 also implies that exporters may have spent one year to gradually revise their beliefs of reversion to yen depreciation after facing a sudden change in 1985. In other words, they kept relatively high export level during the drastic yen appreciation process (especially in the early stage as 1986) because they expected the ongoing appreciation to be temporary. This interpretation receives empirical support as many studies of various survey data show that Japanese exporting firms actually expected that the drastic yen appreciation since 1985 would not persist and that their expectations were only gradually revised over time.

Second, since an exporter in the real world seems to need relatively long time to recognize whether or not the ongoing exchange rate adjustment is permanent, suppose that a firm forms his expectation based on the Bayesian learning process, as has been formalized in Section 2. Assume that the conditional probability of reversion to depreciation is either λ_L or λ_H ($\lambda_L < \lambda_H$) and let the subjectively assessed probability of λ_H be π_t which is updated over time by the following Bayes' rule where initial optimism (quick recovery to depreciation) is gradually replaced by grim reality (long-lasting appreciation) ⁶⁾:

$$d\pi_t/dt = -(\lambda_H - \lambda_L)\pi_t(1 - \pi_t) \tag{10}$$

By solving this differential equation,

$$\lambda_t = \frac{\pi_0 \lambda_H + (1 - \pi_0) \lambda_L \exp((\lambda_H - \lambda_L)t)}{\pi_0 + (1 - \pi_0) \exp((\lambda_H - \lambda_L)t)} \tag{11}$$

As a benchmark in the simulation, the export quantity deviation from the “frictionless” level (i.e. the export quantity chosen under no expected adjustment costs) is useful.⁷⁾ By (9), if $\delta\lambda b = 0$, the export quantity during the currency appreciation phase is given by $q = \alpha(c/e)^{-\theta}$. Then, it will be informative to see the export “excess” rate

$$\frac{\Delta q}{q} = \frac{q_t - q}{q} = \left(1 - \frac{\delta\lambda_t b_t}{c_t}\right)^{-\theta} - 1 \tag{12}$$

which measures how many percent the export quantity is kept higher during the currency appreciation phase compared with the “frictionless” case.

Simulation results are as follows: ⁸⁾ As the initial belief of quicker recovery (π_0) rises from 0.5 to 0.7, the difference in initial belief of this magnitude persistently affects the export quantity adjustment for about one year.⁹⁾ Next, as λ_L increases from 0.3 to 0.5 keeping the gap between

6) This specification of updating introduced here is the same as that in Saint-Paul (1990), where he examines the impact of business pessimism on European sluggish employment recovery.

7) The terminology “frictionless” is used to refer to the no-adjustment-cost case in Bertola and Caballero (1990), for example.

8) I set $\delta = 0.9$ and b_t/e_t (the dollar-base export expansion costs) = 0.1. The export demand elasticity (1.068) is estimated as the coefficient in the log-linear regression on export price. The sample period is from February 1985 to December 1988. In my cost index, $b/e = 0.1$ corresponds to the case where roughly one-quarter of marginal production costs is necessary for one unit of export expansion.

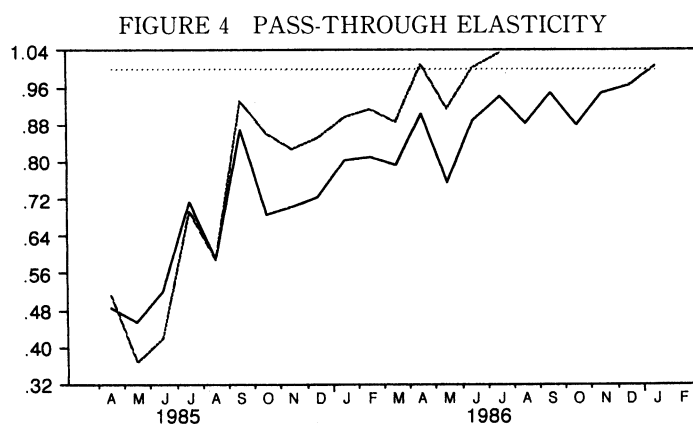
9) I set $(\lambda_L, \lambda_H) = (0.4, 0.8)$. The export excess is adjusted over three year period as the mean over three years after the

λ_H and λ_L constant, the export excess rate is almost doubled.¹⁰⁾

None of the results obtained here should be exaggerated because we have no reliable direct data of the export expansion costs (b) and the expectations about future export expansion (λ). Quite often it is almost impossible to distinguish the export expansion costs from export production costs in corporate accounting data and to measure the assessment of future export expansion possibility.

Next, I like to move to the study of the exchange rate pass-through which we have more reliable estimates. Since this model focuses on the determination of export quantity (not pricing), the linkage is indirect. However, since it has been an important research topic, this paper will briefly analyze the exchange rate pass-through.

Since the export quantity decision is influenced by the expectations λ , which is updated over time, the pass-through should also change over time.¹¹⁾ Figure 4 illustrates the observed dynamic patterns of pass-through changes for Japanese machinery and textiles exports. Let me examine it in what follows :



(NOTE)

The lower line is the pass-through elasticity of the machinery industry and the upper line is that of the textiles industry. The pass-through elasticity in each month is defined as the dollar export price change rate (%) divided by the exchange rate change rate (%) since February 1985.

The pass-through elasticity increases gradually over time and it takes nearly two years to reach perfect pass-through in the machinery case. The level of pass-through is almost always

start of the appreciation is not substantially different (7.84%, 8.21%).

10) I set $(\lambda_L, \lambda_H) = (0.3, 0.9)$ and $(0.5, 0.7)$. π_0 is fixed at 0.5. The export excess rate increases from 5.94% to 9.79% evaluated at the mean.

11) In this model, once we obtain the export quantity, the corresponding export price is determined by the inverse export demand function. Then, given the exchange rate changes, we can calculate the pass-through elasticity (defined as percentage rise in the dollar export price with respect to one-percent yen appreciation). Naturally, the higher the expected adjustment costs become, the more sluggish export is reduced, the lower the dollar export price is realized.

lower than that of the textiles. The model formalized above attributes this to higher expectations of future export expansion possibility in the machinery industry. Although the exchange rate applied to exports is the same for all industries, the technological progress or changes in international competitiveness quite differs among industries. Therefore, even if the exchange rate expectations held by exporting firms show no industrial differences, the assessed future possibility of export expansion can be substantially different depending on the industry. In this sense, the extremely high pass-through in the textiles industry may be the reflection of the pessimistic expectations about the competitiveness of this industry in the global export market, which may be consistent with other anecdotal evidence.¹²⁾

3.2. Learning effect on export price with a hypothetical process

Exploiting various historical episodes surrounding the exchange rate determination, one could construct hypothetical paths of forecast errors. Since there is no decisive evidence as to the expectation formation mechanism in the real world, we have to contend ourselves with examples of expectations hypothetically constructed from numerous information sources which were available to exporters at the time of pricing decisions.

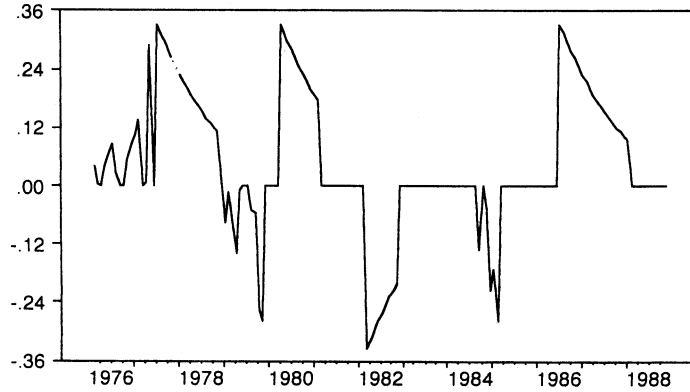
Table 1 lists the events which may have significantly affected the yen exchange rate expectations in chronological order during the period for which the actual path of exchange rate is shown in Figure 1. Figure 5 depicts one hypothetical path of forecast error which I will use in the following study. The assessed probability of exchange rate reversal in the next period is measured on the vertical axis. (If yen appreciation is anticipated during depreciation process, the probability times -1 is plotted.) Needless to say, this is not at all the only path consistent with historical episodes but rather just one example of the many plausible series which could be constructed from the same information set.¹³⁾ (Specific parameter values for this path are shown in notes below the figure.) The periods during which learning proceeds have been chosen based on the events listed in Table 1 and the detailed reasons of the choice of each period are given in Appendix B.

To translate the exchange rate expectations into export price levels, this paper adopts the customer market model of export pricing as the vehicle. The intuition behind this theory goes like this; customers respond to price changes only gradually due to habit formation or quality uncertainty. The sluggish customer flows mean that prices, once chosen, have persistent effects on demand. This, in turn, implies that firms must consider future changes in setting the current price. If we apply this theory to the export pricing, exchange rate expectations must have substantial impact on export prices because future exchange rates are so uncertain that exporters must form their expectations of future exchange rate through the learning process. See Appendix

12) The different market structure may be another factor for different degree of pass-through in these two industries. Industry concentration in the textiles industry is much lower than any machinery industries. Less oligopolistic, or more close to the perfect competition in the textiles industry compared with the machinery industry may explain the almost perfect pass-through in the textiles industry.

13) Figure 5 is drawn for the rather extreme case where the initial belief about reversal in learning process (π_{10}) is set at 1/3 and the size of reversal (m^1) is set at $+/-0.1$, which is quite rare in our sample period. The parameter values of uniform distribution in speculation process are chosen such that final probability is around 1/3.

FIGURE 5 AN EXAMPLE OF ASSESSED PROBABILITY OF SWITCH



(NOTES)

1. LEARNING

1977.7-1978.11, 1980.4-1981.2, 1986.7-1988.1 (depreciation expected)

1982.3-1982.11 (appreciation expected)

 $\pi_{10} = 1/3, |m^1| = 0.1$, normal distribution with $\sigma = 0.24$

2. SPECULATION

1976.1-1977.6 (depreciation expected)

1978.12-1979.11, 1984.9-1985.2 (appreciation expected)

uniform distribution with $\bar{e} = 240$ (1976-77), $\bar{e} = 280$ (1978-79), $\bar{e} = 270$ (1984-85)

3. The assessed probability times -1 is plotted when appreciation is expected.

C-2 for the equation forms used in the simulation.

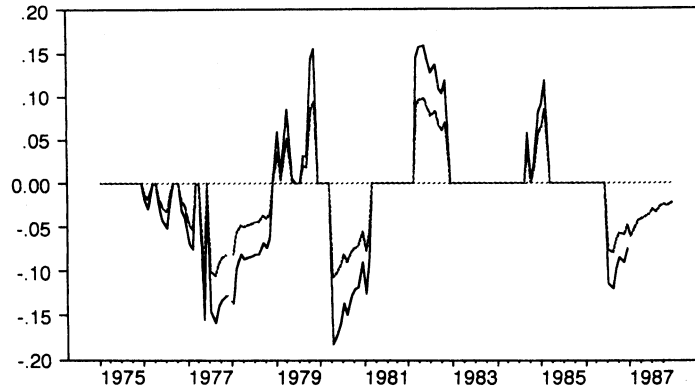
We also need to specify the value of the semi-elasticity ϕ_1 in the exchange rate model, but reliable estimates of ϕ_1 without misspecification are hard to obtain. Hence, as an example, I report the case of $\phi_1 = 1$, which corresponds to the lower value case in Lewis (1989).¹⁴⁾

Figure 6 reports the estimated percentage change in price for the case of Japanese machinery export.¹⁵⁾ Although this hypothetical learning process explains at most $\pm 0.2\%$ of export price changes, the learning effect accounts for nearly ten percent of the forecast-error effect since the forecast-error effect implied by the survey-based expectations in the customer market model ranges from two to three percent in the total variations in export price.

14) I have also tried the value $\phi_1 = 19$ which corresponds to higher value case in Lewis ($\phi_1 = 18$), but the resulted price changes are too small. The case of $\phi_1 = 0.5$ which corresponds to lowest value case in Smith and Smith (1990) is not reported just to save space. The value $\phi_1 = 0$ corresponds to the case where the exchange rate determination in the market is not affected by expectations.

15) The thick solid line corresponds to the case of $h = 24$ and the dotted line to $h = 12$ months, where h denotes the time horizon of summation in (C2-4).

FIGURE 6 EFFECT OF LEARNING ON EXPORT PRICE
 dP_t/P_t (%)



Therefore, although it may not be the dominant factor dictating the observed errors, the Bayesian learning model could provide a partial clue to understand the persistent forecast errors and their effect on export price levels.

4. Concluding remarks

The Bayesian learning model could provide the foundation to formalize the ex-post “irrational” expectations within the framework of ex-ante rational optimization behaviors. The model predicts that when a switch in exchange rate adjustment is anticipated, expectations should be ex-post biased, even if agents fully make use of all available information in forming expectations. To quantify the learning effect on the export adjustment in the real world, this paper has conducted simulation studies of two dynamic models. The results indicate that the Bayesian learning model could explain a significant portion of the deviation from the ex-post rational expectations.

Although they shed light on the role of learning process in export adjustment, the simulation studies reported in this paper should not be exaggerated because they are nothing more than examples. With more elaborated methods and reliable data, we need more cases to evaluate the validity of the learning story in export dynamics.

Appendix A

The source of data employed in estimation are as follows :

[Exports] The export price (p) is the FOB price in terms of yen of machinery (including transport equipment). Source : Bank of Japan *Economic Statistics Annual*, various issues. The export quantity (q) is defined by export value divided by the export price defined above (p). Source : Ministry of Finance, *Custom clearance statistics*.

[Exchange rate] (e) : The realized (or current) rate is the monthly closing yen-U.S. dollar

rate (yen per dollar).

The expected exchange rate is from survey data. Expectations with horizon of 3, 6, and 12 months are taken from Economist data and those with one-month horizon are from Money Market Service (MMS) data. The diskette containing both data is provided by Prof. Kenneth Froot. The Economist Newspaper, Ltd. conducts telephone surveys about expectations with horizon of three months or longer since 1981 and reports the results in Economist Financial Report. MMS conducts, since 1982, weekly or bi-weekly surveys about short-term expectations in both New York and London, of which we employ New York results. More detailed description of various survey data sets are found in Frankel and Froot (1987), for example.

[Other variables] : The marginal cost of domestic production is from the input price based on Input-Output table (wholesale price for domestic input and import CIF price for imported input) of machinery and equipment.

Instrumental variables include producer price in the U.S. (PUS) and in OECD European countries (PEU), and total industrial production of U.S.(IUS) and of OECD European countries (IEU), which are from OECD (1990) *Main Economic Indicators : Historical Statistics 1969-1988*.

Appendix B

The hypothetical series of expected exchange rates under learning process adopted as an example in this paper is constructed in the following way :

1. Based on historical episodes as summarized chronologically in Table 1, choose the periods during which learning (or speculation) proceeds.
2. For periods of learning, set the initial belief of exchange rate switch in the next month (π_{10}) and the size of reversal (m^1). By assuming normal distribution and conditional perfect foresight (i.e. if no switch occurs, expected exchange rate coincides with the realized one.), calculate the assessed probability of reversal in each month (π_{1t}) by using the Bayes' theorem (4). Then, construct a series of forecast error as follows ;

$$E_t[s_{t+1} | m^0] - s_{t+1} = (1 - \theta) m^1 \pi_{1t}$$

, or in terms of exchange rate level ¹⁶⁾

$$d_{t+1} = {}_t e_{t+1} - e_{t+1} = e_{t+1} \{ \exp[(1 - \theta) m^1 \pi_{1t}] - 1 \}$$

Although it can well explain the persistence of expectation bias, the error predicted by the learning model always converges to zero through learning the true value. The expected probability of switch in the real world, however, sometimes like the early 1980s, grows over time, contrary to the learning process. This kind of situation has been extensively studied in the context of

16) Since the exchange rate model is expressed in terms of logarithm, transformation is necessary. But, our transformation is rather casual in that $E_t[\ln e_{t+1} | m] \neq \ln E_t[e_{t+1} | m]$, strictly speaking.

speculative attack to the government's policy fixing the exchange rate with limited reserves. The speculative attack models could supplement the learning model in this regard, although the accumulation of various models prevents us from reproducing the model here. The theoretical prediction of these models relevant for us is that expected probability of switch increases, often at accelerating pace, over time before the switch.

3. For speculation periods, set the parameter value, assuming uniform distribution about critical level of exchange rate \bar{e} , following the speculative attack model by Dornbusch (1987). Calculate the probability of reversal for each month. For example, in the case of possible reversal to appreciation during continuing depreciation process, choosing an upper value for the critical exchange rate;¹⁷⁾

$$\pi_{1t} = Pr\{\bar{e} < e_{t+1} \mid \bar{e} > e_t\} = \frac{e_{t+1} - e_t}{\bar{e} - e_t}$$

Once an forecast error series has been constructed, the percentage price change caused by this error is calculated by (C2-4) in Appendix C.

The reason for the choice of periods of learning/speculation are as follows:

1. The yen appreciation lasts nearly three years since 1976 : 1 until the Carter Administration's announcement of decisive measure to defend the dollar in 1978 : 11. In the early stage of the appreciation, the expectation of reversal to yen depreciation may grow as yen appreciation continues. In the later stage, however, this expectation may gradually diminish as people learn that the exchange rate adjustment in this direction is not temporary. For example, in 1977 : 9, the Government of Japan takes measures to alleviate the damage caused by the yen appreciation. Then, at some point before 1977 : 9 the threshold must have been passed. I choose the sharp acceleration of yen appreciation in 1977 : 6 as the event demarcating these two phases.
2. After 1978 : 11, the yen rate keeps depreciating for more than one year and the anticipation of reversal may grow over time. In this case, I choose, as the peak of speculation, 1979 : 10 when U.S. F.R.B. announces the change in open market operation procedures which leads to expanding interest rate differential.
3. Since the yen stabilization measure in 1980 : 3, the yen is appreciating until early 1981 when the first Reagan Administration starts. During this process, learning that the yen should be depreciated may persist until U.S. changes to explicit non-intervention policy under increasing interest rate differential.
4. Throughout the first half of 1980s, the yen is generally on the depreciating trend. The anticipation of reversal may surge when the Bank of Japan raises interest rates in 1982 : 3, explicitly aiming at promoting yen appreciation. This anticipation may persist through

17) Here, I assume that the critical exchange rate e^* is the only source of uncertainty, or perfect foresight about the exchange rate in the case of no reversal. Then, if the exchange rate appreciates a bit before the anticipated substantial reversal, the probability of reversal (π_{1t}) in that period will be set equal to zero, although the definition yields negative value.

learning process until the sudden yen appreciation in 1987 : 11. After the sudden appreciation lasting only two months, yen depreciation continues and the dollar “over”-valuation becomes almost obvious after the mid-1984. The yen rate depreciates, especially after 1984 : 9, without any slight halt in spite of decreasing interest rate differential.

5. After 1985 : 2, especially after the G-5 at Plaza in 1985 : 9, the yen keeps appreciating at rapid pace. The expectation of reversal may persist at least until G-7 at Louvre in 1987 : 2, explicitly announcing the stabilization of current exchange rates. Because of the old Japanese tradition of government intervention especially for export, and because of the nature of this exchange rate adjustment process which seems to be triggered by one policy change at the Plaza, Japanese exporters may have expected that the Japanese government take the policy to stop the yen appreciation. As a matter of fact, the government policy stance had actually changed and no substantial intervention for depreciating the yen was taken, contrary to their expectations. And since the exchange rates adjustment after 1985 was really unprecedented, the assumption of learning process instead of rational expectations is quite suitable in this case. Since the government of Japan announces, in 1987 : 5, the Emergency Economic Measures including enormous fiscal expansion to alleviate the recession aggravated by accelerating yen appreciation in the spring, people may believe that intervention for depreciating the yen is still possible even after the G-7 at Louvre. Hence, I choose 1988 : 1, when heavy interventions follow the previous month’s G-7 confirming the Louvre arrangement, as the final month of the learning process.

Appendix C

Appendix C is devoted to the explanation of the theoretical models which have been used in the simulation in this paper. Although detailed derivations should be found in the original papers, Tomiura (1992a,b), the basic structure of the model will be briefly introduced to facilitate the interpretation of the simulation results

C-1. Export quantity choice with adjustment costs

The following dynamic export model with adjustment costs has been used in the simulation study in Section 3.1. Reproduced from Tomiura (1992b), this section provides overview of the structure of the model.

First, suppose that a firm exports to the foreign market in a simple two-country framework. To facilitate discussions, let us call the exporter the Japanese firm, and the foreign market the U.S. Further, suppose that the only source of uncertainty is the exchange rate movements. A firm’s maximization program can be summarized by

$$V(q_t) = \max \Pi(X_t) + \delta E_t[V(q_{t+1})] \quad (C1-1)$$

where V is the value function and Π is the per-period export profit. δ is the discount factor ($0 < \delta < 1$, constant). The state variable is the export quantity (q) and the control variable is the export

adjustment ($X_t = q_t - q_{t-1}$).

Next, let the per-period export profit for a firm be

$$\Pi_t = (p_t - c_t) q_t - b_t X_t 1_x \tag{C1-2}$$

where “ 1_x ” denotes the indicator function which is equal to one if $X_t > 0$ (expanding export) and zero otherwise. Let output price(p), marginal production cost(c), and export adjustment cost(b) be expressed in terms of yen.¹⁸⁾

Let me assume that the exchange rate in the long-run follows the two-state Markov process. Suppose that the exchange rate e takes either the appreciated value or the depreciated value ; \underline{e} or e^* ($\underline{e} < e^*$) and that transition probabilities are given by

$$\begin{aligned} \lambda &= \text{Prob}\{e_{t+1} = e^* \mid e_t = \underline{e}\} \\ \rho &= \text{Prob}\{e_{t+1} = \underline{e} \mid e_t = e^*\}. \end{aligned}$$

Then, by assuming log-linear export demand function, the firm’s dynamic program is simplified to ¹⁹⁾

$$V(q^*) = (ae^*q^{*\mu} - cq^* - bX^*1_x) + \delta\{(1-\rho)V(q^*) + \rho V(\underline{q})\} \tag{C1-3}$$

$$V(\underline{q}) = (ae\underline{q}^\mu - c\underline{q} - bX\underline{1}_x) + \delta\{(1-\lambda)V(\underline{q}) + \lambda V(q^*)\} \tag{C1-4}$$

where $q^*(\underline{q})$ denotes the export quantity under the currency depreciation (appreciation, respectively) phase.

Therefore, the firm’s export decision is given as follows : ²⁰⁾

(a) If the exchange rate is at the depreciated level ($e = e^*$), differentiating (C1-3) with respect to q^* yields, because $(1-\rho)V'(q^*) = 0$,

$$q^* = \alpha [(c + b) / e^*]^\theta \tag{C1-5}$$

where θ is the elasticity of export demand and $\alpha = (a\mu)^\theta$.

(b) Next, when the exchange rate is at the appreciated level ($e = \underline{e}$), the export quantity chosen

18) The costs of expanding export include, for example, sales promotion expenses in foreign markets which may be often denominated in dollars, not in yen. However, whether b is denominated in yen or dollars does not affect our qualitative results. Exactly speaking, it is not the exchange rate itself, but the dollar-denominated relative price that consumers care about. Given drastic exchange rate changes and low inflation rate during our sample period, however, we will be allowed to assume constant prices offered by foreign rival firms to concentrate on the dynamics of exporters in this paper.

19) Under the constant-elasticity export demand function, the exchange rate pass-through is perfect (one) without dynamic mechanism. The results obtained in the following is, however, robust for the linear export demand function, for example.

20) Although techniques employed in my theoretical study of Markov process owes much to the macro-labor model by Saint-Paul (1990), his main interest is in the multiplicity of equilibria caused by the voluntary quit decisions on workers’ side.

by the firm i ($i=1,2,\dots,N$) at time t is given by the following formula which is the basis for simulations in this paper :

$$q_{it} = \alpha \left(\frac{c - \delta \lambda_t b_{it}}{e_t} \right)^{-\theta} \quad (C1-6)$$

C-2. Customer market model of export pricing

The second model, customer market model of export pricing developed in Tomiura (1992a), has been used in the comparison with the export price series predicted by the hypothetically constructed learning process in Section 3.2.

First, consider the following standard intertemporal profit maximization of a firm exporting in a simple two country framework, as in the first model of costly export quantity adjustment just introduced.

$$\text{Max } V_t = \sum_s \delta^{s-1} E_t [(p_s - c_s) q_s] \quad (C2-1)$$

Next, decompose the current export demand q into the customer stock (x) and the demand per customer (θ) :

$$q_t = \theta_t x_t \quad (C2-2)$$

The U.S. customer stock of the Japanese firm x is supposed to be determined by

$$x_t = (1 + \eta - \eta p/r)^{\lambda_0} \Pi_k x_{t-k}^{\lambda_k} \quad (C2-3)$$

, where r denotes the exchange rate (yen/dollar). Let $\lambda_k > 0$ for all $k > 0$ and $\eta > 0$.

Then, the first-order condition for maximization is obtained by differentiating (C2-1) with respect to x . I will present the Euler equation in the form to which we can provide economic interpretations, by multiplying by x_t/r_t ,

$$p_t/r_t = \alpha_0 + \alpha_1 c_t/r_t + \sum_i E_t [\beta_i (r_{t+i} q_{t+i}/r_t q_t) + \gamma_i (p_{t+i} q_{t+i}/r_t q_t)] \quad (C2-4)$$

where $\alpha_0 = (1 + \eta)/\eta(1 + \lambda_0) > 0$, $\alpha_1 = \lambda_0/(1 + \lambda_0) > 0$, $\beta_i = -\delta_i(1 + \eta)\lambda_i/\eta(1 + \lambda_0) < 0$, and $\gamma_i = \delta_i\lambda_i/(1 + \lambda_0) > 0$ ($i=1,2,\dots,\infty$).

In estimating (C2-4), I use survey-based expectations for expected exchange rates, while instrumental variables are assigned to other expected variables in the same equation. (Exactly speaking, I introduce the additional geometric lag assumption for β_i and γ_i to further simplify (C2-4) because it includes theoretically infinite sequence of expected variables.)

The forecast-error effect, which is used in the comparison in this paper, is defined as the deviation of export price level predicted by (C2-4) with survey-based exchange rate expectations from that with realized exchange rates, i.e. perfect foresight.

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TABLE 1 CHRONOLOGY

- 1973 The First Oil Shock
- 1977 Carter Administration repeatedly tries to “talk down” the dollar to reduce the U.S. trade deficit.
(The yen appreciation since 1976.1 accelerates in 1977.6)
1977. 9 Japan takes the measures to counter yen appreciation.
- 1978.11 U.S. announces the measures to defend the dollar.
1979. 1 The Second Oil Shock
- 1979.10 U.S.F.R.B. changes open market operation procedures.
1980. 3 Japan announces the measures to stabilize the yen and U.S. announces the measures to resist inflation.
1981. 2 The first Reagan Administration starts. (change to “explicit non-interventionist” policy)
1982. 3 Bank of Japan begins to raise interest rate for appreciating yen. (This policy continues until the drastic yen appreciation in 1982.11.)
1984. 5 Yen-Dollar Agreement (liberalizing capital flows) concluded, but the yen depreciation continues, especially after 1984.9 without an halt.
1985. 2 The second Reagan Administration starts. (“signs” of change in exchange rate policy)
1985. 9 G-5 at Plaza (“encouraging” “non-dollar currency appreciation”) triggering yen appreciation which continues until 1986. 7. without any slight halt.
1986. 9 Japan adopts the measures to cope with yen appreciation.
1987. 2 G-7 at Louvre (stabilization “around current levels”)
1987. 5 Japan takes Emergency Economic Measures (substantial fiscal expansion to stimulate domestic demand)
- 1987.10 Stock market crash
- 1987.12 G-7 (implying “a floor” for dollar value)
1988. 1 “Heavy around-the-clock intervention” to support the dollar

(Source) Frankel (1990), from which all the quotations are cited, and Japan’s *White Paper on Economy* (various issues)