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The IT Revolution and Macroeconomic Volatility in Newly Developed Countries: The Korean and Taiwanese Experiences

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The decade of the 1990's was the era of New Economy, characterized by two trends: rapid globalization of the world economy through trade and investment, and the revolution in information and communication technology (ICT or IT) due to fast upgrading of computer hardware, software, and telecommunication equipment, and steep declining of their prices (Pohjola, 2002a; 2002b; IMF, 2001). The trends are led by the United States. From 1991 to 2001, the US economy experienced rapid growth, low inflation and unemployment, accompanied by extraordinary boom in the stock market.

The fast technological progress and turnover, low cost of learning, externality of networking and the combination of high-tech and labor-intensive manufacturing process have enabled the vertical division of labor between the producers of microcomputers and information equipment in the United States and the manufacturing firms in the developing countries in East Asia and ASEANs. Specialization in IT products in Asia-Pacific countries has enhanced the interdependence between the United States and these countries through trade and foreign direct investment. Elsewhere we have shown that as the United States, along with Japan, is a significant investor and trading partner in this region, the economic relation between Asian-Pacific countries on the one hand, and the world, especially the United States and Japan, on the other, becomes much closer than ever during the last decade, exposing Asia-Pacific countries to international business fluctuations and increasing their macroeconomic volatility (Hsiao and Hsiao, 2003b). Thus, when the US stock market burst and the US economy entered a recession in 2001, the stock markets and the economies of East Asia follow suit.

In this paper, we concentrate on the impact of the IT revolution on the two newly developed countries, Korea and Taiwan, which have similar economic and production structures as well as similar historical background (Hsiao and Park, 2002; Hsiao and Hsiao, 2003a).[1] In 1996, Korea was admitted to the prestigious OECD countries. Taiwan should have followed suite if not for the reason of international politics. In view of their similar pattern of long-run economic growth, one may expect a similar impact of the IT revolution on these two newly developed countries, and the comparisons of their macroeconomic volatility may yield useful policy implications for developing countries.

The impact of the IT revolution on Korea and Taiwan has two routes: one is the impact on GDP growth (the real linkage) through trade and foreign direct investment, the other is the impact on stock price (the financial linkage) through stock markets (Hsiao and Hsiao, 2003b). Thus, unlike the old economy, the stock price plays a significant role in a country's macroeconomic activity in the New Economy. One of the main concerns for economic policy in developed and developing countries is how the volatility of the stock prices is associated with GDP growth. Thus, the purpose of this paper is to find the relationship between the volatility of the financial markets, as represented by stock price indexes, and economic growth, as manifested in the volatility of GDP growth rates, in Korea and Taiwan. According to the modified Mundell-Fleming-Dornbusch macroeconomic model, since other factors, such as exchange rates, money supply, and economic openness are also associated with economic growth, we control these three factors by including them in the causality analysis.

A common method of measuring macroeconomic volatility is to use simple sample standard deviations (Temple, 2002), or sample standard deviations after filtering the time series data (Agenor, McDermott, and Prasad, 1999). These methods ignore the random process which generate the data (Engle, 1982) and distort the data due to smoothing (Bini-Smaghi, 1991). Thus, in this paper, we use the square roots of conditional variances that are generated by the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) procedure (Engle, 1982; Bollerslev, 1986) as the measure of volatility.

In Section II, we attempt to show that by the 1990s Korean and Taiwanese economies have built the critical mass of IT activities from the supply and demand sides of the IT revolution by comparing their IT activities with other developed and developing countries. Section III

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[1] The current literature on this topic emphasizes cross-section analysis of either developed countries or developing countries, see Ramey and Ramey, 1995; Gavin and Hausmann, 1996; Easterly, Islam, and Stiglitz, 2000, etc. One of the problems of cross section analysis is that the countries have heterogeneous economic characteristics and different stages of development.

relates the New Economy with the volatility of the stock price indexes. We then in Section IV embed the stock price index, along with four other variables in a simple macroeconomic model, and explain the sources of data. Section V derives the causalities of the variables. After examining the stationarity of the time-series data, the GARCH (1, 1) model is applied to obtain the estimated conditional variances of stock price index, GDP, and the three other factors. We checked stationarity of the volatility measures, and then use the vector autoregression (VAR) model and pair-wise Granger causality test to find the causality relationships of GDP volatility and stock price index volatility in Korea and Taiwan, and their results are compared. Section VI applies the same method to Taiwanese data, and Section VII compares the results of the causality tests between Korea and Taiwan and concludes.

II. The IT Revolution and Korean and Taiwanese Economies

Both Korea and Taiwan developed their IT industry from the electronics industry[2] in the 1960's. Table 1 shows the percentage share of world electronics production (including information products) of Korea and Taiwan as compared with the other Asian countries. In this paper, the Asian countries include the Asian Developed Countries (ADCs): South Korea (hereafter Korea), Taiwan, Singapore, and Japan, and the ASEAN5+: that is, Indonesia, Malaysia, Philippines, Thailand, Vietnam, and China. When Hong Kong, which is increasingly integrated with China, is included in ADCs, we denote them separately as ADCs+. For comparison, we also show the data of the United States, and South Asia and others, if possible, including Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The benefit of our classification will be clear when it comes to discuss the "digital divide" in Table 3.

Place Table 1 here

In Table 1, the world IT share of Korea and Taiwan increased steadily in the 1990s, except the aftermath of the Asian financial crisis of 1997. Although their absolute shares appear to be low compared with that of Japan, and possibly the United States (the data of which is

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[2] For Korea and Taiwan, see Sato (1997), for Taiwan, see Hsiao and Hsiao (1996) and Kawakami (1996). Kawakame concluded that "the rise of Taiwan's PC industry was not sudden and unexpected, but rather a natural extension of the preceding development of the electronics industry." This is also true for Singapore (Wong, 2002).

missing), it should be noted that in terms of their population size, as shown in the first column, their world shares are roughly comparable[3] to that of Japan, and much better than countries in ASEAN5+ and others in the table, showing the vitality of the two countries.

In 1999, the world IT product shares[4] in both countries in total imports and exports in each country are very high: 23% and 24% for Korea and 23% and 47% for Taiwan, higher than those of Japan and the United States, but smaller than city-state like Singapore and Hong Kong.[5] Similarly, the percentage ratios of the imports and exports of major IT products over GDP range from 7% to 9% for Korea and 9% to 19% for Taiwan, much larger than those of Japan and the United States.

The vigorous production and trading activities in IT products in Korea and Taiwan are also reflected in the structure and productivity of manufacturing industry in these two countries. Figure 1 shows the value-added shares of some manufacturing sectors in Korea (Figure 1a) and Taiwan (Figure 1b). The matched data at the 15 manufacturing sectors from 1978-1996 are taken from Hsiao and Park (2002, 2003). The high-tech industry category consists of four sectors shown in the charts as Elect (electric, electronic machinery products and repairs), Trans (Transportation products and repairs), Mach (Machinery products and repairs), and Misc (Precision Instruments and other manufacturing) sectors, all are denoted in bold italic fonts with underline in the charts. The value-added share of electric and electronic sector in the manufacturing industry in Korea increased from 7% to 17%, while that of Taiwan from 12% to 22%, becoming the largest manufacturing sector in each country, replacing the second largest food (Food, beverage, and tobacco) sector in Korea, and the chem (Chemical products, rubber, and plastics) sector in Taiwan (other labels in Figure 1 are defined in Footnote 7).

Place Figure 1 here

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[3] Singapore is real exception, its world share (3.8%) is 51 times larger than its "fair" world share of 0.07%. Other ADC+ has 5 times for Korea, 8 times for Taiwan, 7 times for HK, and 9 times for Japan.

[4] The value of IT products is the sum of four items: electrical machinery and equipment, electronic equipment and components, office machinery and supplies, telecommunication equipment, as listed in Cornelius, et al. (2002). Also see Table 2 of this paper.

[5] We found a discrepancy in IT exports data in Cornelius, et al. (2002). We multiplied 10 to the original data of four items to obtain 22.9% of the IT products/total HK exports ratio (the original data will give only 2.3%).

Figure 2 shows the time series profile of sequential multiplicative products of the weighted average Malmquist productivity indexes[6] for three categories[7]: traditional, basic, and high-tech, of the manufacturing industry in Korea and Taiwan, along with the Malmquist productivity index of the electric and electronics sector. Like the value-added share in Figure 1, the electric and electronics sector in both countries experienced a massive rise in both countries: Korea about 120%, and Taiwan about 40% from 1978 to 1996.

Place Figure 2 here

Both Figures 1 and 2 demonstrate clearly the prominent role played by the IT industry in Korea and Taiwan. It is the largest, fastest growing, and fastest productivity improving manufacturing sector in both countries. In fact, the governments in the Asia Pacific region place a top priority on developing the IT industry. Korea has the national initiative for "CYBER KOREA 21," Taiwan for "Green Silicon Island," Japan for "e-Japan Strategy," Singapore for "Intelligent Island," and Malaysia for "Multimedia Super Corridor" (Hsiao and Hsiao, 2003b; Liu, 2001). These governments have devoted large resources to R&D in IT development, facilitating technology absorption and adaptation, and induced foreign direct investment. Taiwan is now the world's third largest producer of IT products, next to the US and Japan, and Korea is the world's third largest producer of semiconductor chips, and in the forefront of mobile-phone technology (ADB, 2000).

Table 2 shows the world shares of imports and exports of major IT products in Asian region. Korea and Taiwan together imported 6% of total world IT imports, and exported more than 11% of total IT exports. ACD+ alone had 22% and 35% of the world imports and exports.

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[6] The Malmquist productivity index (MPI) is the product of the technology change index (TI) and the efficiency change index (EI). TI measures the relative movement of the production possibility curve (PPC) between two periods, and MI measures the ratio of the degree of deficiencies of the actual output relative to the corresponding output on the PPC, which, in the case of Figure 2, is constructed from a category-wise cross-industry best-practice meta production frontier from the observed outputs each year by linear programs. For details, see Hsiao and Park (2002, 2003). The lines in Figure 2 trace the change in productivity index each year (Hsiao and Park, 2003).

[7] The manufacturing sectors in the traditional category are 1. Food, beverage and tobacco; 2. Textiles; 3. Apparel and ornaments or "Appa" in Figure 1; 4. Leather; 5. Wood products and non-metalic furniture; 6. Paper and printing. The basic category includes 7. "Chem.," as defined in the text; 8. Petroleum coal and products or "Petro" in Figure 1; 9. Non-metallic mineral products; 10. Basic metal products or "BasicM" in Figure 1; 11. fabricated metal products. The high-tech category includes 12. "Elect"; 13. "Trans"; 14. "Mach"; and 15. "Misc"; as defined in the previous paragraph.

Thus, there is indeed geographic clustering in the IT production and trade. The major products in the trade of both directions are electronic equipment and components, and electrical machinery and equipment, followed by office machinery and supplies and telecommunication equipment. The last part of Table 2 shows the position ranking of the trade performance index.[8] Both Taiwan and Korea generally ranked within top 10, following closely Singapore and Japan, and better than the United States, much better than the ASEAN5+, except possibly Malaysia. The last four columns show the change ranking from 1995 to 1999. The changes are minimal for Korea and Taiwan, indicating that both countries had developed these products before 1995. The exceptions are office machinery and supplies for Korea and electronic equipment and components for Taiwan, both of which increased greatly during this period.

Place Table 2 here

The massive IT production and trading alone cannot qualify Korea and Taiwan to be called the New Economies. The people must also use IT products in its production, service, and consumption activities (Kapur, 2002). Table 3 shows they are indeed just doing so. We have also listed the population density and per capita GDP of these countries. In fact, their domestic use of cellular phones already far exceeded that of Japan and the United States, their internet users also far exceeded those of Japan, although still lags behind those of the United States. The use of telephone mainline is mixed. Taiwan exceeds and Korea lags as compared to Japan, but both lags behind the United States. Their use of personal computers is the slowest, lags far behind that of Japan and the United States.

Place Table 3 here

Interestingly, the table also shows the three layers of "digital divide" by the number of digits (the main exception in ASEAN5+ is Vietnam), and highlights the IT revolution taking place in Korea and Taiwan. In general, we submit that while the statistical evidence are mixed, we may state that the New Economy has created domestic demand for information products and

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[8] For the construction of this index, see Cornelius (2002).

services in Korea and Taiwan as much as other advanced countries, and the majority of people start taking advantages of the IT revolution.
They already have accumulated the critical mass of the IT revolution and entered the era of the New Economy.

III. Increased Volatility of the Financial Market

The arrival of the New Economy strengthened the financial linkages across the countries (IMF, 2001, 121, 128). Since new IT firms tend to be younger, smaller, and riskier, the IT sector relies more on equity financing[9] (ibid., 131). This characteristic has been observed in variety of economies, developed or developing countries. In Taiwan, for example, 44% of the total manufacturing capital in 2000 was invested by the IT industry, and almost 38% of the IT investment was financed through the stock market (Cheng, 2002).

Greater reliance on equity finance, and so the stock markets across the countries, makes the IT sector and the Korean and Taiwanese economies vulnerable to the international stock price movements (Hsiao and Hsiao, 2003b). How does the international linkage of stock markets influence the domestic macroeconomic fluctuations? If the IT stocks are held only by small number of people, and have little weight in the national income, then international financial linkages should not have much effects on domestic consumption or business cycles. However, this is not the case in Korea and Taiwan. Many years of boom in the IT industry before the recent slump boosted the local stock market prices, stimulated stock ownership in these countries. This may be seen from the stock market capitalization relative to GDP. The ADCs+ have capitalization ratio close to or above 50% of GDP in 2000, and Korea ranked 19th, Taiwan 12th, Japan 2nd, USA, 1st, in the world, indicating the predominance of equity assets in the society.[10] In contrast, except Malaysia (which had 128% of GDP and ranked 11th), the ASEAN countries have lower capitalization ratios, ranging from 20% to 60% in 2000, but still high in the world ranking, from the 22nd to the 25th (Hsiao and Hsiao, 2003b). This implies that a sharp change in equity prices will change individual's wealth (the wealth effects), and since wealth is a key factor

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[9] IMF (2001, 131). If a new IT project is promising, "before the dot.com bubble, it usually take five to seven years for start-up firms to go to the IPO market. During the do.com boom, this period was shortened, especially for e-commerce business" (Aoki and Takizawa, 2002). The initial public offering (IPO) in the stock market will launch a new era for the IT firms.

determining consumption, household consumption also changes (Edison and Slok, 2001; Bertaut, 2002), so does the growth of an economy. Thus, the IT revolution has strengthened international dependence and financial linkages (Hsiao and Hsiao, 2003b).

IV. A Simple Macroeconometric Model and Sources of Data

While the classical economists used to think money as veil, the arrival of the New Economy has witnessed the increasing influence of financial markets on the economy. To examine the relation between GDP and other variables, we adopt the Mundell-Fleming-Dornbusch macroeconomic model, which is modified to include the influence of stock prices as follows[11]:

$$Q = C(s, i) + I(i) + N(s, i) + F(E, T),$$
$$M = L(Q, i)$$

where Q is GDP, C is consumption which depends of stock prices s (the wealth effect) and interest rate i (the saving effect), I is the conventional investment as a function of interest rate i, and N is the IT investment as a function of stock price and the interest rate. F is net exports function which is a function of the exchange rate E and the openness T, which is defined as the ratio of the trade amount (imports and exports) over GDP. M is money supply, which is constant, and L is money demand, which depends on GDP, Q, and interest rate i. Since we are interested in the short-run relationship between the economic variables, the non-price variables are measured in the nominal term. As usual, the partial derivatives have the following sign:

$$C_s > 0,\ C_i < 0,\ I_i < 0,\ N_s > 0,\ N_i > 0,\ L_Q > 0,\ L_i < 0$$

Thus, we may solve for the equilibrium variables Q and i as,

$$Q = Q(s, E, M, T)$$
$$i = i(s, E, M, T)$$

or more generally, writing in implicit form,

$$F(Q, i; s, E, M, T) = 0$$
$$G(Q, i; s, E, M, T) = 0$$

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[10] The world ranking is taken from Kurian (2001), which is also based on EIU data but does not mark the year the statistics are taken.
[11] We used this model extensively in Hsiao and Hsiao (1994, 1995).

According to our recent experience, the economy does not seem to be sensitive to the change in the interest rate. Thus, for the first approximation, we ignore the interest rate variable in our inquiry on the relationship among the five variables, especially the direction of influence between GDP and the stock price.

The sources of the data for the five variables in the model are as follows. Korea's quarterly data are obtained from the International Financial Statistics (IFS) published by the International Monetary Fund. The quarterly data from 1990Q1 to 2002Q3 (51 observations) are obtained from January 2003 IFS CDR-Data base. We add 2002Q3 data from the book of IFS, March 2003. The exchange rate was in Won/US$, period average; Money (narrow money, M1) was in billions of Won, at the end of period; Quasi-money, in billions of Won, at the end of period; Share Prices consist of stock price indexes, 1995 = 100, period averages; Exports of goods and services, in billions of Won; Imports of goods and services in billions of Won; and gross domestic product (GDP) in billions of Won.

Taiwan's similar data are obtained from the AREMOS Economic Statistical Database of the Taiwan Economic Data Center. The units are in New Taiwan Dollars.

In econometric analysis, we use the broader measure of money supply (M2) which is the sum of M1 and quasi-money. Openness of the economy is measured by the percentage of the sum of exports and imports to GDP. M2 and GDP are converted into billions of US$. The descriptive statistics of the five time series are shown in the upper part of Table 4. The natural log-values of exchange rate (LEXRT), gross domestic product (LGDP), broad money supply (LM2), openness (LOPEN), and stock price indexes (LSTOCK) are used as the five level series in the empirical studies.

Place Table 4 here

V. Causality Tests for Korea

a. The Unit-root Test on Variables

Before estimating the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) for each of the five variables, we have used the Augmented Dickey-Fuller (ADF) unit-root test to examine the stationarity of each series (Greene, 2003). Part 1 of Table 5 shows that the first four level series all contain unit-roots and they are nonstationary at the 10% level of significance, except that the LSTCOK series has no unit-root and it is stationary at the 10% level. We then proceed to do the ADF unit-root test on the first-difference series (i. e., DLEXRT, DLGDP, etc., the growth rate series). The results are presented in Part 2 of Table 5. The test results show that all five first-difference series are stationary at the 1% or 5% level of significance. Therefore, we can use the first-difference series in the estimation of the GARCH for each variable.

Place Table 5 here

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b. GARCH Estimation and Volatility Measures

We use the standard GARCH (1, 1) model in the estimation of the conditional variance (σ_t^2). The model can be written as:

$$y_t = c + \varepsilon_t$$
$$\sigma_t^2 = \alpha + \beta\varepsilon_{t-1}^2 + \gamma\,\sigma_{t-1}^2 .$$

where y_t = DLEXRT or other first-difference series, respectively, c is the constant term, and ε_t is the error term in the mean equation. The second equation is the conditional variance equation, which specifies that the conditional variance at time t (σ_t^2) is a function of the mean (α), the last period's squared residual from the mean equation (ε_{t-1}^2 is the "news" about volatility, the ARCH term), and the last period's forecast variance (σ_{t-1}^2, the GARCH term). The positive square roots of the time-varying conditional variances estimated from the GARCH (1, 1) process, that is the standard deviation (σ_t), are used as the measures of the volatility for each variable. The five volatility series are denoted as EXRTSD, GDPSD, M2SD, OPENSD, and STOCKSD. Their descriptive statistics are shown in the second part of Table 4.

The ADF unit-root test is used to examine the stationarity of the five volatility series. The test results of the level series are presented in Part 1 of Table 6. We find that EXRTSD, M2SD, and OPENSD are stationary series, but GDPSD and STOCKSD are nonstationary. Therefore, we continue to perform the unit-root test on the first-difference series, DEXRTSD, DGDPSD, etc., and the test results are presented in Part 2 of Table 6. We find that all first-difference series of volatilities are stationary at the 1% or 5% level of significance.

Place Table 6 here

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c. Causality Test by VAR

Since GDPSD and STOCKSD are nonstationary series among the five volatility series, we have at first tried to assume that all level series of volatilities are nonstationary and applied Johansen cointegration test, and found that they are cointegrated. The Vector Error Correction Model (VECM) is then applied to estimate the causality relationships among the five volatility series. However, the coefficients for the lagged error-correction terms were not negative and significant, so the cointegrated assumption did not hold. Thus, we changed the venue and applied the unrestricted Vector Autoregressive Model (VAR) using the five stationary first-difference series of volatilities (for model, see Hsiao and Hsiao, 2003b). We also introduced an exogenous dummy variable to the VAR system to take into account of the effect from Asian financial crisis, which started in July 1997. The dummy variable takes the value of zero in the second quarter of 1997 and before, and it takes the value of one from the third quarter of 1997 and after. The estimated results from the VAR with dummy variable are presented in Table 7.

Place Table 7 here

Table 7 shows that the last period's stock price index volatility has strong and significant effects (at the1% or 5% level) on the current volatilities of the exchange rate, GDP, and money supply. It also has a weak and significant effect (at the 10% level) on the current openness volatility. On the other hand, from equation 5, none of the last period's volatilities has a significant effect on the current stock price index volatility. These results imply that there is a unidirectional causality from the stock price index volatility to the volatilities of exchange rate, GDP, money supply, and openness. In addition, we have also found that last period's GDP volatility has very strong and significant effects (at the 1% level) on the current volatilities of the exchange rate, the money supply, and openness, but it has no significant effect on the stock price index volatility. We also found that the dummy variable is not significant in all equations, except that there is a weak significant effect (at the 10% level) on the GDP volatility (equation 2 in Table 7).

d. Pairwise Granger Causality Test

To examine the causality relationship between a pair of volatilities, such as the stock price index volatility and the GDP volatility (without the interaction from other three volatilities), we apply the pairwise Granger causality test to the five stationary first-difference series of volatilities (for model, see Hsiao and Hsiao, 2003b). The test results are presented in Table 8. We have found the following interesting Granger causality relationships:

Place Table 8 here

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1. For the four pairs that involve the stock price index volatility, all show unidirectional causality from stock price index volatility to the volatilities of exchange rate, GDP, money supply, and openness [Table 8, pair 4 (significant at the 5% level), and pairs 7, 9, and 10 (all are significant at the 1% level)].
2. Five out of six pairs that do not involve the stock price index volatility, GDP volatility and exchange rate volatility (pair 1), money supply volatility and exchange rate volatility (pair 2), openness volatility and exchange rate volatility (pair 3), money supply volatility and GDP volatility (pair 5), and openness volatility and money supply volatility (pair 8) all have bidirectional causality relationships. Only openness volatility and GDP volatility (pair 6) has unidirectional causality from GDP volatility to openness volatility.

VI. Causality Tests for Taiwan

To be completed. The method of analysis is similar to the Section V.

VII. Some Concluding Remarks

In this paper, we have shown that Korea and Taiwan, the two newly developed countries, are powerhouses of IT revolution, either viewed it from world or domestic production and trade or seen it from world or domestic consumption and services. The New Economy strengthened financial linkages across the countries in Asia-Pacific region, and their close tie with the international stock markets, especially those of US and Japan, becomes an important route of the transmitting international business cycle to Korea and Taiwan, affecting their macroeconomic stability.

From this vantage point of view, this paper sets up a simple macroeconomic model and examine the causal relations between the volatility of five variables: GDP, the stock price index, money supply, the exchange rate, and openness of the economy. The results of our causality test for Korea are very illuminating. We were able to identify that there is a very strong unidirectional causality from the stock price index volatility to the volatilities of GDP, the exchange rate, money supply, and openness, but not vice versa. When GDP volatility is lagged one period, then there is a very strong and significant effect on the current volatilities of all other variables except the stock price index volatility.

The first unidirectional causality implies that the important macroeconomic policy of achieving economic stability is, at least in the short run, to reduce the volatility of the stock market prices, not the other way round. For the first time, this paper presents analytically the importance of the stock price volatility in driving business cycle in the newly developed countries. Since, in our model, the stock price affects output through consumption (the wealth effect) and IT investment, our paper points to the need of a closer examination of the relationship between stock prices and consumption and investment. In this sense, we have brought finance into macroeconomic analysis.

Furthermore, the last year's GDP volatility will affect the current year's volatilities of the exchange rate, money supply, and openness, but not that of the stock price index. This last result is in line with our previous findings in testing causality of the impact of foreign economies (Hsiao and Hsiao, 2003). The causality test of the stock indices among the countries shows that other things being equal, there is a very strong unidirectional causality from the United States to Korea and Taiwan, but not vice versa. Thus, the stock prices in Taiwan and Korea are most likely exogenously determined by the foreign stock markets in this age of internet.

(Whether this conclusion also holds for Taiwan we don't know yet. We will use the same method to examine the Taiwanese case and will report the results at the conference.)

In the literature, Aghion, Banerjee and Pikkety (1999) and Acemoglu and Zilibotti (1997), Darrat and Haj (2002), Easterly, Islam, and Stiglitz (2000), and Levine and Zervos (1998) find that the financial development reduces macroeconomic volatility. These findings are also consistent with our results. We plan to discuss these in details in the future.

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Figure 1a. Value-added share in Mnufacturing Korea

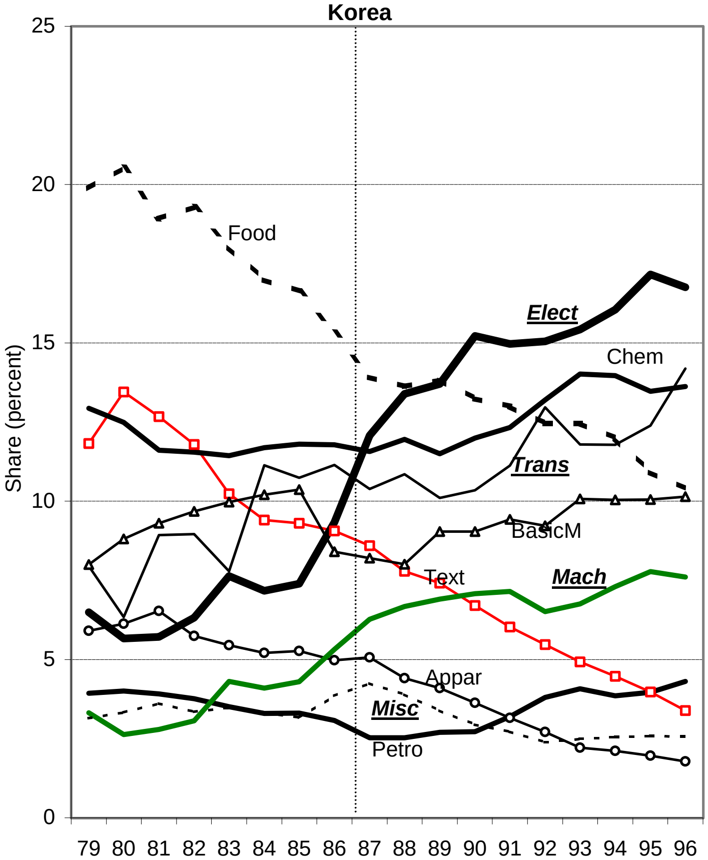

Figure 1b. Value-added share in Manufacturing Taiwan

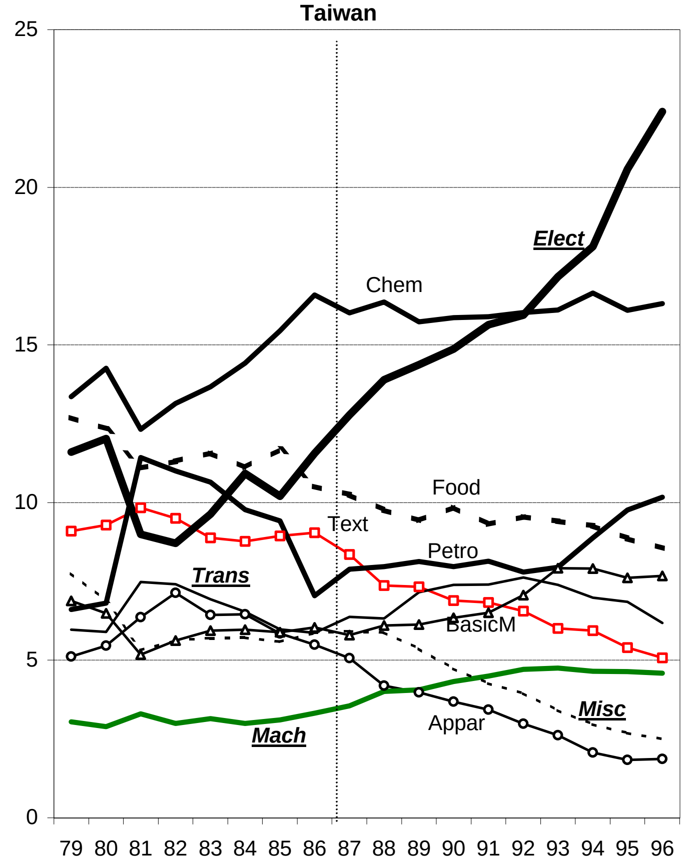

Figure 2. Mfg Productivity Change of Three Industrial Categories Traditional, Basic, and High tech Industries

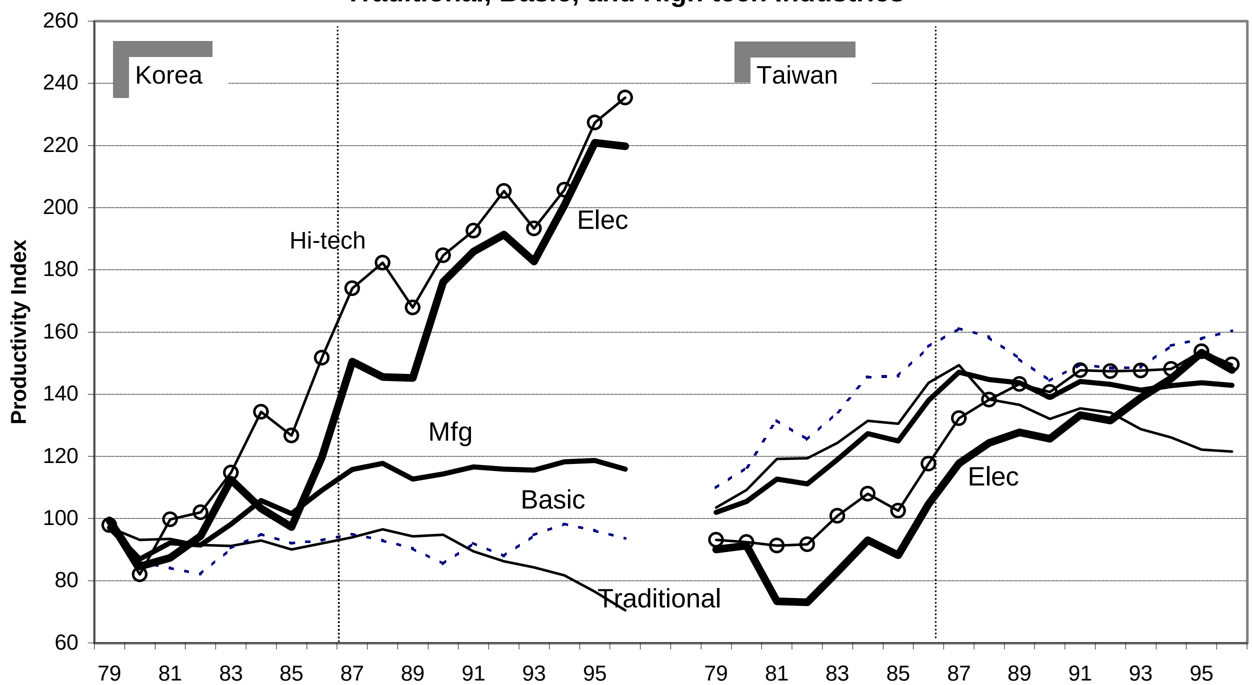

Table 1: Digital Divide- Supply Side

	Pop % of World 2002	% share of World Electronics Prod 1990	1995	1998	Imports IT Pdct (1999)	Imports World (1999)	Exports IT Pdct (1999)	Exports World (1999)
	ADC+							
Korea	**0.78**	**3.3**	**4.7**	**3.6**	**22.8**	**2.1**	**23.7**	**2.5**
Taiwan	**0.37**	**2.1**	**2.8**	**3.1**	**23.2**	**1.9**	**46.5**	**2.2**
Singapore	0.07	2.1	3.8	3.5	41.9	1.9	53.7	2.0
Japan	2.09	26.4	25.7	18.0	14.9	5.4	23.1	7.4
HK	0.11	1.2	0.9	0.8	24.5	3.1	2.3	3.1
Sum	*3.41*	*35.1*	*38.0*	*29.0*		14.4		17.2
USA	4.72				17.2	18.3	17.2	12.4
	ASEAN5+							
Indonesia	3.47	0.2	0.5	0.5	11.5	0.4	5.4	0.9
Malaysia	0.40	1.1	2.7	2.5	43.2	1.1	47.5	1.5
Philippines	1.31	0.3	0.4	0.7	45.2	0.6	61.1	0.6
Thailand	1.01	0.6	1.2	1.3	24.3	0.9	27.7	1.0
Vietnam					5.9	0.2	2.9	0.2
China	21.04	1.7	2.7	4.3	20.2	2.9	15.6	3.5
Sum	*27.23*	*3.8*	*7.5*	*9.3*		6.0		7.7
	South Asia and others							
India	17.06	0.7	0.6	0.6	4.5	0.8	1.5	0.6
Sri Lanka	0.31				3.7	0.1	3.1	0.1
World	100.0	100.0	100.0	100.0		100.0		100.0
Value	6106	699	1039	1088	15	5803	14.7	5654
(unit)	(million)	(US$ billion)			%	(US$b)	%	(US$b)

Sources: Population data are from International Telecommunication Union (ITU), 2003, IT trade data are from Cornelius, et al. (2002), commodity trade data are from WDI-CD (2002), World electronics production data are from Wong (2002)

Table 2. Imports and Exports of ICT Products (1999)

	World share (%)								Trad performance Index							
	Imports				Exports				Position ranking				Change rkg (95-99)			
	OffMa Eqpt	ElEqpt &Cmp	ElMa Eqpt	Tele Eqpt	OfMa Eqpt	ElEqpt &Cmp	ElMa Eqpt	Tele Eqpt	Of Eq	Ele EqC	EIM Eq	Tel Eq	Off Eq	Ele EqC	EIM Eq	Tel Eq
ADC+																
Korea	**2.6**	**7.3**	**1.3**	**1.4**	**1.6**	**9.3**	**3.4**	**4.2**	**6**	**6**	**22**	**20**	**9**	**34**	**15**	**37**
Taiwan	**2.5**	**5.6**	**2.0**	**1.7**	**4.6**	**7.6**	**9.3**	**2.6**	**4**	**4**	**9**	**8**	**32**	**7**	**44**	**49**
Singapore	4.0	9.9	4.4	1.8	3.4	10.9	9.8	2.1	2	1	16	12	31	14	41	44
Japan	4.1	6.1	6.1	3.7	15.0	14.5	9.1	7.3	3	2	2	6	39	29	49	48
HK	5.3	6.1	4.2	5.4	0.5	1.0	0.2	0.1	37	18	40	45	47	42	52	50
Sum	18.6	35.0	18.0	14.0	25.1	43.4	31.9	16.2								
US	17.3	17.6	25.9	20.7	13.4	18.4	13.1	13.8	13	10	18	11	38	20	45	46
ASEAN5+																
Indonesia	0.7	0.0	0.1	0.9	0.4	0.2	0.4	0.1	32	26	41	37	45	2	7	20
Malaysia	2.6	8.4	1.1	0.4	2.1	8.1	5.6	2.0	5	8	32	10	2	11	28	3
Philippines	1.0	4.7	0.6	0.5	0.8	5.7	2.8	0.5	16	5	42	25	3	3	4	13
Thailand	1.9	2.3	0.8	0.6	1.7	1.8	2.6	0.7	17	14	26	24	28	1	20	28
Vietnam	0.2	0.0	0.0	0.1	0.1		0.0	0.0	44	48	52	46	25	48	38	16
China	5.1	4.8	2.2	4.4	5.2	1.6	4.2	2.9	9	19	23	30	36	8	3	5
Sum	11.5	20.2	4.9	6.9	10.5	17.3	15.6	6.2								
South Asia and Others																
India	0.4	0.1	0.2	0.2	0.1	0.0	0.1	0.0	40	35	45	33	49	28		29
Sli Lanka	0.1	0.0	0.0	0.1	0.0	0.0	0.0		48	46	51		26	15	1	
World (US$ b)	219	216	328	105	209	201	309	111								

Sources: Compiled from Cornelius, et al. (2002).

Table 3. Digital Divide- Demand Side

	Pop Density per km2 (2002)	Percapita GDP US$ (2001)	ICT Exp. share of GDP % (1995)	% 1999)	Per 1,000 persons Telephone mainlines (1999)	Cellular phones (1999)	Personal computers (1999)	Internet users (2000)
	ADC+							
Korea	**484**	**9023**	**5.1**	**4.4**	**441**	**504**	**189**	**323**
Taiwan	**624**	**12553**	**3.5**	**4.8**	**545**	**522**	**181**	**288**
Singapore	6099	20752	6.7	7.7	482	419	527	419
Japan	337	32554	5.4	7.1	494	449	290	214
HK	6378	24383	6.1	8.3	578	636	291	260
Average	2784	19853			508	506	295	301
USA	31	35843	8.9	7.9	682	312	511	537
	ASEAN5+							
Indonesia	111	695			29	11	9	2
Malaysia	73	3700			203	137	69	69
Philippines	267	913			40	37	17	6
Thailand	120	1874			86	38	23	17
Vietnam	247	406			27	4	9	1
China	134	907			86	34	120	13
Average	159	1416			78	44	41	18
	South Asia and others							
Bangladesl	925	346			3	1	1	0
India	329	459			27	2	3	5
Nepal	164	241			11	a	3	1
Pakistan	185	387			22	2	4	9
Sri Lanka	289	836			36	12	6	3
Average	378	454			20	4	3	4

Sources: International Telecommunication Union (ITU), 2000, 2003and Nua Internet Survey 2000. Adopted from Quibria, at el. (2003)

Table 4. Some Discriptive Statistics of the Data

	Original data (a)				
	EXRT	GDP	M2	OPEN	STOCK
Unit	Won/US$	US $ billion	US $ billion	%	Indes
Mean	965.7	98.9	202.0	68.8	78.4
Median	808.9	101.0	182.5	63.3	78.5
Maximum	1605.7	140.6	418.7	100.1	115.0
Minimum	690.4	54.6	84.7	51.6	34.5
Std.Dev.	243.6	22.0	94.1	12.6	18.1

	Volatilities (b)				
	EXRTSD	GDPSD	M2SD	OPENSD	STOCKSD
Mean	0.053	0.105	0.067	0.077	0.143
Median	0.042	0.105	0.057	0.069	0.130
Maximum	0.274	0.150	0.231	0.219	0.209
Minimum	0.030	0.069	0.054	0.057	0.116
Std. Dev.	0.040	0.023	0.031	0.025	0.027

Sources: (a) See the text. (b) Authors' calculation

Table 5. ADF Unit-root Test: Korean Five Variables

Variable	k	Test statistic	Critical value
Part 1: Level series			
LEXRT [c, t]	1	-2.748	-3.180
LGDP [c]	1	-2.357	-2.598
LM2 [c, t]	1	-2.884	-3.180
LOPEN [c, t]	2	-2.439	-3.182
LSTOCK [c]	1	-2.883 *	-2.598
Part 2: First-difference series			
DLEXRT [c]	1	-5.209 ***	-3.571
DLGDP [c]	4	-3.190 **	-2.927
DLM2 [c]	1	-5.454 ***	-3.571
DLOPEN [c]	3	-2.935 **	-2.926
DLSTOCK [c]	1	-4.203 ***	-3.571

Note:
1. *** (** or *) denotes significance at the 1% (5% or 10%) level, respectively. 2. In Part 1, the critical values are all at the 10% level ofsignificance. In Part 2, the critical values are at the 5% level for DLGDPand DLOPEN, and the other critical values are at the 1% level. 3. [c, t]denotes that the testing equation has included constant term [c] andsignificant time trend [t]. 4. The optimal lag length k is chosen at theminimum AIC from lag = 1 to lag = 8.

Table 6. ADF Unit-root Test: Korean Five Volatilities

Volatility	k	Test statistic	Critical value
Part 1: Level series			
EXRTSD [c]	1	-4.427 ***	-3.571
GDPSD [c]	1	-1.846	-2.599
M2SD [c]	1	-3.650 ***	-3.571
OPENSD [c]	1	-4.400 ***	-3.571
STOCKSD [c]	2	-1.500	-2.600
Part 2: First-difference series			
DEXRTSD [c]	1	-7.526 ***	-3.575
DGDPSD [c]	1	-5.376 ***	-3.575
DM2SD [c]	1	-6.118 ***	-3.575
DOPENSD [c]	2	-6.955 ***	-3.578
DSTOCKSD [c]	1	-3.780 ***	-3.575

Notes:
1. *** (** or *) denotes significance at the 1% (5% or 10%) level, respectively. 2. The critical values are at the 10% level for GDPSD and STOCKSD, and the other critical values are at the 1% level of significance. 3. [c] denotes that the testing equation has included constant term. 4. The optimal lag length k is chosen at the minimum AIC from lag = 1 to lag = 8.

Table 7. Granger-Causality for Volatilities with Dummy Variable

	Dependent Variables									
Equation	1		2		3		4		5	
	DEXRTSD		DGDPSD		DM2SD		DOPENSD		DSTOCKSD	
Independent Variables, Lag = 1										
Constant	-0.005		0.002		-0.002		-0.002		0.0004	
	(0.89)		(1.43)		(0.69)		(0.70)		(0.22)	
DEXRTSD(-1)	-0.091		-0.006		0.013		-0.278		0.098	
	(0.36)		(0.10)		(0.08)		(1.70)	*	(1.02)	
DGDPSD(-1)	2.952		-0.217		1.583		2.045		-0.151	
	(5.98)	***	(1.83)	*	(4.78)	***	(6.36)	***	(0.81)	
DM2SD(-1)	0.041		-0.284		0.240		1.320		-0.268	
	(0.09)		(2.68)	**	(0.81)		(4.59)	***	(1.60)	
DOPENSD(-1)	0.176		-0.001		0.106		-0.463		0.102	
	(0.90)		(0.03)		(0.80)		(3.61)	***	(1.36)	
DSTOCKSD(-1)	0.944		-0.637		0.686		0.483		-0.022	
	(2.20)	**	(6.18)	***	(2.38)	**	(1.73)	*	(0.13)	
Dummy	0.011		-0.003		0.005		0.006		0.0008	
	(1.35)		(1.72)	*	(0.88)		(1.07)		(0.24)	
Adj. R-squared	0.604		0.711		0.482		0.731		0.022	

Notes:
1. The values in parentheses are the absolute values of the t-statistics.
2. *** (** or *) denotes significance at the 1% (5% or 10%) level, respectively.
3. At DF=40, critical t-value is 2.704, 2.021, or 1.684 for the 1%, 5%, or 10% level of significance, respectively.

Table 8. Pairwise Granger Causality Tests of Volatilities, Lag = 1

Pair		Test Result		F-Statistic	p-value	Causality Direction
1	DGDPSD	⟶	DEXRTSD	62.853	4.4E-10 ***	
		⟵		22.906	1.9E-05 ***	Bidirectional
2	DM2SD	⟶	DEXRTSD	9.016	0.004 ***	
		⟵		5.247	0.027 **	Bidirectional
3	DOPENSD	⟶	DEXRTSD	10.379	0.002 ***	
		⟵		22.819	1.9E-05 ***	Bidirectional
4	DSTOCKSD	⟶	DEXRTSD	5.709	0.021 **	Unidirectional
		↚		0.350	0.557	
5	DM2SD	⟶	DGDPSD	34.238	5.2E-07 ***	
		⟵		39.595	1.1E-07 ***	Bidirectional
6	DOPENSD	↛	DGDPSD	1.918	0.173	
		⟵		15.165	0.0003 ***	Unidirectional
7	DSTOCKSD	⟶	DGDPSD	37.495	2.0E-07 ***	Unidirectional
		↚		1.051	0.311	
8	DOPENSD	⟶	DM2SD	3.755	0.059 *	
		⟵		21.152	3.4E-05 ***	Bidirectional
9	DSTOCKSD	⟶	DM2SD	8.242	0.006 ***	Unidirectional
		↚		0.030	0.864	
10	DSTOCKSD	⟶	DOPENSD	8.543	0.005 ***	Unidirectional
		↚		2.610	0.113	

Note: *** (** or *) denotes significance at the 1% (5% or 10%) level.