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IS THERE IRRATIONAL EXUBERANCE?

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This paper presents a framework in which we can examine whether stock prices are overvalued or undervalued. This paper estimates equilibrium stock prices based on the Lucas (1978) tree model using the Hansen and Sargent (1980) cross-equation restriction approach and the VAR approach. By comparing equilibrium stock prices with actual stock prices, we can judge whether stock prices are overvalued or undervalued. This paper finds that Korean stock prices for the period 1983:1 to 2002:3 were valued substantially more than their equilibrium prices while US stock prices for the period 1871:1 to 2001:9 were on average valued substantially less than their equilibrium prices.

Keywords: Stock Price, Irrational Exuberance
JEL classification: E44, G12

1. INTRODUCTION

Alan Greenspan delivered the following famous speech at the American Enterprise Institute for Public Policy Research on December 5, 1996. "But how do we know when irrational exuberance has unduly escalated asset values, which then become subject to unexpected and prolonged contractions as they have in Japan over the past decade?"

Many governments have paid close attention to their stock markets. Stock market performance directly affects individual investors' wealth and hence their consumption. Stock market also affects how well firms can raise their funds and hence their investment. Therefore, stable stock market performance is essential for the stability of the macroeconomy. Without understanding whether the stock market is overvalued or undervalued, however, it is difficult for governments to stabilize the stock market. If the stock market is already overvalued, governments should not try to stimulate the stock market since it will lead to a bubble. Governments could stimulate the stock market if the stock market is undervalued.

Recent declines in US and Korean stock markets have suggested that stock prices may have been overvalued. Yet, we hear only anecdotal evidence for the overvaluation.

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This paper presents a framework in which we can examine whether stock prices were overvalued or undervalued.

This paper constructs an equilibrium stock price based on the Lucas (1978) tree model with the Hansen and Sargent (1980) cross-equation restriction approach and the VAR approach. Then, we can evaluate whether actual stock prices are higher or lower than their equilibrium stock prices. We find that the equilibrium Korean stock prices for the period 1983:1 to 2002:3 were on average 70-72% less than the actual Korean stock prices while the equilibrium US stock prices for the period 1871:1 to 2001:9 were on average 140-161% more than the actual US stock prices. At the end of each time period examined in Korea and in the US, both stock prices were shown to be substantially overvalued, which suggests the future stock prices would decrease substantially. The recent data confirm the overvaluation and exhibit significant decreases in the stock prices.

When Greenspan warned of the irrational exuberance in December 1996, the real S&P composite price index was 791.05 while the computed equilibrium stock price was 569.56. Yes, this paper finds that there was irrational exuberance in December 1996.

Section 2 discusses the Lucas (1978) tree model. Section 3 develops estimation strategies and compares the actual stock prices with the equilibrium prices. Finally, Section 4 concludes the paper.

2. LUCAS TREE MODEL

This paper uses an asset pricing model based on Lucas (1978) and Blanchard-Fischer (1989). Lucas tree model is an exchange economy in which output each period is exogenous and perishable. Therefore, consumption is equal to output in equilibrium, and hence becomes exogenous. There exists an asset which generates a stochastic physical return in the form of perishable goods, equal to d_t per period. For example, we can think of the asset as a tree and the output as seedless apples. This economy consists of identical infinitely lived consumers. A representative agent chooses $\{c_t\}_{t=0}^{\infty}$ so as to maximize

$$Max\ \ E_0[\textstyle\sum_{t=0}^{\infty} \beta^t U(c_t)]$$

subject to the sequence of budget constraints

$$c_t + p_t x_t = (p_t + d_t)x_{t-1} \tag{1}$$

for $t = 0, \ldots, \infty$. β is discount rate, c_t is consumption, p_t is ex-dividend price of the asset, d_t is dividend, and x_t is quantity of the asset that the consumer holds between t and $t+1$. In each period, a consumer receives dividends on the asset that he holds. Then, the consumer decides how much to consume and how much to save in each period.

The first-order conditions are

$$p_t U'(c_t) = \beta E_t[U'(c_{t+1})(p_{t+1} + d_{t+1})]. \tag{2}$$

For the market equilibrium, the quantity of the asset demanded must be equal to the exogenous supply. Assuming there is one unit of the asset, the equilibrium condition implies that $x_t = 1$ for all t. Therefore, from budget constraint (1), $c_t = d_t$. Solving Equation (2) recursively and assuming no bubbles, an equilibrium asset price p_t^e can be expressed as

$$p_t^e = E_t[\sum_{i=1}^{\infty} \beta^i \frac{U'(c_{t+i})}{U'(c_t)} d_{t+i}]. \tag{3}$$

The equilibrium price is equal to the expected present discounted value of dividends where the discount rate used for $t+i$ is the marginal rate of substitution between consumption at time $t+i$ and consumption at time t.

Assume consumers are risk neutral so that $U'(c)$ is constant. Then equilibrium asset price (3) becomes

$$p_t^e = E_t[\sum_{i=1}^{\infty} \beta^i d_{t+i}]. \tag{4}$$

The equilibrium price is now equal to the expected present discounted value of dividends discounted at a constant rate. Equilibrium price (4) is the pricing formula often used in volatility tests as in Shiller (1981) and LeRoy-Porter (1981). This is the equilibrium stock price which this paper uses.

3. ESTIMATION OF AN EQUILIBRIUM STOCK PRICE

This paper follows Kim (1996) to estimate equilibrium stock prices, using the Hansen and Sargent (1980) cross equation restriction approach and the VAR approach.

For the Korean data, this paper uses monthly KOSPI composite price index and dividends for the period 1983:1 - 2002:3,[1] which was obtained from the website of the Korea Stock Exchange, www.kse.or.kr, and *Stock*. Since the Korea Stock Exchange only maintains data on dividend yields, this paper converts the dividends yields into

[1] Data on dividend yields before 1983 is not comparable and hence is omitted in this paper.

dividends by multiplying by the corresponding KOSPI index. Nominal stock prices and dividends are converted to real prices and dividends by PPI (producer price index).[2] CPI (consumer price index) and PPI are obtained from the Korea National Statistical Office website, www.nso.go.kr. Using the 3-year commercial bond rates[3] from the Bank of Korea website, www.bok.or.kr, the average annual nominal interest rate is computed as 13.278%. Using the CPI, the average annual inflation rate is computed as 4.685% during this period, which implies that the average annual real interest rate is equal to 8.592%.[4] Hence, for the Korean data set, this paper sets $\beta = 0.99315$, which corresponds to 8.592% interest rate on an annual basis, assuming that the discount rate for future consumption is equal to the real rate of return from asset holdings: $\beta = 1/(1+r)$.

For the US data, this paper uses the monthly S&P composite price index and dividends for the period 1871:1 - 2001:9, which was used in Shiller (2000). The updated data set was obtained from the website of Professor Robert J. Shiller.[5] Monthly dividend data are computed from the S&P four-quarter tools for the quarter since 1926, with linear interpolation to monthly figures. Dividend data before 1926 are interpolated from annual data in Cowles and Associates (1939). Stock price data are monthly averages of daily closing prices. Nominal stock prices and dividends are converted to real prices and dividends by CPI. Using the Shiller data set, the average annual nominal interest rate is 4.88%[6] and the average annual inflation rate is 2.213% during this period, which implies that the average annual real interest rate is equal to 2.749%.[7] Hence, for the US data set, this paper sets $\beta = 0.99774$, which corresponds to 2.749% interest rate on an annual basis.

[2] Normalizing with consumer price index does not make a qualitative difference to the results, and hence is omitted here.

[3] The rates are based on the transactions at the Korea Stock Exchange before 1987:1, and are based on transactions in the OTC markets after 1987:1.

[4] Assuming the annual real interest rates to be equal to 4%, 6% or 10% does not change the qualitative results of this paper, and hence they are omitted from the paper.

[5] Please see his website, http://www.econ.yale.edu/~shiller/data.htm, for a detailed description of the data set.

[6] According to Shiller's website, the nominal interest rate series is the total return to investing for six months in January at the January 4-6 month prime commercial paper rate (six month starting January 1980) and for another six months at the July 4-6 month prime commercial paper rate (six month starting July 1980). (Starting 1998, 6-month commercial paper rate is replaced here by the 6-month certificate of deposit rate, secondary market.) It is computed as $100[1/((1-R_{jan}/200)(1-R_{jul}/200))-1]$. Data starting 1938 are from the Federal Reserve Bulletin. Data before 1938 are from Macaulay (1938), Table 10, pp. A142-A160.

[7] Assuming the annual real interest rates to be equal to 1%, 4% or 5% does not change the qualitative results of this paper, and hence they are omitted from the paper.

First, using the Hansen-Sargent (1980) cross equation restriction methodology, equilibrium stock price (4) becomes

$$p_t^e = [\frac{\beta L^{-1} - \beta a^{-1}(\beta) a(L) L^{-1}}{1-\beta L^{-1}}] d_t + \frac{\beta}{1-\beta} a^{-1}(\beta)\mu \,,$$

using the Wiener-Kolmogorov formula in Sargent (1987), and assuming univariate dividend processes $a(L)\, d_t = \mu + \varepsilon_t$. We specify the dividend process as AR(1), AR(2) and a random walk since the Wiener-Kolmogorov formula may be sensitive to dividend specifications. AR(1) and AR(2) dividend processes imply the following equilibrium stock prices respectively:

$$p_t^{e1} = [a^{-1}(\beta) - 1] d_t + \frac{\beta}{1-\beta} a^{-1}(\beta)\mu \,,$$

and

$$p_t^{e2} = [a^{-1}(\beta) - 1] d_t + a^{-1}(\beta)\beta a_2 d_{t-1} + \frac{\beta}{1-\beta} a^{-1}(\beta)\mu \,.$$

Alternatively, if we assume that the dividend series is a random walk with a drift as in Mankiw and Shapiro (1985), and Stock and West (1988), the corresponding equilibrium stock price is

$$p_t^{e3} = \frac{\beta}{1-\beta} d_t + \frac{\beta}{(1-\beta)^2}\mu \,.$$

Second, we use a two-variable VAR of dividends and prices to forecast future dividends since agents are likely to use more information than their past dividends to forecast their future dividends. Under the market efficiency hypothesis, the stock price is a forward looking variable and is likely to help to predict future dividends:

$$\begin{pmatrix} d_t \\ p_t \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} a(L) & b(L) \\ c(L) & d(L) \end{pmatrix} \begin{pmatrix} d_{t-1} \\ p_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_t^1 \\ \varepsilon_t^2 \end{pmatrix}$$

where the polynomials in the lag operator $a(L)$, $b(L)$, $c(L)$, $d(L)$ are all of order p, and ε_t^1 and ε_t^2 are white noises with mean zero. This can be stacked into a first-order system:

$$\begin{pmatrix} d_t \\ d_{t-1} \\ \vdots \\ d_{t-p+1} \\ p_t \\ p_{t-1} \\ \vdots \\ p_{t-p+1} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ 0 \\ \vdots \\ 0 \\ \mu_2 \\ 0 \\ \vdots \\ 0 \end{pmatrix} + \begin{pmatrix} a_1 & \dots & a_p & b_1 & \dots & b_p \\ 1 & & & & & \\ & & & & & \\ & 1 & & & & \\ c_1 & \dots & c_p & d_1 & \dots & d_p \\ & & & 1 & & \\ & & & & & \\ & & & & 1 & \end{pmatrix} \begin{pmatrix} d_{t-1} \\ d_{t-2} \\ \vdots \\ d_{t-p} \\ p_{t-1} \\ p_{t-2} \\ \vdots \\ p_{t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_t^1 \\ 0 \\ \vdots \\ 0 \\ \varepsilon_t^2 \\ 0 \\ \vdots \\ 0 \end{pmatrix}$$

which can be written compactly as

$$z_t = \mu + Az_{t-1} + \varepsilon_t .$$

Let $e = (1,0,....,0)$ be a $2p$ row vector. Then,

$$E_t d_{t+i} = E_t(ez_{t+i}) = eA^i z_t + e\sum_{j=0}^{i-1} A^j \mu .$$

Thus, equilibrium stock price (4) can be constructed as

$$p_t^{e4} = e\beta A(I - \beta A)^{-1} z_t + e\frac{\beta}{1-\beta}(I - \beta A)^{-1} \mu .$$

In order to quantitatively compare whether actual stock prices overvalue or undervalue their equilibrium stock prices, we compute the extent to which the constructed equilibrium stock prices deviate from actual stock prices as in Kim (1996):

$$E[\frac{p_t - p_t^e}{p_t}] .$$

Table 1 computes the equilibrium stock prices with Hansen and Sargent approach. Table 1(a) shows that p_t^{e1} is on average 72.01% less, p_t^{e2} is 72.06% less, and p_t^{e3} is 69.88% less than the actual Korean stock prices. Table 1(b) shows that p_t^{e1} is on average 149.48% more, p_t^{e2} is 139.92% more, and p_t^{e3} is 149.63% more than the actual US stock prices. In other words, the Korean stock prices during 1983:1-2002:3 tended to be significantly overvalued, while US stock prices during 1871:1-2001:9 tended to be significantly undervalued.

Table 1. Hansen-Sargent Approach

	μ	a_1	a_2	$E[\frac{p_t - p_t^e}{p_t}]$
(a) Korea				
p_t^{e1}	0.0006	0.9257		0.7201
	(0.0003)	(0.0387)		
p_t^{e2}	0.0006	0.8926	0.0355	0.7206
	(0.0003)	(0.0440)	(0.0500)	
p_t^{e3}	0.0000	1.0000		0.6988
	(0.0001)			
(b) US				
p_t^{e1}	0.0007	0.9999		-1.4948
	(0.0008)	(0.0008)		
p_t^{e2}	0.0006	1.5838	-0.5844	-1.3992
	(0.0004)	(0.0423)	(0.0422)	
p_t^{e3}	0.0006	1.0000		-1.4963
	(0.0003)			

Notes: p_t^{e1}, p_t^{e2}, and p_t^{e3} are constructed from AR(1), AR(2) and random walk dividend processes respectively. Standard errors are in parentheses.

Table 2 computes the equilibrium stock prices with the VAR approach with VAR lags 1,..,5. Columns 2 and 3 are regression coefficients of lagged dividends and prices when the dependent variable is the dividend. Columns 4 and 5 are regression coefficients of lagged dividends and prices when the dependent variable is the price. The table presents the sums of coefficients to save space with appropriate standard errors in parentheses. Past dividends are all significant in predicting future dividends, and past stock prices are all significant in predicting future stock prices. Table 2(a) shows that for the Korean data, past stock prices are all significant in predicting future dividends, and past dividends are all insignificant in predicting future stock prices, which is consistent with the hypothesis that a stock price is a forward looking variable. Yet, Table 2(b) shows that for the US data, past stock prices are all insignificant in predicting future dividends, and past dividends are mildly significant in predicting future stock prices, rejecting the hypothesis that a stock price is a forward looking variable. Column 6 shows that the equilibrium stock prices are 70.94%-71.74% less than the actual Korean stock prices and 145.80%-160.63% more than the actual US stock prices, which is comparable to Table 1.

Table 2. VAR Approach

	$\sum_{i=1}^{p} a_i$	$\sum_{i=1}^{p} b_i$	$\sum_{i=1}^{p} c_i$	$\sum_{i=1}^{p} d_i$	$E[\frac{p_t - p_t^e}{p_t}]$
(a) Korea					
Lag = 1	0.8878***	0.0001**	-0.0478	0.9773***	0.7094
	(0.0290)	(0.0000)	(18.0672)	(0.0144)	
Lag = 2	0.8889***	0.0001**	0.4797	0.9757***	0.7125
	(0.0302)	(0.0000)	(18.7069)	(0.0147)	
Lag = 3	0.8875***	0.0001**	4.9517	0.9738***	0.7124
	(0.0307)	(0.0000)	(19.3518)	(0.0151)	
Lag = 4	0.8992***	0.0001**	5.6472	0.9742***	0.7152
	(0.0315)	(0.0000)	(20.0583)	(0.0155)	
Lag = 5	0.9044***	0.0001**	8.6193	0.9716***	0.7174
	(0.0323)	(0.0000)	(20.6327)	(0.0159)	
(b) US					
Lag = 1	0.9995***	0.0000	2.6343	0.9989***	-1.5915
	(0.0012)	(0.0000)	(1.7256)	(0.0023)	
Lag = 2	0.9986***	0.0000	3.2553*	0.9968***	-1.5946
	(0.0009)	(0.0000)	(1.6787)	(0.0022)	
Lag = 3	0.9984***	0.0000	2.9051*	0.9975***	-1.6063
	(0.0009)	(0.0000)	(1.6813)	(0.0022)	
Lag = 4	0.9985***	0.0000	3.0837*	0.9971***	-1.5342
	(0.0009)	(0.0000)	(1.6880)	(0.0023)	
Lag = 5	0.9983***	0.0000	3.2822*	0.9966***	-1.4580
	(0.0009)	(0.0000)	(1.6935)	(0.0023)	

Notes: Appropriate standard errors are in parentheses. ***, **, * represent significance at 1, 5 and 10 percent respectively.

Figures 1 plots the actual stock prices and the equilibrium stock prices using Hansen and Sargent cross-equation restriction approach for AR(2). Figures for AR(1) and random walk specifications are similar and are omitted here. Figure 1(a) shows that actual Korean stock prices were significantly higher than their equilibrium stock prices. Figure 1 also plots its deviation ratios. They range from 20% to 90%. Figure 1(b) shows that the actual US stock prices were lower than their equilibrium stock prices before 1993:10, and became higher afterwards. Their deviation ratios ranged from -539% to 61%. The dividend-price ratios were 2.17% for the Korean stock index and 4.66% for the US stock index. Since Korean stocks paid less dividends, their equilibrium prices may have been lower.

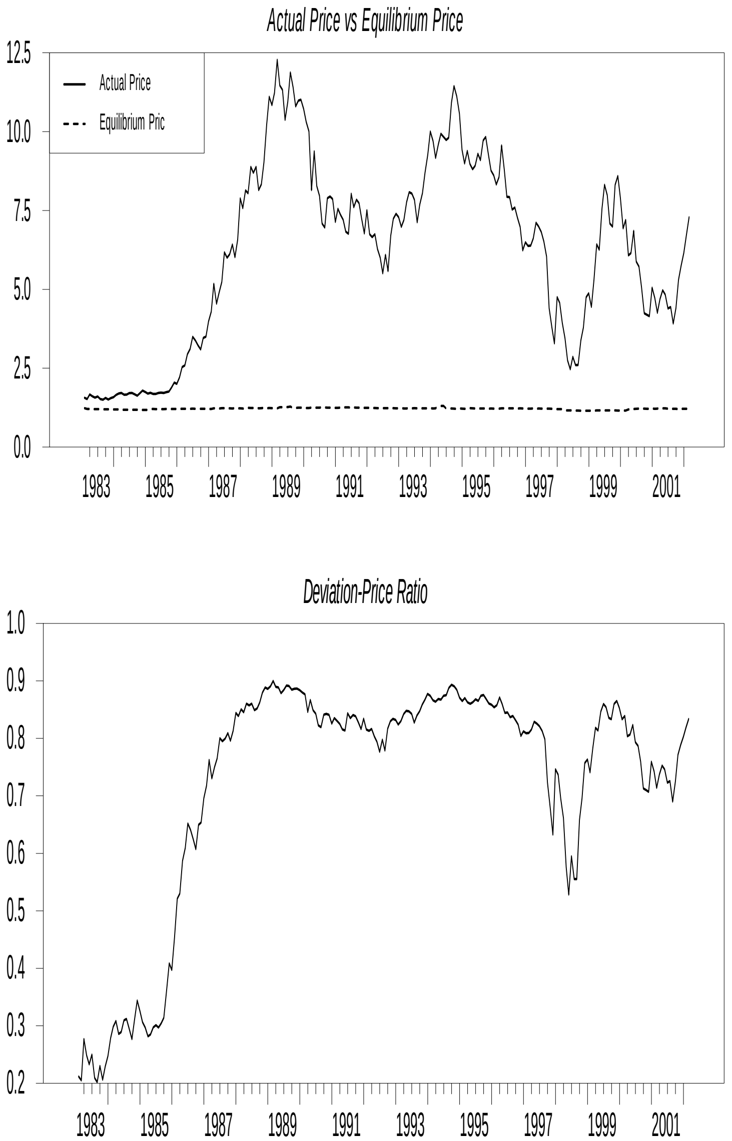


Figure 1a. Korean Stock Prices using the Hansen-Sargent Approach AR(2)

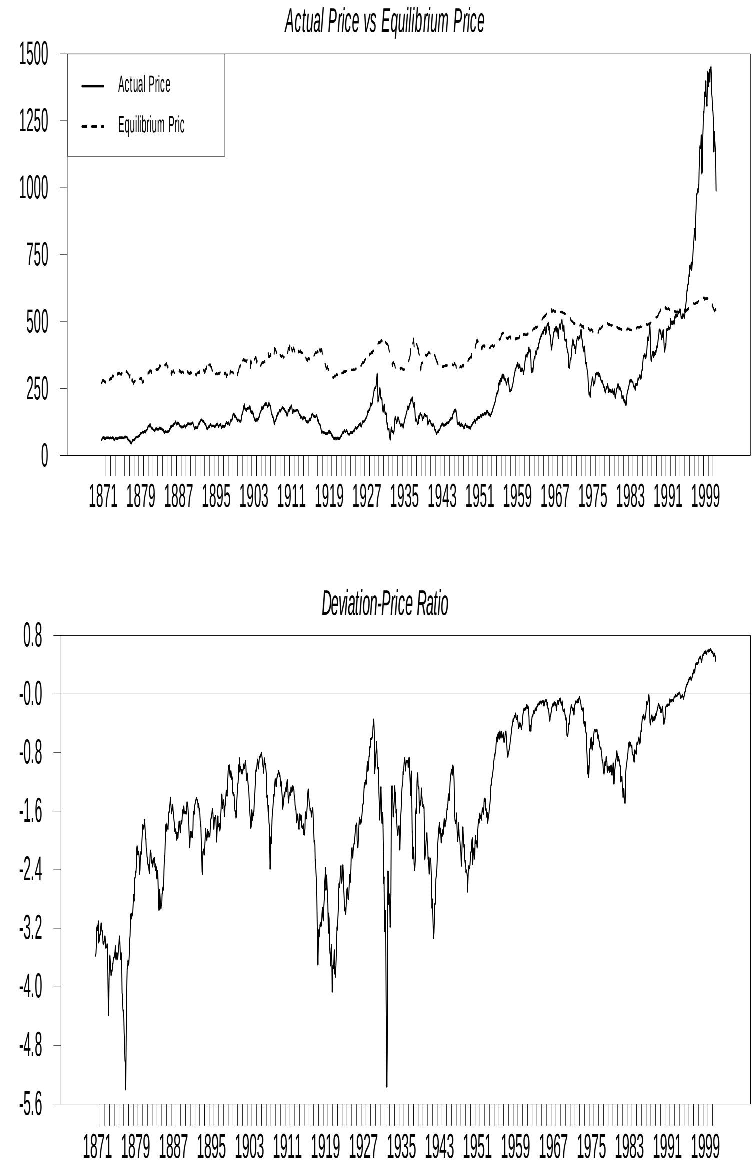


Figure 1b. US Stock Prices using the Hansen-Sargent Approach AR(2)

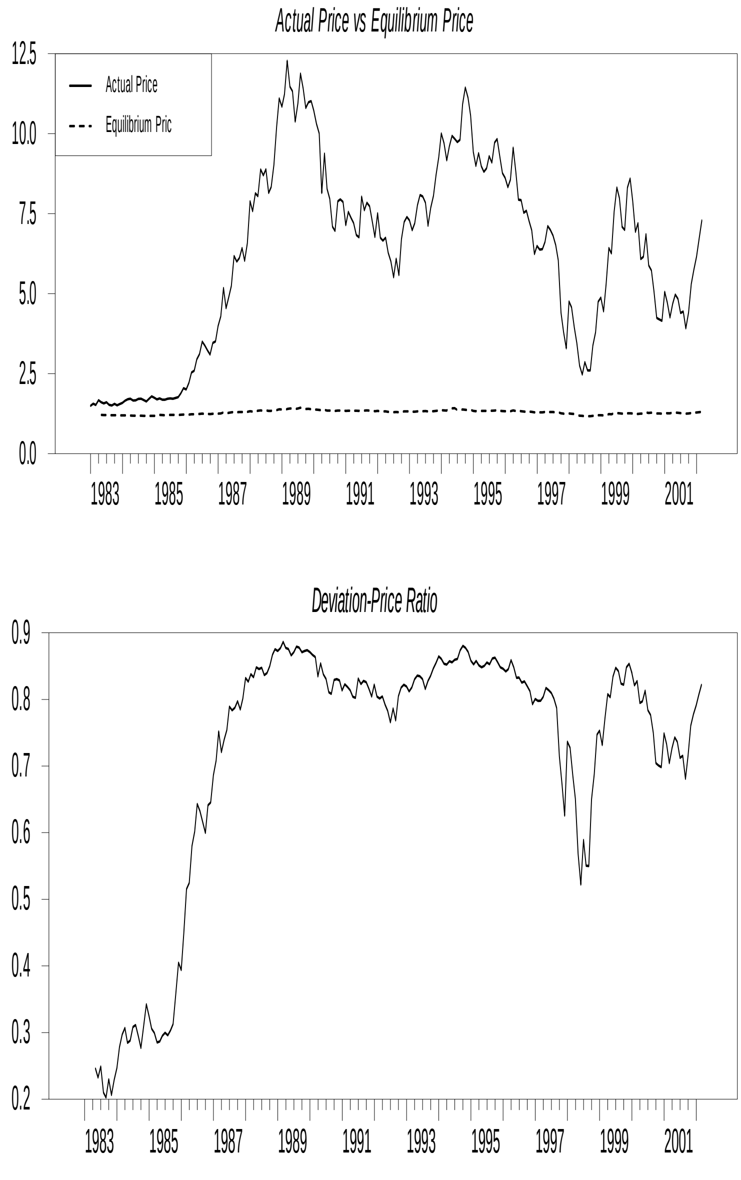


Figure 2a. Korean Stock Prices using the VAR Approach for Lag = 5

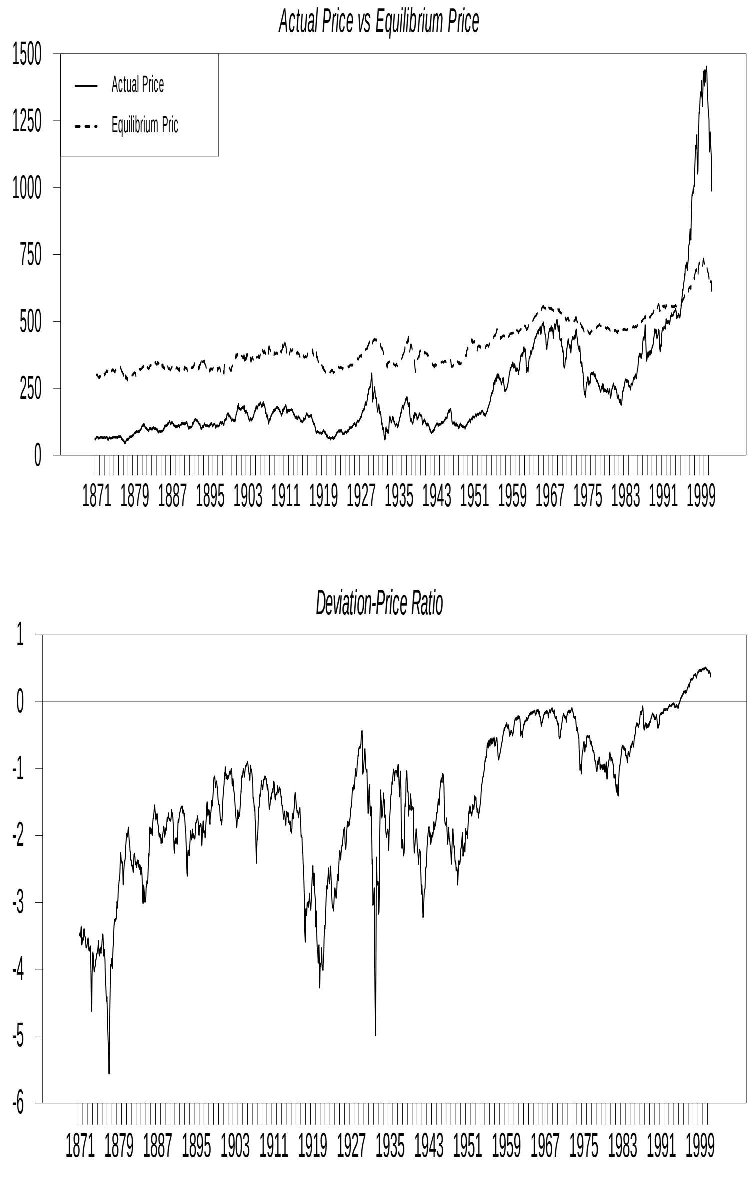
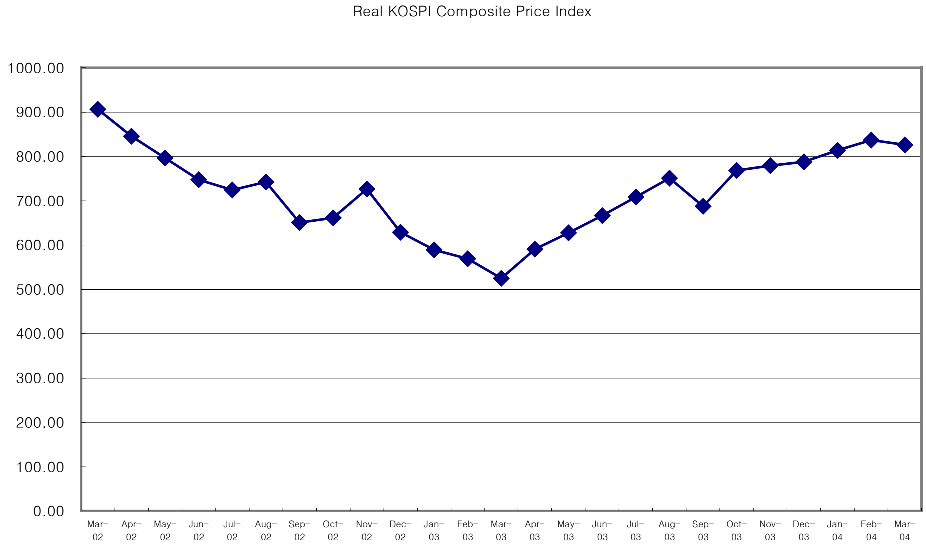


Figure 2b. US Stock Prices using the VAR Approach for Lag = 5



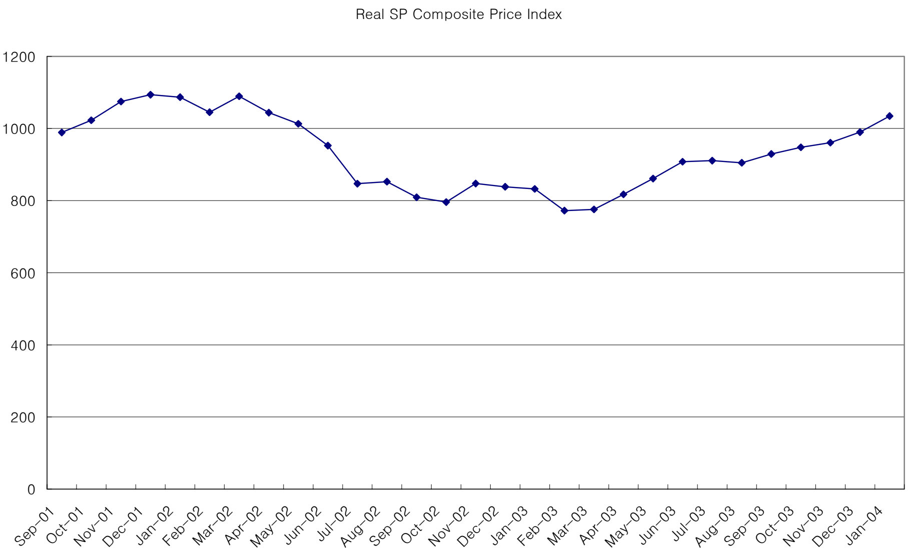


Figure 3. Stock Prices after the Period

Figure 2 plots them using the VAR approach with lag 5, which are similar to the figures from Hansen and Sargent approach. VAR approach with other lags is very similar to Figure 2, and hence is omitted here. They all suggest that Korean stock prices for the period 1983:1 to 2002:3 were valued substantially more than their equilibrium prices while US stock prices for the period 1871:1 to 2001:9 were on average valued substantially less than their equilibrium prices.

Figure 3 plots the actual stock prices after the period which this paper examines: after March 2002 for the KOSPI composite price index and after September 2001 for the S&P composite price index. In March 2002, the real KOSPI composite price index was 906.46 and the deviation ratio was 0.83, which implies that the equilibrium price may be around 154.10. Although the actual price did not go down as far as 154.10, the price did go down to 524.68 in March 2003. Considering the fact that new information had arrived between March 2002 and March 2003, we do not expect the stock price would be exactly equal to what the paper predicts. Yet, the observation that the stock price was overvalued substantially in March 2002 suggests that the stock price would decline substantially in the future, which was confirmed by the actual data. In September 2001, the real S&P composite price index was 988.98 and the deviation ratio was 0.45, which implies that the equilibrium price may be around 598.55. Although the actual price did not go down as far as 598.55, the price did go down to 772.20 in February 2003. Therefore, these exercises may be useful in judging the future direction and magnitude of stock movements even if they are not exactly accurate about the magnitudes of future movements.

4. CONCLUSION

This paper suggests a framework to evaluate whether stock prices are overvalued or undervalued. Stock prices are overvalued if the actual stock prices are higher than the equilibrium stock prices. This paper demonstrates that Korean stock prices for the period 1983:1 to 2002:3 were valued substantially more than their equilibrium prices while US stock prices for the period 1871:1 to 2001:9 were on average valued substantially less than their equilibrium prices.

We, however, note that the overvaluation of the Korean stock prices and the undervaluation of US stock prices may have resulted from specific assumptions underlying the construction of their equilibrium stock prices rather than fundamental overvaluation or undervaluation. For example, equilibrium stock price (4) may not accurately describe the actual stock price. Although we can debate whether or not this paper constructs the equilibrium stock prices properly, this method improves upon anecdotal approaches such as comparing P/E ratios to examine over or under evaluation of stock prices.

Furthermore, this exercise can also shed light on whether the stock price is overvalued or undervalued at a certain point in time as well as on average. Therefore, this method can be useful in trying to forecast tomorrow's stock price. At the end of each time period examined in Korea and in the US, both stock prices were shown to be substantially overvalued, which suggests that the future stock prices would decrease substantially. The recent data confirm the overvaluation and exhibit significant decreases in the stock prices.

Although it may not be possible to accurately forecast the future stock price, this exercise can be useful in our efforts to predict the future stock price. This exercise cannot accurately predict how much the stock price will move or when the stock price adjustment will take place, but this can be a first check on how the stock price may move in the future.

When Greenspan warned of the irrational exuberance in December 1996, the real S&P composite price index was 791.05 while the computed equilibrium stock price was 569.56, which justified his warning. Despite his warning, however, the real S&P composite price index shot up to 1451.07 in August 2000 and later fell to 772.20 in February 2003. Although Greenspan was right about the irrational exuberance in December 1996, exuberance can have a life of its own even if it is irrational. This makes the stock price prediction difficult and challenging.

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