

**IMES DISCUSSION PAPER SERIES**

**Effects of the Developments of Knowledge-based  
Economy on Asset Price Movements: Theory and  
Evidence in the Japanese Stock Market**

Kiyohiko G. NISHIMURA

Toshiaki WATANABE

Kentaro IWATSUBO

**Discussion Paper No. 98-E-18**

**IMES**

**INSTITUTE FOR MONETARY AND ECONOMIC STUDIES**

**BANK OF JAPAN**

**C.P.O BOX 203 TOKYO**

**100-8630 JAPAN**

NOTE: IMES Discussion Paper Series is circulated in order to stimulate discussion and comments. Views expressed in Discussion Paper Series are those of authors and do not necessarily reflect those of the Bank of Japan or the Institute for Monetary and Economic Studies.

**Effects of the Developments of Knowledge-based  
Economy on Asset Price Movements: Theory and  
Evidence in the Japanese Stock Market**

Kiyohiko G. NISHIMURA

Faculty of Economics, University of Tokyo

Toshiaki WATANABE

Faculty of Economics, Tokyo Metropolitan University

Kentaro IWATSUBO

Graduate School of Economics, University of Tokyo

Abstract

Recent development of knowledge-based economy, especially the innovation of information technology, might have affected the price mechanisms in asset markets, such as stock and real estate, through various channels. The paper discusses the theoretical implications of such impacts on asset price movements and examines the magnitude their impacts by using the Japanese stock market data.

Key words: Asymmetry of Information, Market Microstructure,  
Heterogeneous Expectation, Excess Sensitivity

JEL classification: D82, G12

This paper was prepared for the Eighth International Conference, "Monetary Policy in a world of Knowledge-Based Economy, Quality Change and Uncertain Measurement," held by the Institute for Monetary and Economic Studies, Bank of Japan, on June 18-19, 1998. We are grateful to the participants of the conference for valuable comments and suggestions. Section 2 is rewritten after the conference to incorporate points made at the conference. The work of the first author is partially supported by a grant from Trust 60.

## 1. Introduction

In the last fifteen years, East and South East Asian countries have experienced turbulent asset prices that resulted in subsequent severe economic recessions. Japan enjoyed renewed vigor in her economic activity in the late 1980s due to the upsurge of stock and real estate prices that culminated in 1990, but since then the following precipitous fall in their prices created bad loan problems that dragged her growth for almost a decade. Booming economies of the early 1990s in Thailand and other South East Asian countries also suffered from severe downfall in their asset markets in 1997, and the resulting financial crisis slowed their growth considerably.

This period of turbulent asset prices has also been characterized as the era of transition to "knowledge-based economy" in which innovation of information technology deeply transformed the world economy. Industrial structure has changed due to advent of new technology of information. Moreover, the way people use information has also changed because of availability of sophisticated information processing and transmitting devices. East and South East Asian economies are no exception. Then, a natural question arises: Has the recent development of knowledge-based economy influenced the turbulent behavior of asset prices experienced in the north western edge of the Pacific?

To examine this problem, the textbook finance theory is not suitable since it pre-

supposes well-developed asset markets, implicitly assuming full-fledged information technology. The hallmark of the modern finance theory is the no-unexploited-arbitrage-opportunity condition, meaning smooth transaction and fast information diffusion. This may be a good description of the U. S. financial markets, but it may not be an appropriate characterization of other markets, especially Asian markets.

The purpose of this paper is two-fold. Firstly, we develop a model of less developed asset markets taking explicit account of high transaction and information costs, and examines the effect of the knowledge-based economy on the magnitude of asset price sensitivity. We characterize less-developed asset markets as an asset market of atomistic price-posting. We examine whether prices in such a market exhibit excessive sensitivity to changes in the underlying factors. Secondly, we examine the validity of this model in the Japanese stock market. We then gauge the impact of the knowledge-based economy there.

The plan of this paper is as follows. In Section 2, we develop a theory of less-developed asset markets with transactionally and informationally separated trading posts, and examine excess sensitivity of asset prices. Section 3 examines the Japanese stock market data, and tests the validity of the theory. A concluding remark is found in Section 4.

## 2. Asset Markets with Atomistic Price-Posting

### 2.1. A Model of Less-Developed Asset Markets

Let us consider an asset market of "developing" economies<sup>1</sup> where there are substantial transaction costs making arbitrage insufficient, and information costs making market participants under-informed about the market. Some investors are well-informed but others are not. Investors' opinion varies about the intrinsic value of particular stocks. Sellers and buyers post their offer atomistically and transaction takes place if their offer is accepted by the other investors. Thus, *there is no Walrasian auctioneer, nor market maker who might act as a stand-in of the Walrasian auctioneer.*<sup>2</sup>

In such a market, both sellers and buyers are price-makers rather than price-takers. Moreover, because of insufficient arbitrage and diverse opinion, the seller who offers a high asking price still has a chance to sell his stock although the chance is smaller than when he offers a low asking price. This implies that sellers have some market

---

<sup>1</sup>Here the adjective "developing" may not be appropriate since developed economies may also have this type of under-developed asset markets. See the next footnote.

<sup>2</sup>This description fits well to *Zaraba* price formation in the Tokyo Stock Exchange. Between the opening of the market and its closing, the market price is determined by *Zaraba* pricing scheme. In the *Zaraba* scheme, limit orders are accumulated as buyers and sellers make them. Then at one point in time, if a buyer (seller) makes a market order, then the lowest (highest) limit order is executed and the lowest (highest) limit order price becomes the market price. If the quantity of the particular buyer's market order is more than the lowest-price limit selling order, then the second-lowest price limit selling order is executed, and so on. If a buyer (seller) makes a limit order and his price is matched by the existing lowest selling (buying) order, then that order is executed. If the buyer's order does not match the existing orders, the buyer's order is simply posted as other unexecuted limit orders. Here buyers and sellers make price, and transactions take place if their offer is accepted by other investors.

power: by changing their asking price, they can influence the *probability* of successful sale of their stock. The same is true for the buyer. The buyer bids a low price still has a chance to buy the stock though his chance is smaller than the buyer who bids a high price. Thus, the market can be characterized as monopolistic competition than perfect competition. This deviation from perfect competition is the hallmark of this market.

Let us consider price determination in such a market. In the following we explain a simple version of Nishimura (1999).<sup>3</sup> A large number of stocks are traded in individual trading posts, and we consider one stock called  $i$ , as a representative stock. There are a few investors who are well informed of the true intrinsic value of the stock, while the other investors are uninformed. To make analysis simple, we assume that one investor is well-informed and offers the price (*i.e.*, places a limit order), and while the other investors are uninformed and determine whether to accept it or not (*i.e.*, to place a market order or not). All investors are assumed to be risk neutral. Because of transaction costs, information costs, and/or the limited ability of investors, not all uninformed buyers show up in all trading posts of stocks. For analytic simplicity, we assume that only one buyer shows up in this particular trading post. Finally, we assume an once and for all market in which

---

<sup>3</sup>Nishimura specifies the structure of the non-Walrasian asset market and distribution of investors' expectations in detail, and derives rational expectations (Bayesian Nash) equilibrium. Since it is rather complicated, we adopt a simpler approach here.

if the trade between them fails then there is no further trade on this particular stock.

Let us consider the case that the informed investor is the seller while the uninformed investor is the buyer. (A symmetric argument applies and the result is the same in the opposite case that the informed investor is the buyer while the uninformed investor is the seller.) The informed investor's pricing problem is as follows. Let  $x_i$  be the unexpected change in the intrinsic value of this stock  $i$  that is the value of holding this stock. We have assumed that only the seller (informed investor) knows  $x_i$ .

The buyer (uninformed investor)  $j$  has his own subjective expectations about  $x_i$ , denoted by  $E^j(x_i)$ . The seller does not know the expectations  $E^j(x_i)$  of the particular buyer he encounters, but he is assumed to know the distribution of the expectations among uninformed investors:

$$Pr(E^j(x_i) < y) = F(y) \tag{2.1}$$

(For example, an investor survey may be conducted and the result may be made public). The seller determines his price change  $p_i$  corresponding to  $x_i$  based on this information.

Since the buyer  $j$  is risk neutral, he buys the stock if the price change  $p_i$  is no more



than his expected intrinsic-value change  $x_i$ , or equivalently,  $p_i \leq E^j(x_i)$ . Thus, the probability of successful sale,  $\phi(p_i)$  is a function of  $p_i$  such that

$$\phi(p_i) = 1 - F(p_i). \quad (2.2)$$

Taking this in mind, the risk neutral seller determines  $p_i$  to maximize his expected profit:

$$\text{Max}_{p_i} \text{ Expected Profit}_i = \phi(p_i)(p_i) + (1 - \phi(p_i))(x_i) \quad (2.3)$$

It is evident that the optimal price change (2.3) satisfies the following equation.

$$p_i = \left(1 + \frac{\phi(p_i)}{\phi'(p_i)p_i}\right)^{-1} x_i = \frac{1}{1 - (1/\eta_\phi)} x_i \quad (2.4)$$

where

$$\eta_\phi = -\frac{p_i}{\phi} \phi'(p_i)$$

is the price elasticity of the sale probability. If the trade is completed, this is the market price change of the stock.

Equation (2.4) shows that the price change  $p_i$  is a mark-up of the unexpected intrinsic-value change  $x_i$ . Moreover, the mark-up rate depends on the inverse of the price elasticity  $\eta_\phi$  of the sale probability  $\phi(p_i)$ . The smaller is the elasticity, the more sensitive is the price. In addition, so long as  $\eta_\phi$  is positive and greater than

unity, the coefficient of  $x_i$  in (2.4) is always greater than unity. Thus in this case, we have excess price sensitivity.

Equation (2.2) implies that the sale probability depends on  $F$ , the distribution of buyers' expectations. Thus, (2.4) shows that the price effect of the unexpected change in the intrinsic value crucially depends on the shape of the distribution of uninformed investors' expectations.

To illustrate this point, let us note that the price elasticity of  $\phi(p_i) = 1 - F(p_i)$  is small if, for given  $p_i$  [ $> 0$ ] and  $\phi$ , the absolute value of  $\phi'(p_i)$  is small. Since  $-\phi'(p_i) = F'(p_i) = f(p_i)$ , where  $f$  is the density function, this means that smaller  $f(p_i)$ , or in the other words, the more dispersed expectations around the optimal price, implies higher price sensitivity. Thus, foregoing analysis suggests that in some cases an increase in the variance of expectations' distribution may induce excessive price response to unexpected change in the intrinsic value of stock.

In this subsection, we *ignore* the effect of uninformed investors' rational expectation formation on price. Thus, uninformed buyer behavior in this sub-section is described as unsophisticated, when it is compared with rational (Bayesian) behavior under imperfect information. Rational expectations will be considered in the next subsection.

## 2.2. Information Technology and Variable Price Sensitivity

The advancement of information technology, which underlies the emergence of the knowledge-based economy, means that economic agents become sophisticated in their decision making. It also implies that more information about the market becomes available. In this subsection, we explore implications of this sophistication in information gathering and processing on price behavior in the non-Walrasian asset market. We summarize the result obtained by Nishimura (1999) which incorporate rational expectations into the model of the previous sub-section.<sup>4</sup>

### 2.2.1. Sophistication in information processing: rational expectation formation

One immediate consequence of rational expectations is that the buyer will learn about the fundamental value  $x_i$  from the price offer  $p_i$  of the seller. Then, one may argue that the excess sensitivity result in the previous sub-section is due to non-rational expectations. Bayesian buyers learn the intrinsic value through sellers' offer, which diminishes the *ex post* heterogeneity considerably so as to reduce the price sensitivity. However, this is not generally true.

The intuitive reason is following. Although buyers' learning reduces their *ex post* heterogeneity and thus price sensitivity, there is a new source of excess sensitivity

---

<sup>4</sup>Nishimura (1998) contrasts the effect of imperfect information between asset and product markets under rational expectations framework.

which is inherent in the case of rational expectations. Since the buyer tries to get information from the seller's offer, the seller can influence the buyer's perception of the stock by changing his offer. In general, the buyer thinks rightly that a high price is a (though noisy) signal of a high intrinsic value and *vice versa*. Thus, on the one hand, the optimistic seller's optimal price increases further than otherwise, since his higher price may lead the buyer to think the stock's value is higher, making room for further price raise.

On the other hand, the pessimistic seller's optimal price decreases further than otherwise, since his low price may be taken as a signal of a low stock value so that he has to lower his price further in order to ensure successful sale. Thus, even under fully rational expectation formation, we still have the excessive sensitivity. This expectation-influencing mechanism makes prices more sensitive than otherwise.

### **2.2.2. Advancement of information technology**

The advent of information technology makes more and more market information accessible to market participants with a lower cost. Such advancement of information technology is likely to reduce the price sensitivity in the long run. Firstly, it may increase the accuracy of individual prior information about the market fundamental, and thus reduces expectation heterogeneity. Secondly, faster information diffusion due to advanced technology may enable various contemporaneous information about

the market to reach investors. Such additional information is valuable for investors in improving forecast accuracy, and thus reduces expectation heterogeneity. In the short run, however, learning about new technology and new sources of information may produce errors and mistakes, which may counteract the positive effect of information technology advancement.

In sum, sophistication of information processing and advancement of information technology do not alter the basic picture of less-developed asset markets. Their prices may be excessively sensitive to unexpected changes in the underlying market fundamentals. However, the sensitivity is likely reduced in the long run as more and more information is available with a lower cost.

### **3. Expectation Heterogeneity and the Sensitivity of the Japanese Stock Price**

#### **3.1. Methodology**

The model developed in the previous section can be incorporated into the framework of the Arbitrage Pricing Theory. In this theory, the innovation of an asset price is determined by the innovation of  $k$  factors  $f_{j,t}$  ( $j = 1, \dots, k$ ), *i.e.*

$$p_t = \alpha_t + \sum_{j=1}^k \beta_{j,t} f_{j,t} + u_t, \quad (3.1)$$

where  $\beta_{j,t}$  ( $j = 1, \dots, k$ ) are the factor loadings which measure the sensitivity of the asset return to the factors. For simplicity, assuming that  $k = 1$ , we use the following one factor model.

$$p_t = \alpha_t + \beta_t f_t + u_t. \quad (3.2)$$

In the conventional framework,  $\beta_t$  is a constant parameter. However, our model (equation (2.4)) suggests that it depends on the dispersion of expectation and the state of information technology. Consequently, we assume

$$\beta_t = g(\sigma_t) + h(t), \quad (3.3)$$

where  $\sigma_t$  is a variable which measures the dispersion of investors' expectations, and that time  $t$  represents the effect of increasing usage of sophisticated information technology over time. Then, we have

$$p_t = \beta_t f_t + u_t = \{g(\sigma_t) + h(t)\} f_t + u_t. \quad (3.4)$$

Since  $p_t$  and  $f_t$  are innovation, we have  $E(f_t | \mathbf{I}_{t-1}) = 0$  and  $E(u_t | \mathbf{I}_{t-1}) = 0$ , where  $\mathbf{I}_{t-1}$  is the information set available up to time  $t - 1$ . For identification, we assume that  $E(f_t^2 | \mathbf{I}_{t-1}) = 1$ . We further assume that the  $u_t$  is homoskedastic, *i.e.*  $\sigma_u^2 \equiv E(u_t^2 | \mathbf{I}_{t-1})$  does not depend on time  $t$ . This is an augmented APT model, in

which factor loading depends on the expectation diversity  $\sigma_t$  and time  $t$ . The data used for  $\sigma_t$  will be discussed in the next subsection.

The theory does not impose any restriction on the functions  $g(\sigma_t)$  and  $h(t)$ . In the following analysis, we consider the following three specifications.<sup>5</sup>

$$g(\sigma_t) = \begin{cases} g_0 + g_1\sigma_t, & 1. \text{ linear,} \\ g_0 + g_1 \exp[-\sigma_t/\Phi_1], & 2. \text{ negative exponential,} \\ g_0 + g_1 \exp[\sigma_t/\Phi_1], & 3. \text{ positive exponential,} \end{cases} \quad (3.5)$$

$$h(t) = \begin{cases} h_0 + h_1t, & 1. \text{ linear,} \\ h_0 + h_1 \exp[-t/\Phi_2], & 2. \text{ negative exponential,} \\ h_0 + h_1 \exp[t/\Phi_2], & 3. \text{ positive exponential,} \end{cases} \quad (3.6)$$

where  $g_0$ ,  $g_1$ ,  $h_0$ , and  $h_1$  are parameters to be estimated,  $\Phi_1$  and  $\Phi_2$  are scale parameters. In the following analysis, we assume that  $\Phi_1$  is the sample mean of  $\sigma_t$  and  $\Phi_2$  is the sample size. We have checked the sensitivity of the results to several different values of  $\Phi_1$  and  $\Phi_2$ , but the results are not very sensitive to the particular choice of  $\Phi_1$  and  $\Phi_2$ .

To estimate the parameters in the model that consists of equations (3.3)-(3.6), we

---

<sup>5</sup>Some researchers have used the second specification similar in order to examine the relation between volatility and autocorrelation in stock returns. (e.g. LeBaron (1992), Bollerslev, Engle, and Nelson (1995), and Watanabe (1998).)

take the following approach.<sup>6</sup> Firstly, we extract the innovations of economic variables and asset return by fitting the vector autoregressive (VAR) model to the vector that consists of the economic variables and the asset price. The VAR model is estimated by using ordinary least squares (OLS). Given the OLS estimates, we take the residual as innovations of the economic variables and the asset price. Secondly, we assume that the innovations of the economic variables,  $\boldsymbol{\epsilon}_t$ , are determined by the same factor  $f_t$  that determines the asset price, *i.e.*

$$\boldsymbol{\epsilon}_t = \mathbf{C}f_t + \mathbf{w}_t, \quad (3.7)$$

where  $\mathbf{C}$  is a  $(M \times 1)$  vector of factor sensitivities for the economic variables, and  $\mathbf{w}_t$  is a  $(M \times 1)$  vector of idiosyncratic error terms. We assume that  $E(\mathbf{w}_t|\mathbf{I}_{t-1}) = 0$ ,  $E(f_t\mathbf{w}_t|\mathbf{I}_{t-1}) = 0$ ,  $E(u_t\mathbf{w}_t|\mathbf{I}_{t-1}) = 0$ , and  $E(\mathbf{w}_t\mathbf{w}_t'|\mathbf{I}_{t-1}) = \mathbf{\Gamma}$ , a positive semi-definite diagonal matrix. For simplicity, we assume that  $\mathbf{w}_t$  are also homoskedastic. Thirdly, given the residuals obtained from the VAR, we simultaneously estimate the parameters in the following system that consists of equations (3.3)-(3.7) by the maximum likelihood method:

$$\boldsymbol{\zeta}_t = \mathbf{B}_t f_t + \mathbf{v}_t \quad (3.8)$$

---

<sup>6</sup>In this paper, we follow recent empirical studies on asset pricing (see Engle, Ng, and Rothchild (1990), Ng, Engle, and Rothchild (1992), King, Sentana, and Wadwhani (1994)) except for one point. These empirical studies applying factor analysis to asset pricing assume that the sensitivity is constant, but they explicitly take into account the heteroskedasticity in both of asset returns and factors. Here we allow that the sensitivity is variable but assume homoskedasticity. To allow both variable sensitivity and heteroskedasticity is more desirable, but estimation procedure becomes complicated and expensive (see Aguliar and West (1998)).



where

$$\boldsymbol{\zeta}_t = \begin{bmatrix} p_t \\ \boldsymbol{\epsilon}_t \end{bmatrix}, \quad (3.9)$$

$$\mathbf{B}_t = \begin{bmatrix} \beta_t \\ \mathbf{C} \end{bmatrix}, \quad (3.10)$$

$$\mathbf{v}_t = \begin{bmatrix} u_t \\ \mathbf{w}_t \end{bmatrix}, \quad (3.11)$$

in which the log-likelihood may be written as

$$\ln L = -(M+1)T \ln(2\pi)/2 - (1/2) \sum_{t=1}^T \ln |\boldsymbol{\Sigma}_t| - (1/2) \sum_{t=1}^T \boldsymbol{\zeta}_t' \boldsymbol{\Sigma}_t^{-1} \boldsymbol{\zeta}_t, \quad (3.12)$$

where

$$\boldsymbol{\Sigma}_t = \mathbf{B}_t \mathbf{B}_t' + \begin{bmatrix} \sigma_u^2 & 0 \\ 0 & \boldsymbol{\Gamma} \end{bmatrix}. \quad (3.13)$$

Given the parameter estimates, we can estimate the factor by using

$$E(f_t | \mathbf{I}_t) = \mathbf{B}_t' \boldsymbol{\Sigma}_t^{-1} \boldsymbol{\zeta}_t. \quad (3.14)$$

## 3.2. Estimation Results

### 3.2.1. The Japanese Stock Market

The stock price we use is the closing figure for the Tokyo Stock Price Index (TOPIX) on the last trading day of each month. The TOPIX is the value-weighted average of prices of all stocks traded in the First Section in Japan. The sample period is 1985:5 to 1997:12.

To measure the dispersion of investors' expectations, we use the survey data collected by the Japan Center for International Finance (JCIF) in Tokyo.<sup>7</sup> The JCIF has conducted telephone surveys twice a month, in the middle and at the end of the month, on Wednesday, since May 1985. Point forecasts of the yen/dollar exchange rate for the one-, three-, and six-month horizons are obtained from foreign exchange experts in 44 companies.<sup>8</sup> The JCIF calculates the average, the standard deviation, the maximum, and the minimum of the 44 responses. Among them, we use the standard deviation calculated based on the survey at the end of each month as a proxy for the dispersion of investors' expectations.<sup>9</sup> Similar survey data on stock market, if existed, would be more desirable, but unfortunately we do not have such data. Figure 2 plots the standard deviation series, which appear to have a negative

---

<sup>7</sup>For the details of this data, see Ito (1990).

<sup>8</sup>These companies consist of 15 banks and brokers, 4 securities companies, 6 trading companies, 9 export-oriented companies, 5 life insurance companies, and 5 import-oriented companies.

<sup>9</sup>We also used the standard deviation divided by the sample mean, i.e. the coefficient of variation, but the results are unaltered.

time trend. This might be the effect of increased sophistication in information usage due to advancement of information technology. The augmented Dicky-Fuller (ADF) test rejects the null hypothesis of the presence of unit root in this series, while the statistically significant time trend is detected. We remove the time trend by regressing the log of the standard deviation on a constant and on time  $t = 1, 2, \dots, T$ . The exponential function of the residual of this regression is used for  $\sigma_t$ . The secular effect which might measure the effect of increased information is represented in the time trend.

To extract factors, we use monthly data on the eight macroeconomic variables that may be expected to affect stock returns in Japan:<sup>10</sup> (i) short-term interest rates measured by the collateralized call rate, (ii) long-term interest rates measured by the yield on 10 year government bonds, (iii) the dollar-yen exchange rate, (iv) industrial production, (v) consumer price index, (vi) trade balance, (vii) money supply measured by M1 plus quasi-money currency, and (viii) Saudi Arabian light oil spot price per barrel in Japanese yen. Details of the definitions and sources of these index variables may be found in Appendix. In the following analyses, we take logarithm of all eight variables except the trade balance. The ADF tests do not reject the null hypothesis of the presence of unit root in all eight macroeconomic variables, so that the VAR model is fitted to the vector that consists of the stock price change and

---

<sup>10</sup>Our choice of economic variables follows King, Sentana, and Wadwhani (1994).

the first-order differences in all macroeconomic variables. The fitted VAR model also includes monthly dummies. Both of the Akaike (1973) Information Criterion (AIC) and the Schwarz (1978) Information Criterion (SIC) lead to the lag length of one. However, when the lag length is set one or two, Ljung-Box (1978) tests strongly reject the null hypothesis of no autocorrelation in the obtained residuals for some variables. Table 1 presents the conventional Ljung-Box statistics up to twelfth order autocorrelation and the one corrected for heteroskedasticity following Diebold (1986) when the lag length is set three. No matter which Ljung-Box statistic is used, the null hypothesis of no autocorrelation is not rejected at any standard level in the residuals of all variables except the money supply. Even for the money supply, the conventional Ljung-Box statistic does not reject the null hypothesis at 1% significance level, while neither does the heteroskedasticity-corrected one at 5%. We therefore set the lag length equal to three.

### 3.2.2. Results

Now, we estimate the parameters in the model (3.8) by maximizing the log-likelihood given by (3.12). As a frame of reference, let us first make the conventional assumption that  $g(\sigma_t)$  and  $h(t)$  are constant and independent of  $\sigma$  and  $t$  (constant  $\beta$ ). Table 2 presents the estimate of  $\beta$  jointly with the estimate of factor loading  $\mathbf{C}$  for each of our economic variables described above. Their standard errors are calculated using the Hessian of the log-likelihood at the optimum. Although not so strong, we find

evidence that the factor affects the stock price. Specifically, a standard two-sided  $t$  test rejects the null hypothesis of  $\beta = 0$  at the 10 % significance level. Table 3 shows the factor score weights, obtained by regressing the factor estimates calculated using equation (3.14) on the innovations in our economic variables. The factor has relatively large weights on the innovation in the oil price and the yen-dollar exchange rate. Hence, the negative value for the estimate of  $\beta$  is intuitive, when one takes account of the heavy dependence of the Japanese economy on oil imports. Moreover, close relationship between the factor on the one hand and the exchange rate and the oil price on the other justifies our usage of the standard deviation of exchange-rate forecasts as the relevant expectation diversity.

Next, let us examine whether  $\beta_t$  has a time trend. This is an indirect test of whether advancement of information technology significantly affects the stock market sensitivity to innovations in macroeconomic variables. Here, we neglect the possibility for the dependence on  $\sigma_t$  so that we postulate that  $\beta_t = h(t)$ , where three specifications given by equation (3.6). Table 4 presents the estimates of the parameters in each specification. No matter which specification is used, we do not find evidence for significant time trend in  $\beta_t$ . Thus, we fail to detect any significant effect of information technology advancement on stock price sensitivity.

Finally, let us turn to the effect of expectation diversity on price sensitivity, *i.e.*,

the relation between  $\sigma_t$  and  $\beta_t$ . Since  $\beta_t$  does not have a significant time trend, we assume that  $\beta_t = g(\sigma_t)$ . Table 5 presents the estimates of the parameters in equation (3.5). A significant negative relation between  $\beta_t$  and  $\sigma_t$  is detected when the standard deviation of three-month-ahead forecasts is used for  $\sigma_t$ . In all three specifications of the three-month-ahead forecast case, both of the  $t$  test and the likelihood ratio test reject the null hypothesis of  $g_1 = 0$  at the 5 % significance level. This is consistent with theory of the previous section. However, we need one more step before jumping into conclusion. The theory predicts that the sign of  $\beta_t$  does not depend on  $\sigma_t$  and the absolute value of  $\beta_t$  is increasing in  $\sigma_t$ . (For instance, the oil price increase must have a negative effect on the stock price index like TOPIX no matter how the increase is large or small, and the negative effect must be larger when the increase is larger). We should examine whether this is true in our empirical analysis. Table 5 also presents the maximum value and minimum value for the estimates of  $\beta_t$ . In all three specifications, the maximum value is positive, while the minimum value is negative. If the sign of  $\beta_t$  changes depending on the value for  $\sigma_t$ , it is inconsistent with our theory. Table 6 presents the estimates of  $g(\underline{\sigma}_t)$  and  $g(\overline{\sigma}_t)$  with their standard errors, where  $\underline{\sigma}_t$  and  $\overline{\sigma}_t$  denote the minimum value and the maximum value of  $\sigma_t$  in the sample. A standard one-sided  $t$  test do not reject the null hypothesis of  $g(\underline{\sigma}_t) \leq 0$  at any standard level, while the null hypothesis of  $g(\overline{\sigma}_t) \geq 0$  is strongly rejected. Therefore, we can conclude that  $\beta_t$  is not significantly different from zero when  $\sigma_t$  is sufficiently small, while it is significantly below zero

and decreasing in  $\sigma_t$  when  $\sigma_t$  is sufficiently large. This result is consistent with our theory.

Thus far, we assumed that  $\Phi_1$  is equal to the sample mean of  $\sigma_t$ . We also estimate the model that consists of equation (3.8) with (3.5) setting  $\Phi_1 = 1/10, 1/5, 1/2, 1, 2, 5,$  and 10. We find that the likelihood value is the largest when  $\Phi$  is set 1/5 in specification 3. The estimation results of the specification 3 with  $\Phi_1 = 1/5$  are shown in Table 7, where both of the maximum and minimum values decrease to 0.415 and -14.32 respectively.

#### **4. Concluding Remarks**

In this paper, we have developed a model of less-developed asset markets, and have shown that the sensitivity of asset prices to unexpected changes in their fundamental value depends on the heterogeneity of investors' expectations. The more dispersed investors' expectations are, the more sensitive asset prices are with respect to unexpected changes in the fundamental value. It has also been argued that advancement of information technology is likely to reduce price sensitivity, since more and more information is available to improve investors' forecast.

We have then tested the validity of these implications in the Japanese stock market. Using the data on exchange-rate expectations, we have found a strong evidence that

the sensitivity of Japanese stock price innovation to the intrinsic-value factor innovation (which is closely related to the yen-dollar exchange rate and the oil price) depends on the standard deviation of three-month-ahead exchange-rate forecasts of investors. This strongly suggests that the Japanese stock market might be explained by the model developed in this paper. However, we have failed to detect statistically significant downward trend in the price sensitivity over the sample period. Thus, whether advancement of information technology reduces the price sensitivity or not is still inconclusive.

The result of this paper thus suggests importance of heterogeneity in investors' expectations in understanding asset price behavior. However, there are several problems and possible extensions of the model and empirical analysis. Firstly, in our empirical result, diversity in one-month-ahead and six-month-ahead forecasts apparently do not matter although it does in three-month-ahead forecasts. It is an interesting question to explain the difference between three-month-ahead forecasts and the others.

Secondly, the stock market is not the only asset market. For example, the market of real estates may be closer to the postulated model of less-developed asset markets than the stock market, since transaction and information costs are higher in the real-estate market than the stock market. To examine whether real-estate prices are



excessively sensitive to the innovation in their market fundamental is an important topic, and we are doing preliminary research on this subject.

Thirdly, our specification of the advancement of information technology, *i.e.*, time trend in the price sensitivity function, may not be appropriate to measure its real effect. The failure to detect its effect may be due to this possible misspecification. Although it is generally hard to find data on advancement of information technology, more direct test is desirable and a subject of future research.

## **Appendix: Data Source**

The definition of variables used in Section 3 and the source of the data are as follows.

*Stock Prices:* TOPIX, end of period, *Tokyo Stock Exchange Statistics Report*, various issues.

*Short-Term Interest Rate:* Call-market interest rate, monthly average, taken from *Nomura Research Institute Database*.

*Long-Term Interest Rate:* yield on ten-year Kokusai, end of period, taken from *Datastream Database*.

*Exchange Rate:* Japanese yen per U.S. dollar, end of period, taken from *Datastream Database*.

*Index of Industrial Production:* taken from *Datastream Database*.

*Consumer Price Index*: all items seasonally adjusted, taken from *Datastream* Database.

*Trade Balance*: taken from *Datastream* Database.

*Money Supply*: M1 plus quasi-money currency, end of period, taken from *Datastream* Database.

*Oil Price*: Saudi Arabian light oil spot price per barrel, end of period, taken from *Datastream* Database.

Figure1: Standard Deviation of Exchange Rate Forecasts

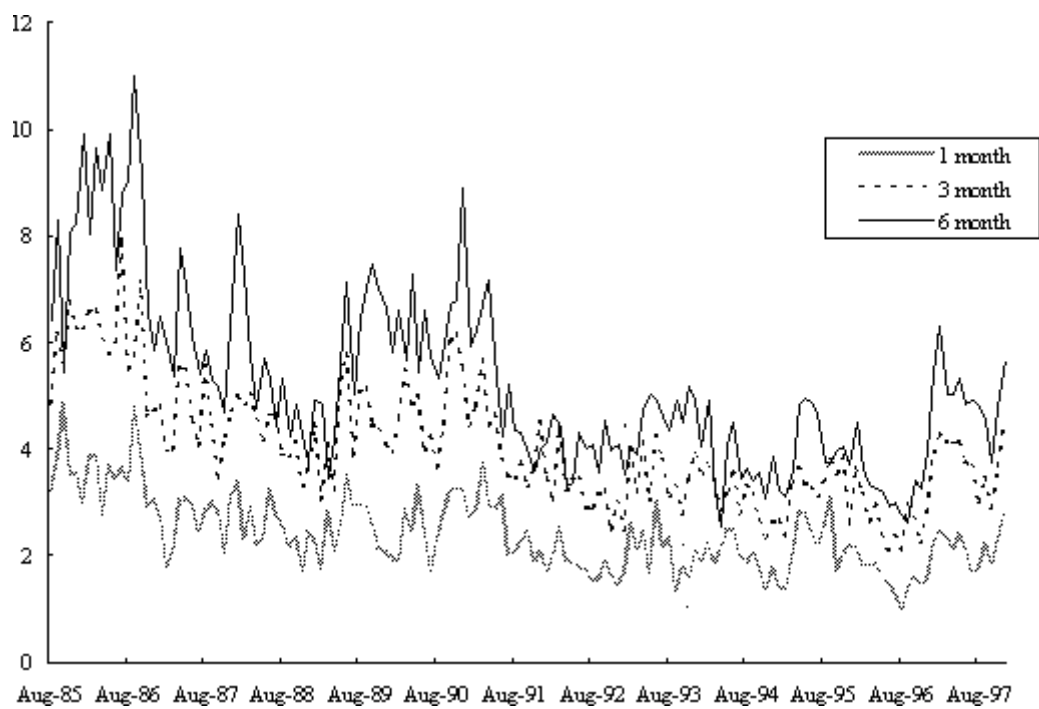


TABLE 1. Ljung-Box Test for Innovations in Macroeconomic Variables

Variable (innovations in)	LB(12)	LB*(12)
Stock Price	10.47	11.04
Short Interest Rate	18.82	14.48
Long Interest Rate	12.61	9.26
Dollar/Yen Exchange Rate	17.11	16.59
Industrial Production	6.32	6.06
Consumer Price	7.70	8.32
Trade Balance	5.31	4.81
Money Supply	23.66	20.68
Oil Price	5.91	5.91

---

<sup>1</sup>LB(12) is the Ljung-Box statistic for up to twelfth order autocorrelation. LB\*(12) is the heteroskedasticity-corrected Ljung-Box statistic (e.g. Diebold (1988)). The asymptotic distributions of LB(12) and LB\*(12) are  $\chi^2$  with twelve degrees of freedom.  $\chi^2(12)$  critical values: 18.55 (10%), 21.03 (5%), 26.22 (1%).

TABLE 2. Estimates of Factor Loadings  $\beta$  and  $\mathbf{C}$  when  $\beta$  is constant

	Estimate	Standard Error
$\beta$	-1.103	0.618
<b><math>\mathbf{C}</math></b>		
Short Interest Rate	0.227	0.132
Long Interest Rate	0.368	0.146
Exchange Rate	0.498	0.190
Industrial Production	0.042	0.116
Consumer Price	-0.171	0.171
Trade Balance	-0.103	0.130
Money Supply	0.110	0.152
Oil Price	0.604	0.231

<sup>10</sup>Estimates of  $\mathbf{C}$  in equation (3.7):  $\epsilon_t = \mathbf{C}f_t + \mathbf{w}_t$ .

TABLE 3. Factor Score Weights (Regression Coefficients)

Variable (innovations in)	Weights
Short Interest Rate	0.105
Long Interest Rate	0.197
Exchange Rate	0.309
Industrial Production	0.020
Consumer Price	-0.081
Trade Balance	-0.041
Money Supply	0.035
Oil Price	0.445

---

<sup>10</sup>Based on OLS regression of factor estimates calculated using equation (3.14) on innovations in economic variables.

TABLE 4. Estimates of Time Trend in  $\beta_t$ 

Specification	$h_0$	$h_1$	Log-likelihood	LR
1. Linear	-1.485 (1.079)	0.006 (0.013)	-2134.32	0.136
2. Negative Exponential	-1.103 (0.615)	0.000 (0.106)	-2134.15	0.000
3. Positive Exponential	-2.546 (2.082)	0.871 (1.195)	-2134.15	0.458

<sup>10</sup>Standard errors in parentheses. LR denotes the likelihood ratio statistic to test the null hypothesis of no time trend, i.e.  $H_0 : h_1 = 0$ . The asymptotic distribution of this statistic is  $\chi^2$  with one degrees of freedom.  $\chi^2(1)$  critical values: 2.71 (10%), 3.84 (5%), 6.63 (1%).

TABLE 5. Estimates of the Relation between the Expectation Heterogeneity  $\sigma_t$   
and  $\beta$

Panel A. One Month Ahead Forecasting

Specification	$g_0$	$g_1$	Log-likelihood	LR	Max	Min
1. Linear	3.479 (4.508)	-4.233 (4.212)	-2133.34	2.08	1.25	-3.405
2. Negative Exponential	-5.382 (3.056)	12.053 (8.368)	-2133.36	2.05	1.83	-2.914
3. Positive Exponential	3.008 (3.137)	-1.401 (1.078)	-2133.46	1.85	0.667	-3.831

Panel B. Three Month Ahead Forecasting

Specification	$g_0$	$g_1$	Log-likelihood	LR	Max	Min
1. Linear	7.215 (2.918)	-7.516 (2.635)	-2130.57	7.63	2.009	-5.337
2. Negative Exponential	-8.521 (2.957)	20.784 (8.262)	-2131.30	6.17	2.231	-4.279
3. Positive Exponential	7.131 (2.896)	-2.809 (0.953)	-2129.87	9.02	1.702	-6.631



Panel C. Six Month Ahead Forecasting

Specification	$g_0$	$g_1$	Log-likelihood	LR	Max	Min
1. Linear	2.554 (2.641)	-3.583 (2.540)	-2133.33	2.10	0.426	-3.624
2. Negative Exponential	-5.415 (2.777)	11.314 (7.053)	-2133.07	2.63	0.928	-3.307
3. Positive Exponential	1.819 (2.215)	-1.045 (0.785)	-2133.65	1.47	-0.045	-3.790

<sup>1</sup>Standard errors in parentheses. Max and Min denote the maximum value and the minimum value of the estimated  $\beta_t$  respectively. LR denotes the likelihood ratio statistic to test the null hypothesis of no relation between  $\sigma_t$  and  $\beta_t$ , i.e.  $H_0 : g_1 = 0$ . The asymptotic distribution of this statistic is  $\chi^2$  with one degrees of freedom.  $\chi^2(1)$  critical values: 2.71 (10%), 3.84 (5%), 6.63 (1%).

TABLE 6. Estimates of  $g(\underline{\sigma}_t)$  and  $g(\bar{\sigma}_t)$

Three Month Ahead Forecasting

Specification	$g(\underline{\sigma}_t)$	$g(\bar{\sigma}_t)$
1. Linear	2.009 (1.360)	-5.337 (1.588)
2. Negative Exponential	2.231 (1.522)	-4.279 (1.329)
3. Positive Exponential	1.702 (1.150)	-6.632 (1.904)

---

<sup>10</sup>Standard errors in parentheses.  $\underline{\sigma}_t$  and  $\bar{\sigma}_t$  denote the minimum value and the maximum value of  $\sigma_t$  in the sample, respectively.

TABLE 7. Estimates of the relation between the Expectation Heterogeneity and  $\beta$

when  $\Phi_1 = 1/5$

Three Month Ahead Forecasting

Specification	$g_0$	$g_1$	Log-likelihood	Max	Min
3. Positive	0.545	-0.005	-2128.57	0.415	-14.322
Exponential	(0.857)	(0.0013)			

<sup>10</sup>Standard errors in parentheses. Max and Min denote the maximum value and the minimum value of the estimated  $\beta_t$  respectively.

## References

- [1] Aguilar, O., and M. West (1998), “Bayesian Dynamic Factor Models and Variance Matrix Discounting for Portfolio Allocation,” Manuscript, ISDS, Duke University.
  
- [2] Akaike, H. (1973), “Information Theory and Extension of the Maximum Likelihood Principle,” in B.N. Petrov and F. Csaki, eds., *Second International Symposium on Information Theory*, Akademiai Kiado: Budapest.
  
- [3] Bollerslev, T., R.F. Engle, and D.B. Nelson (1995), “ARCH Models,” in R.F. Engle and D. McFadden (eds), *The Handbook of Econometrics*, Volume 4, North-Holland, Amsterdam.
  
- [4] Diebold, F.X. (1988), *Empirical Modeling of Exchange Rate Dynamics*, Springer-Verlag, New York.
  
- [5] Engle, R.F., V.M. Ng, and M. Rothchild (1990), “Asset Pricing with a Factor-ARCH Structure: Empirical Estimates for Treasury Bills,” *Journal of Econometrics*, 45, 213-237.

- [6] Ito, T. (1990), "Foreign Exchange Rate Expectations: Micro Survey Data," *American Economic Review*, 80, 434-449.
- [7] King, M., E. Sentana, and S. Wadhvani (1994), "Volatility and Links between National Stock Markets," *Econometrica*, 62, 901-933.
- [8] LeBaron, B. (1992), "Some Relations between Volatility and Serial Correlations in Stock Market Returns," *Journal of Business*, 65, 199-219.
- [9] Ljung, G.M., and G.E.P. Box (1978), "On a Measure of Lag of Fit in Time Series Models," *Biometrika*, 67, 297-303.
- [10] Nishimura, K. G. (1999) "Expectation Heterogeneity and Excessive Price Sensitivity in the Land Market," *Japanese Economic Review*, forthcoming.
- [11] Nishimura, K. G. (1998) "Expectation Heterogeneity and Price Sensitivity," *European Economic Review*, 42, 619-629.
- [12] Ng, V.M., R.F. Engle, and M. Rothchild (1992), "A Multi-Dynamic Factor Model for Excess Returns," *Journal of Econometrics*, 52, 245-266.

- [13] Ross, S. A. (1976) "The Arbitrage Theory of Capital Asset Pricing," *Journal of Economic Theory*, 13, 341-360.
- [14] Schwarz, G. (1978), "Estimating the Dimension of a Model," *Annals of Statistics*, 6, 461-464.
- [15] Watanabe, T. (1998), "Margin Requirements, Positive Feedback Trading, and Stock Return Autocorrelations: The Case of Japan," Manuscript, Department of Economics, Tokyo Metropolitan University.
- [16] White, H. (1980), "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity," *Econometrica*, 48, 817-838.