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FOREWORD

Since its formation at the 1994 APEC Ministerial meeting in Jakarta, the Economic Committee has pursued a work program aimed at fulfilling the three major objectives established for it: namely to serve as a forum for discussion of economic trends and issues in the region; to support the Ministerial and Leaders' meetings and other APEC fora; and to disseminate information on economic issues and linkages in the region. As an important part of meeting these objectives, the Committee has involved, to the extent possible, outside experts in its discussions through regularly organized symposia, workshops and public-private sector dialogues.

Last year, the Committee benefited in its annual review of the economic outlook for the APEC region from the discussion of the relevant issues at a first-ever Economic Outlook Symposium that was held in Seoul, Korea, in September 1997. Building on this event, the 1998 APEC Economic Outlook Symposium was held in Xiamen, China, May 16-17, 1998 under the auspices of the APEC Economic Committee and the State Development Planning Commission of the People's Republic of China. In all, 84 delegates and expert speakers participated, representing 13 of the APEC member economies as well as a number of institutions, including the Asian Development Bank, Japan Center for Economic Research, Export-Import Bank of Japan, the University of Connecticut, the Stockholm School of Economics, Tsinghua University, SRI International, the Research Institute on Structural Economic Reform and the Stock Exchange Executive Council, Beijing.

The discussions at the Symposium highlighted the differences between the Asian financial and economic crisis and previous crises, including its structural nature and its origins in private sector rather than public sector imbalances. The Symposium also considered the implications for future economic research of the unexpected onset of the Asian financial and economic crisis: not only was the crisis not predicted by economic forecasters, the eventual depth and breadth of the impacts were not apparent even several months after its onset. Meanwhile, the discussion on the role of science and technology in economic growth focused on the importance of building innovative capabilities through increased R&D activities, learning by doing, and technical cooperation. Various mechanisms and case examples in member economies were reviewed and discussed; as well, experts highlighted the evolving thinking on intellectual property rights.

The present volume documents the discussions at that Symposium and compiles the papers that were developed as contributions to it. Consistent with its mandate to disseminate information on economic developments in the region, the Committee hopes, through publication of this material, to deepen the understanding of recent economic trends and issues in the region.

Particular thanks are due to the Xiamen City government for its gracious hospitality in hosting the Symposium and the staff of the State Development Planning Commission for the effective organization of, and support, during the event. Thanks are also due to Dan Ciuriak for final editing of the text and to Ms. Julie Gould, Director (Program) at the APEC Secretariat who has taken particular responsibility for seeing this volume of proceedings through to publication.

John M. Curtis

Chair
APEC Economic Committee
Ottawa, November 1998

INTRODUCTION AND OVERVIEW

The second APEC Economic Outlook Symposium took place May 16-17, 1998 in Xiamen City, Fujian Province, China, under the auspices of the APEC Economic Committee and the State Development Planning Commission of the People's Republic of China. In all, 84 delegates and expert speakers from 13 of the APEC member economies as well as from a number of international organizations participated. This volume provides a summary of the discussions that took place at Xiamen and makes available to a wider audience the papers and contributions made by expert speakers who gathered there.

1. The Context

In his opening statement to the Symposium, **Dr. John M. Curtis, the Chair of the APEC Economic Committee**, noted that the Asia Pacific region has experienced an economic convulsion that has had few precedents in recent history and many potentially far-reaching implications for the international economy. Its significance is not simply due to the depth of the impact on growth but also to several singular characteristics – the surprise with which it struck, its source in private sector rather than public sector finances, the virulence and rapidity of transmission of contagion through the region, and the extent to which it has challenged the capacity of the international community to respond. Like previous major events such as the collapse of the Soviet Union and with it the concept of planned economies, and the depression of the 1930s which spawned a range of policy innovations such as the social safety net and deposit insurance, the East Asian crisis has prompted a new look at fundamental features of economic systems, in this instance at the international architecture for capital flows, highlighted the need to deepen international surveillance to meet the needs of a global age, and focussed attention on institutional governance issues that have been implicated in the crisis.

However, there have also been other noteworthy developments in the region in 1998 that challenge the received economic wisdom or that at least cause us to dust off old texts. These include the lowest inflation in the US in decades in the context of a decline in unemployment below any prevailing estimate of the non-accelerating inflation rate of unemployment (NAIRU); the remarkable disinflation in China that has brought the rate of price increase to a standstill in 1998 from more than 20 percent only three years earlier; and, of course, the equally remarkable conjuncture in Japan with historically low interest rates and the economy mired in an apparent liquidity trap.

In his keynote address, **Mr. Chunzheng Wang, Executive Vice Minister of China's State Development Planning Commission**, reflected on the political-economic challenges that the crisis had posed for the Asia Pacific region, for APEC as its pre-eminent organization for economic cooperation, and in particular for China which found itself still largely preserved from contagion and thus a critical anchor of economic growth and stability for the region. The Vice Minister reiterated China's resolve to meet this challenge with appropriate macroeconomic and financial policies,

including by accelerating infrastructure investment to counter the slowing trend in China's GDP and to offset the emerging downward pressure of the crisis on China's exports; and by preserving the stability of the currency. He also emphasized the importance of maintaining the commitment to policies addressing the longer-term fundamentals of growth, which include technological modernization (the key structural theme addressed in the Symposium), and commented in this connection on the important role that APEC could play by intensifying economic and technical cooperation.

The main Symposium discussions which followed these remarks included sessions on:

- *The Impacts of the Financial Crisis and Measures to Restore Economic Growth*, chaired by Mr. He Liu, Vice Chairman of China's State Information Center;
- *Knowledge, Technology and Economic Growth*, chaired by Ambassador Timothy Hannah, Deputy Executive Director at the APEC Secretariat; and
- *The Financial Crisis and Implications for Economic Research*, also chaired by Mr. He Liu.

2. The Impacts of the Financial Crisis and Measures to Restore Economic Growth

The principle focus of discussion of the economic conjuncture in the region was, of course, the financial crisis, the deepest impacts of which up to that point had been felt in the developing economies of Southeast Asia and in Korea. In addition, however, presentations were made on the three largest economies in the region, the USA, Japan and China, each of which also presented an unusual constellation of economic trends which played a dominant role in shaping overall regional performance.

The discussion was led off by **Dr. Pradumna Rana, Senior Economist at the Asian Development Bank (ADB)**, who reviewed the situation in the developing economies of East Asia. In "*The Financial Crisis in East Asia and Its Economic and Social Impacts*", Rana notes that the ADB's most recent update on the economic outlook saw "light at the end of the tunnel" for all the affected economies except Indonesia, where unfolding events made the outcome as yet incalculable. For the developing economies in the region, 1998 was emerging as a "lost year", 1999 would see only slow recovery and the earliest time at which a return to high growth was now possible was 2000 and beyond. And this was contingent upon no further shocks, such as devaluation by China, which had become a subject of speculation in the financial press. Meanwhile, the social consequences of the real-side disruptions and soaring unemployment rates, and the sorting out of the financial mess left by the spate of bank failures and corporate bankruptcies, would persist even longer. The crisis was thus now clearly becoming a medium-term event.

Rana also draws out some of the unusual aspects of the crisis, in particular the fact that it has not been associated with the weak fundamentals and public sector fiscal imbalances that had typified previous crises but rather seemed to be rooted in private sector financial decisions. In retrospect, there had been policy mistakes (in particular the opening up of capital markets while maintaining fixed or semi-fixed exchange

rates), which had created macroeconomic and financial vulnerability to shifts in international capital markets.

Looking to the longer term, Rana notes that the ADB remains "bullish" on Asia since the basic building blocks of growth in East Asia (commitment to human resources development, high savings rates, and openness to trade and investment) remained intact; accordingly the ADB sees no reason why a return to pre-crisis growth rates would not be possible.

Outside of Southeast Asia, the economy most affected by the crisis has been Korea. **Dr. Sang-Kyom Kim of the Korean Institute for International Economic Policy (KIEP)** reviewed the events in that economy and the steps now being taken to stabilize the situation. Kim emphasized just how deep a shock and surprise the crisis was to Korea, which only the previous year had capped 3½ decades of sustained high growth with entry into the OECD and now suddenly found itself on the brink of national default and financial sector collapse. Korea was now struggling to come to terms with the realization that the years of strong growth had masked neglected structural reforms and a number of "excesses" that were now seen in retrospect as having precipitated the crisis. While he felt that the "worst was over", and that tough reforms were being implemented (including the sanctioning of hostile takeovers, restructuring of Korean *chaebol* and involuntary "voluntary" wage cuts), the road ahead would not be at all easy. In contrast to Mexico, which had experienced an isolated crisis and thus had a broadly favourable international environment during its recovery, Korea was facing the prospect of carrying out its reforms in the context of a regional crisis that was causing a contraction of import demand and falling asset prices throughout the region.

Turning to the situation in the region's major economies, **Mark Hopkins of the USA's Council of Economic Advisers** brought the Symposium up to date on the extraordinary performance of the US economy in what was now the seventh year of its expansion. Hopkins noted that, notwithstanding the advanced stage of the economic cycle in the USA, no typical "end of expansion" signs are visible: productivity continues to rise, inflation is falling even with the unemployment rate below NAIRU, and interest rates are low with the Federal Reserve watchful but not moving to raise rates. In the latter regard, the one positive element that one might extract from the Asian crisis has been its contribution to low inflation through falling import and commodity prices (although as Hopkins pointed out, even taking into account the effects of low energy and import prices and the incomplete reflection in the CPI of technology improvements, inflation in the US was still stable). To some extent, accordingly, the crisis has contributed to forestalling an increase in US interest rates, thus allowing the US economy to continue to act as a stabilizing force by absorbing imports from the region. Hopkins noted that the interest rate effect more or less offset the negative impacts on US growth from the decline in US exports to the region, leaving the overall rate of growth of the US economy to date broadly unaffected by the crisis. That being said, the composition of growth has been shifting with domestic demand accounting for an increasing portion the growth and the current account deficit rising towards 3 percent of GDP.

The US situation was in sharp contrast to that in region's second largest economy, as described in "The Japanese Economy: Recent Developments and Short-term Prospects" by **Jun Saito, Senior Economist at the Japan Center for Economic Research (JCER).** Saito noted that Japan has been effectively in recession since the second quarter of 1997 when GDP fell sharply due in large part to the April 1 consumption tax increase. JCER forecasts suggest that a genuine recovery is not in sight until into 1999, notwithstanding a significant contribution to growth from the fiscal stimulus package (+1.8 percent and +1.5 percent in FY98 and FY99 respectively) which is preventing economic free-fall. The problems for Japan are numerous. The economy continues to feel the drag on growth coming from declining exports to Asia and the working out of problems in the financial sector as Japanese financial institutions work to restore capital positions undermined by the evaporation of previously booked but unrealized capital gains. These effects are not unrelated since there is a further link between slumping output in Southeast Asia and impacts on Japanese banks with exposure to the region. Moreover there are effectively no multiplier effects from the fiscal stimulus package as consumers pocket extra income as precautionary savings and business investment remains flat. As Saito noted, the only real answer is structural reform, but that takes time. Meanwhile, the yen has been acting as a barometer for these troubles and weakening. Here too there was a tangle of issues: exchange rate equations, as Saito pointed out, suggest much stronger equilibrium values for the yen than its trading range in 1998 so the market pressures were moving it away from, rather than towards equilibrium, and in so doing were generating pressures on related exchange rates.

The situation in China, the region's third largest economy was yet again a study in contrasts. As described by **Ren Ruoen of the Stock Exchange Executive Council, Beijing**, in "*Purchasing Power Parity, the Exchange Rate and China's International Competitiveness",* China's economy had so far weathered the Asian crisis in reasonably good fashion, with growth continuing albeit at a reduced rate. Nonetheless, the impacts were building as reflected in slowing export growth. The authorities remained optimistic about meeting the 1998 growth targets, counting on domestic stimulus measures. Ren agreed that the key issue as regards China was the stability of the yuan. He put the effective appreciation of the yuan at that point at about 10 to 15 percent and noted that this played into the question of whether Southeast Asia's difficulties stemmed in part from increased competition from China following its unification of exchange rates in 1994. Ren argued that, to the extent that the devaluations in Southeast Asia now created a competitiveness problem for China, the answer lay in the structural reforms that China is undertaking.

This session was wrapped up with a review of the impacts of the Asian crisis on trade flows in the region by **Ken-ichi Kawasaki of the Research Institute for International Investment and Development at the Export-Import Bank of Japan.** In his paper "*How Detrimental is the Asian Crisis: Assessment by Model Simulations*", Kawasaki uses a dynamic, multi-region Computable General Equilibrium (CGE) model with international capital mobility to calculate the effect of the Asian currency devaluation on the global economy as transmitted through trade linkages. He finds that, although the several most-affected Asian economies will experience very deep declines in the level of economic activity, the impact on economies outside the region would not be especially large. This reflects the effect of the Asian slump in dampening

price growth, which has an offsetting positive effect on GDP outside the region. Kawasaki also performs several alternative "policy response" simulations, considering in turn the global impacts of a devaluation by China, a Japanese fiscal stimulus, and APEC trade liberalization. His findings emphasize the importance of stability-oriented policies and commitment to open markets and point to the importance of restoring access to trade finance in the most affected economies in order to support trade flows.

3. Knowledge, Technology and Economic Growth

The session on Knowledge, Technology and Economic Growth considered the current state of thinking on the role of knowledge and technology in supporting economic growth and development and, in particular, the evolving concept of the knowledge-based economy.

The discussion was led off by **Richard N. Langlois of the Department of Economics and Department of Management at the University of Connecticut**. Langlois argues that, contrary to the view of knowledge articulated in neoclassical accounts (including the New Growth Theory), the knowledge essential to economic growth is not slippery and easily transmissible but is in fact often sticky and tacit. Moreover, those to whom knowledge is transmitted (or to whom it "spills over") cannot easily utilize that knowledge unless they possess the capabilities (including existing stocks of knowledge) to receive and "absorb" that knowledge. Moreover, social and business institutions are storehouses of useful knowledge that provide the "absorptive capacity" necessary for growth. The research agenda of economic growth, then, should focus less on the "optimal" production of R&D by unexamined units called firms and far more on the nature and role of institutions in generating – and receiving and using – productive knowledge. In short, an economy cannot simply accumulate inputs, even knowledge inputs as those are conceptualized in the New Growth Theory, without the proper set of background and business institutions to permit the assimilation of the knowledge others have spilled over onto them. Economies as well as firms need absorptive capacity.

Shi-Ji Gao and Gang Xu of the Institute of Economic Systems and Management, State Commission for Restructuring the Economic System, People's Republic of China, presented a paper on the following theme: " To Learn to Innovate: Learning in Technological Progress and a New Production Paradigm in Developing Economies". They suggest that, as latecomers, developing economies do enjoy the advantage of being able to learn from advanced economies; therefore the process of technological progress can be compressed. Like Langlois, they emphasize the primacy of learning and the implicit dimension of the learning process. In the information age, the prevalence of information and communication technology (ICT) has radically changed the learning environment, thus making it possible for developing economies to advance their technological development by fully integrating various available technologies. They cite examples such as the emergence of the VCD and agricultural vehicle industries in China to support the argument that technological progress for developing economies may well take a different course from those of the advanced economies. By allocating resources to technological innovations, starting from modification and improvement of existing technologies according to local factor endowments, new

trajectories of technological development can be created. The development of ICT has provided a unique chance for developing economies to integrate available technologies in a creative way so that product as well process innovations can be generated. Four basic principles are outlined as the essential components of the new technological strategies for developing economies in the age of information; and the view is offered that a new production paradigm can emerge from the developing economies that adopt these new technological strategies.

Catherine P. Ailes, Director, S&T Policy Program at SRI International, then introduced the topic of "The National Innovation System: Government, Industry, University Roles", illustrating through two case studies the issues involved, namely: the importance of the relatively easy flow of ideas, knowledge, technology and people across institutional boundaries; the widely varying and frequently unpredictable roles of government, industry, and universities; and the overarching significance of first-class technical education and training for company and national industrial competitiveness.

One of the case studies examined several recent, significant engineering innovations such as magnetic resonance imaging; reaction injection molding of polymer composites; the Internet; computer-aided design applied to electronic circuits (CAD/EC); optical fiber for telecommunications; and the cellular telephone. The studies examined the interplay of government, industry, and universities as the innovations evolved; the role of, and interaction between, fundamental research and technology development; and the role of intellectual property rights protection. The studies also examined the specific ways in which government activities influenced the evolution of these engineering innovations and revealed the essential role that had been played by government support of education and training, especially graduate education. The cases also reveal clearly the importance of 'invisible colleges': scientists and engineers who share results and know-how via networks that span both cooperating and competing institutions. Isolation thus appears clearly as the enemy of innovation. In terms of intellectual property rights protection, the six case studies reveal that the innovations evolved successfully despite, rather than because of, such protection.

These findings were generally reinforced by the study of the Engineering Research Centers (ERC) program that was established to create long-term collaborations between universities and industry, to create industry-relevant knowledge at the intersections of traditional disciplines, and to prepare a new generation of industry leaders who are more capable of engaging in team-based, cross-disciplinary engineering practice. The study showed that it is access to the ideas, know-how and core research at the universities – as well as the students trained in a center that interacts closely with industry – that industry basically desires, gets, and highly values when it occurs in its interactions with ERCs.

Jon Sigurdson of the Stockholm School of Economics presented a note that posed the question: "A New Technology Landscape in Asia? Comments on emerging new Structures and Capabilities". Sigurdson notes that, throughout the Asia Pacific region, science and technology is perceived as being, or becoming, the key factor that will fuel the region's continued economic development. He reviews the evidence regarding the evolution of innovative capacity in the region, including patenting activity and

publication of scientific papers, and finds that, since the mid-1970s, Pacific Asia has been in a catch-up phase with the combined publication of scientific papers still at a much lower level than in the US and EU, but with the annual increase being much higher. Thus, he expects that the gap between Pacific Asia and the other two regions will dramatically narrow over the next 20 years.

Sigurdson also notes the emergence of Cross-National Production Networks (CPNs) and argues that large firms operating in an international environment control a very substantial proportion of all industrial research and constitute a firm-based system of technological development that is increasingly impinging on national innovation systems and diminishing the effectiveness of national policies within state borders. However, he maintains that globalization has not yet created a borderless global economy as national systems of production have persisted although with an increasingly strong regional structure, which is shaped by history, and political and economic institutions. Location-specific advantages remain in spite of globalization, which is partially a reflection of agglomeration of skills and acquisition of knowledge, which is closely linked to the local/national education and research structure. He concludes that to improve technology performance requires broad and systematic knowledge of the innovation system, domestically and abroad as well as a keen understanding of the increasingly interlocking character of large global companies. Without such intelligence, realistic national objectives cannot be formulated.

Finally**, Bob Coward of the Science and Technology Policy Program of SRI International** provided a perspective on the "Internationalization of Science and Technology and its Impact on International Cooperation." He observes that science has always been culturally international in nature and that international exchanges, meetings, publication, travel and exchange represent the *modus operandi* of a community that knows that its specialized interests are often more shared abroad than at home. Nowadays, with globalization moving technology across borders, staying on top of innovation requires a nose for international developments. He identifies a number of rationales for international cooperation in this area.

However, Coward also suggests that we do not know enough about the innovation process that develops new technologies. He notes the general abandonment of the "linear model," in which innovation represents a direct pipeline that passes from scientific research, through engineering development, testing, and pre-production phases, to end with the introduction of a new product or process. Whatever is in the "black box" of the innovation process, it is a complex process that involves constant feedback and iterative interaction between the research and development processes. This needs to be reflected in discussions of international scientific cooperation.

He also notes that many developing economies are poorly prepared to support international cooperation in S&T. There is a general lack of local S&T infrastructure. Industries have often not developed a culture of research and the ability to cooperate with research institutions, at home or abroad. As well, there are cultural issues, both national and institutional – for example, it is very hard to recruit U.S. scientists to do cooperative projects in Japan because of the language problem. There are potential professional jealousies – how is the data to be shared; who gets to publish, where, and

when? And efforts to establish international agreements are fraught with concerns about who benefits most. A major barrier is the potential loss of commercial advantage. Agreements must deal with intellectual property rights (IPR). Who gets the IPR, and *is* there an IPR regime that is acceptable and facilitating? While cooperative relationships may go well and never lead to an IPR issue of any importance, the perception that an economy involved in cooperation lacks a world standard IPR regime can prevent an agreement from ever being reached. Other concerns about international cooperation in S&T include the question of whether such activities limit competition among researchers, which may, in turn, inhibit innovation. Finally, establishing and guaranteeing long-term commitments is difficult.

Because S&T plays such an important role in the "created comparative advantage" that now represents such an important part of international competitiveness, barriers to development of relationships will continue to exist. However, despite the problems and barriers, Coward concludes that there is evidence that international cooperation in S&T is increasing and he suggests that it will continue to increase in the next century in various forms.

4. The Financial Crisis: Implications for Economic Research

The final session of the Symposium returned to the theme of the financial crisis and addressed the implications that it might raise for economic research.

The session was led off by a presentation by **Mark Hopkins of the Council of Economic Advisers, U.S.A**., of a paper on the question: "Was the Asian Crisis Foreseeable?" As Hopkins notes, a more or less standard explanation of the Asian currency crisis using well established and broadly understood economic logic emerged soon after it broke. The alacrity with which this conventional wisdom on the cause of the crisis was achieved is quite remarkable, given that the crisis was completely off the radar screen only a few months before. This naturally leads to the question of why the crisis was not foreseen, when it was so easily explained only a few months later.

Hopkins points out that this question leads to something of a paradox if markets indeed work perfectly: that is, if the Asian crisis had been foreseen, adjustments would have been made earlier that would have prevented it from occurring. Indeed, in theory, agents in efficient markets, forming expectations of the future based on all available information, should take advantage of any arbitrage opportunities they perceive resulting from market misalignments, such as a future change in the value of a currency or a stock price. In aggregate, by changing demand for the currency or stock in line with their expectations, the actions of these individual agents should act to correct the existing misalignment. Hopkins notes that investors already had a good deal of relevant information, including macroeconomic data, trading patterns, foreign debt levels and maturities, and government policies, as well as the lessons of centuries of currency crises. In the cases where key data were not made available, this itself still provided investors with information – namely, that they should be concerned about risk, and be properly hedged. He points out the challenges that this raises to the perfect capital markets theory and argues that the question of whether the Asian crisis was actually

foreseen by markets is an empirical one that should be sorted out by studying the market valuation of hedging mechanisms prior to the crisis.

If the answer is that the crisis was expected, then proponents of the "self-fulfilling prophecy explanation" are likely to feel vindicated. The Asian crisis may have occurred more because of these market expectations than because of a change in economic fundamentals. This would explain the lack of an obvious exogenous "trigger" for the crisis, why the depreciations and capital outflows that occurred seemed disproportionate to the weakness of the fundamentals, why speculative attacks occurred both in Thailand and in Hong Kong, China despite the very different situation and quality of the fundamentals in these two economies. However, if the answer is that the crisis was not expected, then it is important to examine why we failed to predict it. If the answer is that it could not have been foreseen, Hopkins concludes that we should simply focus our attention on improving the speed and quality of the international response to such crises, and on preventative measures such as those being suggested in the discussion of a new international financial architecture.

Hopkins reviews three possible explanations for the failure of the model: that agents were not rational, that market competition was imperfect, and that information was incomplete. He concludes that the last of these, imperfect information, seems the most likely candidate and considers the further implications of this for theory and practice – including possible roles for APEC.

Dan Ciuriak of the Department of Foreign Affairs and International Trade in the Government of Canada, in his paper "The Asian Crisis: The Challenge to Conventional Wisdom" takes as a point of departure the emerging consensus view that sees the crisis as reflecting the confluence of a number of factors, none of which individually would have been sufficient to explain the crisis, but which added up to a deadly cocktail. He argues that this falls short of a full explanation and documents how patterns associated with non-linear dynamics fit elements of the Asian crisis that conventional economic theory fails to explain adequately.

He suggests that the defining characteristics of the Asian Crisis were its sudden, unanticipated emergence, the absence of a significant external shock, the wide difference between the size of the apparent causes and the eventual intensity of the impacts, and the depth of transformation of the economic landscape of Asia that it has wrought. These characteristics are typical of non-linear, dynamic, non-equilibrium systems; they are not typical of linear equilibrium systems. He notes further that, in commentaries and descriptions, metaphors for the crisis have been drawn from areas such as the weather ("storms"), nuclear physics ("meltdown"), biology ("flu", "contagion", "virulence"), mass psychology ("panic" and "herd behaviour") amongst others, none of which falls into the class of linear equilibrium systems. He then compares statements about the Asian Crisis to statements about, and features of, complex non-linear systems such as:

- Unpredictability: the long-term future is inherently unknowable because of the nature of the system itself and not because of external factors.
- The escalation of small errors to alter completely the behaviour of the system.

- The huge range of effects to which a single cause can lead and the impossibility of tracing links between cause and effect in the complexity of interactions.
- The role of negative and positive feedback loops such as self-reinforcing trends, bandwagon effects, chain reactions, self-fulfilling prophecies, virtuous/vicious circles.
- The aperiodic nature of the movement of the system over time within the region of its "attractor" (i.e., "bounded instability").
- "Sensitive dependence", where even minute changes in parameter values lead to huge variations in system behaviour, with shifts from periodic to chaotic and back again.
- The self-organizing order that emerges from chaotic situations without formal design.
- The parallels between the transmission mechanisms of the crisis and features of dissipative, non-equilibrium system dynamics.
- "Double-loop learning" which results in "paradigm shifts": i.e., the changing of behavioural rules of actors within a system by the actors in response to the behaviour of the system.
- Discontinuities in a system (which correspond to "the straws that break the camel's back") are described by the mathematics of "catastrophe theory", pointing to underlying geometries that do not fit the standard assumptions of linear models.
- Physical systems where speed of change leads to turbulence (e.g., change from "laminar" or smooth flows to turbulent flows past a certain speed).
- Non-equilibrium dynamic systems which must be driven by a source of energy (in contrast to equilibrium systems, which revert to a state of rest following disturbance).

Ciuriak concludes that, to the extent that economic and social systems include important aspects of such non-linear dynamic models, the emphasis of policy should be on structures and processes that promote maximum flexibility (i.e., sound institutions); attention needs to be paid to initial conditions; and account must be taken of the fact that improved information leads to changes in system dynamics. Ultimately, he poses the question of whether the Asian crisis is also a crisis of the accepted "core" macroeconomic model.

The third paper presented in this session is from **Dr. Mark McKergow**, "The East Asian Economic and Financial Crisis: Lessons from Complexity Theory." This paper considers the "management" issues raised if the crisis is indeed reflective of an underlying complex, non-linear structure. McKergow notes that, due to key features of complex systems (e.g., their self-referential and non-linear nature), they are inherently non-deterministic (i.e., wholly accurate predictions of future states cannot be made, however well the current and past states are known) and they show emergent properties – patterns which result from the overall action of all the elements of the system, that are not obvious even if the system interactions are precisely known, and may be rich and unexpected. He draws parallels between the wide-ranging set of causes cited in the

Asian crisis and the complex set of facts that contribute to a person having an accident or the interactions among drivers that precipitate a traffic jam.

He summarizes the "Lessons from complexity theory" as follows:

1. Searching for "The Cause" of the crisis is futile. Think instead about the way ahead.
2. Don't ask whose fault it was. Ask instead about the influences to be brought to bear on the future.
3. Don't ask "What's going to happen?" Ask "How would we recognize a useful way ahead?"
4. Don't seek a grand plan for recovery. Seek small steps combined with positive feedback to grow the recovery.

5. Conclusion

The 1998 APEC Economic Outlook Symposium contributed importantly to the development of the *1998 APEC Economic Outlook* that was presented to Ministers and Leaders at their meetings in Kuala Lumpur, November 1998. The contributions of outside experts as well as the discussions among the members of the Committee were an important element of the "value added" in the Outlook document itself. It is hoped that, through the publication of these papers and proceedings, these ideas can be shared with a wider audience and that the dialogue started at Xiamen can be continued and developed.

PART 1

IMPACTS OF THE FINANCIAL CRISIS AND MEASURES TO RESTORE ECONOMIC GROWTH

THE FINANCIAL CRISIS IN EAST ASIA AND ITS ECONOMIC AND SOCIAL IMPACTS

Pradumna B. Rana [*]
Asian Development Bank

1. Evolution of the Crisis — Is the East Asian Crisis Over?

The partial rebound in the financial markets and the resolution of the immediate liquidity problems in the East Asian economies since the early part of 1998 is certainly encouraging. But is the East Asian Crisis over? Some light can be seen at the end of the tunnel. But, as Mr. Gabriel Singson, the Governor of the central bank of the Philippines warned recently, it could be the light of an approaching train.

The depth, breadth and the speed of the East Asian crisis has surprised everybody. Even analysts like Paul Krugman, who several years ago had seen diminishing returns setting in within the region and had forecast a gradual slowdown in East Asia, did not foresee a sudden and dramatic regional collapse.

The currency crisis in East Asia has completed three phases. The first started with the onset of turbulence in Thailand in early July 1997 and the contagion that affected the neighboring economies. The second phase began in mid-November when the crisis moved to Northeast Asia and affected Korea. The third began in early January of this year when Indonesia started to experience serious problems.

Although from a low base, the recovery in currency and stock markets of the affected economies since end-January this year is encouraging. The Thai baht has appreciated by about 35 percent, the Malaysian ringgit and Korean won by about 15 percent. Initial concerns over the freefall of currencies appear to be over. But are these trends sustainable? Will there be a fourth round of the Asian contagion? Several uncertainties prevail. Recent signs from Indonesia are more encouraging than before, but the social unrest clouds the picture. The progress in the implementation of the third agreement with the IMF was encouraging and the IMF recently released the second tranche of US$ 3 billion although not all at once. While a soft-landing was planned in China, the sharp slowdown in exports and industrial production in the first quarter of 1998 is a cause for some concern. In Japan, where the banking and corporate sector problems are well known, the recently announced fifth stimulus package will probably result in some positive economic growth in 1998 but this will likely not be enough to pull up East Asian exports to Japan very significantly.

[*] Dr. Rana is Senior Economist, Asian Development Bank. This note was prepared for the 1998 APEC Economic Outlook Symposium, held 16-17 May 1998, in Xiamen, China. The views expressed in this paper are those of the author and do not necessarily reflect the views or policies of the Asian Development Bank.

Investor confidence seems to be returning slowly in at least four of the five affected economies except Indonesia. The Philippines recently successfully floated a US$ 500 million Yankee bond and portfolio capital inflow in the first quarter of 1998 was higher than the level a year earlier. In Korea, a second round of rescheduling was completed in March 1998 and a US$ 4 billion sovereign bond was floated recently. Thailand is planning the issuance of a US$ 1 to 1.3 billion Yankee bond.

Weak banking and corporate governance were the Achilles Heels of East Asia. While the recapitalization and reform processes have begun, they have a long way to go. Costs are bound to be very high. For example, it is estimated that the cost of bank restructuring in Korea will total over US$ 50 billion. Much more needs to be done to attract foreign capital.

Finally, a full-fledged real and social sector recovery will take many years. A very modest recovery is seen beginning sometime next year in the affected economies but the rapid growth of past years is still far away. Social costs in terms of rising unemployment, cuts in pay, higher prices, and reduced access to social services are expected to be particularly acute. Unemployment levels are expected to approximately triple in the affected economies, before they start to improve, reaching about 10 percent in Indonesia. Again in Indonesia, the incidence of poverty is expected to rise to 20 percent from about 11 percent several years back.

In other words, while there are encouraging signs that the affected economies, except Indonesia, might have turned the corner in terms of restoring investor confidence and stability in currency and stock markets, the East Asian crisis is not over yet. The banking crisis and corporate bankruptcies will continue.

2. The Root Causes of the Crisis

All crisises tend to be different. However, a consensus seems to be now emerging on the root causes of this particular crisis. First, the root causes of the crisis in East Asia were structural – weaknesses in the financial and corporate sectors compounded by policy mistakes in managing private capital inflows and global financial integration. Macroeconomic fundamentals were relatively less important contributory factors. In fact, East Asia had the strongest fundamentals among the developing regions. Second, the problems in East Asia were not due to fiscal profligacy but the excessive borrowing by the private sector, mainly in the form of short-term capital. Government policies that permitted the borrowing were also, of course, at fault. There was a sudden collapse in investor confidence and foreign capital flows reversed in 1997.

The first implication of the differences in the root causes of this crisis from previous ones is that, in the East Asian case, various macroeconomic austerity measures had to be complemented by structural measures, including measures to deal with private sector debt and coordination between diversified creditors and debtors.

Second, structural problems are more difficult to resolve for several reasons: (a) a set of fully articulated structural reforms is difficult to design in the middle of a financial crisis; (b) the required political and economic consensus might be difficult to achieve;

(c) the structural reform agenda will take time to implement, and the results may take even more time; and (d) progress in implementing structural issues will be more difficult to observe and assess.

Comparison with the Mexican peso crisis, which began in December 1994 and was due mainly to macroeconomic factors, illustrates why the structural crisis in East Asia could be more protracted, notwithstanding that initial conditions were more favorable in East Asia than in Mexico (in the sense that savings and investment rates were higher) and the magnitude of the adverse shock was lower in East Asia. With respect to the latter point, within the first two months of the crisis, the Mexican stock market (in dollar terms) had plunged by about 50 percent – the figures were lower in East Asia. Similarly, within the first three months of the crisis, the peso had fallen by over 30 percent in Mexico. In the East Asian case, the corresponding figures were lower except in Indonesia.

Despite these differences, economic recovery began earlier in Mexico than in East Asia. In Mexico, the stock market began to recover three months after the crisis and five months later it had reached almost 90 percent of its December 1994 level. In the case of the exchange rate, recovery began a month later and reached 80 percent of its pre-crisis level. By comparison, in the East Asian economies, currencies and stock markets started to recover only 7 months after the onset of the crisis and they are still considerably below the July 1997 level

Partly because of the NAFTA agreement, Mexico's exports continued to surge during the crisis period. In the East Asian case, exports have slumped (except in the Philippines) mainly because of the higher cost of capital and imported inputs, the shortage of trade finance (particularly), and the recession in the regional economies. Exports started to recover in all of the affected economies (particularly, the Philippines and Korea) 7 months into the crisis but these need to be sustained. Also, while in Mexico foreign capital inflows recovered to their pre-crisis level 6 months after the onset of the crisis, in East Asia it is only recently that capital flows are starting to trickle in and very cautiously and slowly.

Finally, GDP growth and investment ratios started to turn around in Mexico 10 months into the crisis. In East Asia, the real sector is not expected to recover until sometime next year depending on the pace of policy reforms.

3. Economic Impacts of the Crisis

In this time of economic turmoil, making economic projections is a hazardous task. The economic situation is changing rapidly. In the Asian Development Bank, we are constantly reviewing our projections and the latest picture as we see it in the Asian Development Outlook 1998 are as follows:

- We expect the growth of developing Asia to fall significantly in 1998 to 4.1 percent. The most significant declines will take place in the affected economies. Korea (-1 percent), Thailand (-3 percent) and Indonesia (-3 percent) are projected to

register negative growth. Meanwhile Malaysia and the Philippines are expected to grow at a positive rate but less than one-half of their 1997 rate. We expect a minor rebound in 1999, when average GDP growth in developing Asia will reach 5.1 percent. We anticipate that all the affected economies will post small but positive growth.

- China will experience a further reduction in its growth rate in 1998, partly reflecting weakening domestic demand, excess capacity in some industries and a possible decline in export growth (stemming form the depreciation of currencies in the affected economies). China is projected to experience further deceleration in growth in 1999, although growth will still remain strong at 6.8 percent.

- All Asian economies will experience a higher inflation rate in 1998, especially in the affected economies. Inflation is expected to reach about 20 percent in Indonesia and 15 percent in Thailand. Korea is also expected to experience double-digit inflation.

- Current account situation in all economies will be affected by the contraction of exports.

In sum, we expect that for much of Asia, 1998 will be a lost year. However, we expect an economic turnaround in 1999 with all subregions posting positive growth. For Asia as a whole, growth will still remain modest compared to the historical trend but will still exceed the world average. Recovery to the old historical trend rate of growth will require time.

4. ADB Assistance to the Affected Economies

The ADB has argued, from the very beginning, that the East Asian Crisis was a different type of crisis and required a different set of prescriptions. There is now an evolving consensus on this view. Accordingly, the ADB joined the IMF-led rescue packages for Thailand, Indonesia, and Korea and committed over US$ 9 billion in emergency assistance to support structural reforms and capacity building efforts, and to mitigate the costs of structural reforms. The Bank's efforts have sought to: (i) accelerate banking and capital market reforms; (ii) promote efficiency in trade and industrial sectors, including trade finance; (iii) promote good governance and corporate management; and (iv) mitigate the social costs of adjustment. Many of the programs, for example the US$ 4 billion Financial Sector Program Loan to Korea, were prepared in record time. The following are the economy-specific contributions:

- *Thailand*. The ADB pledged US$ 1.85 billion focused on financial and social sectors. The US$ 300 million Financial Sector Program Loan was approved on 19 December 1998. A US$ 500 million Social Sector Program Loan and a US$ 1.0 billion Export Financing Facility was approved more recently. The latter was organized with 10 international commercial banks.

- *Indonesia*. The ADB has pledged US$ 3.5 billion over the next three years of which US$ 1.5 to US$ 1.8 billion will be new money. A US$ 1.5 billion Financial Governance Reforms Sector Program Loan is at an advanced stage of preparation. A Social Protection Sector Development Loan is also being prepared.

- *Korea*. A US$ 4.015 billion Financial Sector Program Loan was approved last December.

Finally, the East Asian Crisis has highlighted that contagion tends to be most serious among neighboring economies. There may, therefore, be a need to complement individual economy and global surveillance with regional efforts. Such an effort will involve peer surveillance and will bring to bear the unique perspective stemming from an in-depth knowledge of local conditions. Under the Manila Framework and as requested by the ASEAN Finance Ministers, the ADB is considering the establishment of a regional monitoring mechanism.

THE JAPANESE ECONOMY: RECENT DEVELOPMENTS AND SHORT-TERM PROSPECTS

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1. Economic free-fall averted for the time being

The economic contraction in Japan that began in the spring of 1997 was a result of the production cutback undertaken in order to adjust the level of inventories to a more appropriate level. The overstock of inventories was a result of a fall in final demand, which became evident after April 1997. Final demand became sluggish in the second quarter of 1997 in response to a number of shocks: the rise in the consumption tax rate from three to five percent on April 1, 1997; the shift of spending into the first quarter as consumers rushed to make purchases in anticipation of the consumption tax rate hike; and the withdrawal of the special income tax cut arrangement that had been in place since 1994.

Before this initial shock had fully been absorbed by the economy, the Asian financial crises aggravated the already negative sentiment towards the economy. In anticipation of the negative impact on the Japanese economy, which had built close ties with the economies in trouble, the Asian financial crisis sent the Tokyo stock market into a tailspin.

The magnitude of the impact was, however, subject to considerable uncertainty. In order to gauge the impact of the Asian Crisis on the Japanese economy, a simulation was undertaken in the JCER. It compared the baseline forecast with a simulation based on a counterfactual assumption that the crisis-effected economies had maintained their effective pegging of currencies to the US dollar. The results showed that the Asian currency devaluation would reduce Japanese real GDP growth by 0.2 percentage points in fiscal 1997, and by 1.0 percentage points in fiscal 1998.

The drop in stock prices, in turn, had grave consequences. It quickly raised doubts about the soundness of the financial system, which relied heavily on unrealized capital gains on stock portfolios. In fact, a number of large financial institutions failed in November 1997. The situation brought about a greater feeling of uncertainty about the future, which worked to further discourage private demand. At the end of 1997, there was a risk of an economic free-fall.

This situation was confirmed by the quarter-on-quarter growth of negative 0.2 percent in the preliminary GDP figures for the October-December quarter of 1997, published in mid-March 1998.

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In the January-March quarter of 1998, a decline in public investment and net exports seem to have taken place. This, coupled with the already depressed private demand, is expected to result in a second consecutive quarter of negative growth. Real GDP for fiscal 1997 as a whole is now expected to record a year-on-year decline of around 0.5 percent, thus marking the first negative growth since fiscal 1974, immediately following the first oil shock[1].

As the potential for a collapse of the economy became greater, the Government successively introduced some countermeasures, which can be grouped into three. The first group consists of measures to stabilize the financial system, and involved allocating public funds up to 17 trillion yen to protect depositors of failed financial institutions. The second group consists of measures to counteract the capital-crunch situation. To encourage lending, the Government made provisions of public funds up to 13 trillion yen to allow financial institutions to boost their capital base; relaxed the introduction of Prompt Corrective Action; and made the evaluation rules for stocks and lands more flexible. The third group consists of measures intended to stimulate the economy. Early measures include reinstatement of the 2 trillion yen special income cut tax arrangement for 1998, which was announced in December 1997 and came into effect after February 1998. More recent efforts are manifested in the Comprehensive Economic Measures announced in April 1998, which include an increase in public works by 7.7 trillion yen, and an introduction of further special income tax cuts worth 4 trillion yen.

2. Economic impact of the comprehensive economic measures

According to an estimate made by the JCER, the economic impact of the Comprehensive Economic Measures on Japanese nominal GDP growth amounts to 1.8 percentage points in fiscal 1998, and 1.5 percentage points in fiscal 1999.

It should be noted, however, that this result was obtained by applying multipliers that were drawn from macroeconomic model simulations. Since there are reasons to believe that the multipliers overestimate the actual impact that would tale place under current circumstances, the result should be regarded as the upper bound of the expected impact of the Measures. The reasons are as follows:

First, the tax cuts are temporary and do not lead to an increase in permanent income. Since uncertainty perceived by the households has also increased, there are also tendencies to increase precautionary savings. These would imply that the marginal propensity to consume out of the tax cut would be smaller than the standard simulation results.

[1] The quarterly national account statistics published in June show that real GDP growth for the January-March quarter of 1998 was minus 1.3 percent. It also revised the figure for the previous quarter (October-December quarter of 1997) downward to minus 0.4 percent. Real GDP growth for fiscal 1997 became, as a result, minus 0.7 percent.

Second, those sectors that are the main channels through which the economic impact of an increase in public works takes place, such as the construction and real-estate sectors, are undertaking restructuring and balance-sheet adjustments. This being the case, any increase in sales of these industries may not lead to an increase in business investment and other forward looking spending. The secondary effect of public works spending would be dampened as a result.

It should also be noted that these results have an important implication for economic growth in fiscal 1999. If the estimated impacts, which are impacts on *levels* of nominal GDP, are translated to impacts on *growth rates* of nominal GDP, it implies that the growth rate in fiscal 1999 would fall by 0.3 percentage points (1.5 minus 1.8). It is vitally important, in this sense, to see what the framework for the initial budget for fiscal 1999 is going to be like. If it is going to be constrained by the Fiscal Reconstruction Law, which requires the appropriation for public works in the initial budget for fiscal 1999 to be below that in the initial budget for fiscal 1998, the negative impact would be reinforced rather than offset. This would have a significant implication to an economy that still lacks the momentum for an autonomous recovery.

3. Prolonged economic downturn

Notwithstanding the reservations, the countermeasures will be sufficient for the economy to avert a free-fall. This does not mean, however, that the economy would immediately be placed on a recovery path. On the contrary, the recession will be prolonged.

The first factor behind the prolonged recession is the expectation that private plant and equipment investment, which had been growing at healthy rates in fiscal 1995 and 1996, will enter an adjustment phase. Private investment has been slowing down because corporate profits have been falling. Moreover, financing has become restricted by the recent increase in stringency of lending practices of financial institutions. With the increased uncertainty, firms have also been inclined to postpone investment for the time being and the declining trend seems to have been reinforced by the fall in the medium-term growth rate expected by the firms. In this latter regard, the recent survey by Japan's Economic Planning Agency shows that expected average growth rate for the coming three years has declined from 1.8 percent in January 1997 to 1.4 percent in January 1998. With the implied downward adjustment to the required growth of the capital stock, a decline in private investment for some time is inevitable.

The second factor is the slowdown of external demand, which had until now been expanding and making up for the poor performance of domestic demand. The devaluation of the Asian currencies and the slower growth in the region due to structural adjustment have started to affect the trade figures. Moreover, slowdown in the US economy, and the gradual appreciation of the yen as a result of the rapid growth in the current account surplus, will discourage exports and encourage imports.

4. Growth in real income leads to recovery in private consumption

Reflecting these developments, growth in final demand will be limited in fiscal 1998, and a continued adjustment of production levels cannot be avoided. The recession may well be a lengthy one.

What, then, will be the factors that will prevent a more serious decline and permit the economy to bottom out and turn the corner to positive growth? One important factor will be the fact that private consumption will show a gradual recovery in conjunction with an increase in real household disposable income.

The decline in corporate profits in fiscal 1997 has led to a gradual slowdown in the growth of nominal wages. However, real wages faced by *the firms* will increase in fiscal 1997 and 1998 because prices faced by firms, who can pass the burden of the rise in the consumption tax rate on to households, will fall.

In contrast, real wages for *the households* fell in fiscal 1997. Since households had to bear the burden of the increase in consumption tax, the increase in prices facing the households more than canceled out any gains in nominal wages. However, in fiscal 1998, the effects of the consumption tax rate hike will disappear from the changes in prices, and real wages will once again increase.

In addition to the recovery in real wages in fiscal 1998, there will also be special income tax cuts amounting to 4 trillion yen in all. Thus, even if employment growth does slow down, the real disposable income of households in fiscal 1998 will increase. As for private consumption, even though consumer sentiment will be pessimistic, the effect of the rush-buying in anticipation of the consumer tax rate hike will have disappeared, so that the improvement in income will lead to its gradual recovery in fiscal 1998.

Another important factor that is expected to support the economy in recovering is the sustained high level of public investment due to the fiscal stimulus package. Without the package, public investment would have declined, exerting a strong downward pressure on the economy. Moreover, the process of capital stock adjustment will attain and pass its peak. As a result of these factors, growth in final demand will gradually increase, and the production cutback will end.

5. Timing of the bottoming out

In the JCER's March 1998 quarterly economic forecast (see Table below), the decline in production was expected to end in the October-December quarter of 1998, thus allowing the economic downturn to bottom-out in the January-March quarter of 1999. The expected real GDP growth rate for fiscal 1998 was estimated to be 1.2 percent over the previous fiscal year. Since March, however, there have been developments that influence the economy in opposite directions; the forecast needs to be revised accordingly.

Positive developments include the announcement of the Comprehensive Economic Measures in April. Compared to the assumptions underlying the March forecast, which assumed economic policy packages appropriating 7.2 trillion yen to public works and 2 trillion yen to extend the special income tax cut to 1999, the Government announcement exceeded the expectation in the tax-cut front.

Negative developments include the fact that economic indicators are worse than projected. In particular, the unemployment rate of 3.9 percent for March seems to indicate rapid deterioration in employment situation.

These factors will be taken into account in the JCER economic forecast to be published in late-June 1998.

6. Economic recovery to be slow

Finally, it should be noted that, even after passing through the trough of the business cycle, we cannot be so optimistic as to expect that all the problems are behind us. The reasons are twofold:

First, even after the economy bottoms out, economic growth will be very modest. This is because firms and financial institutions have still not succeeded in restructuring and cleaning up their balance sheets, essential measures that had been demanded of them since the bursting of the bubble in the early 1990s.

Second, by deeming short-term measures more urgent, such medium-term structural measures as implementing fiscal structural reform and financial system reforms have essentially been postponed. After the economy has bottomed out, the economy will have to deal with these difficult tasks anew.

PURCHASING POWER PARITY, THE EXCHANGE RATE AND CHINA'S INTERNATIONAL COMPETITIVENESS

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1. Purchasing Power Parity and the Exchange Rate: China's Case

Much has been said and written about China's exchange rate and international competitiveness since the beginning of the financial crisis in Asia. This paper addresses this issue from the perspective of purchasing power parity.

It has been recognized that, in the low-income developing economies, the actual exchange rate differs widely from that based upon purchasing power parity (PPP), as derived by the standard international comparison approaches.[1] In principle, international comparisons can be made from the expenditure, income or production side to derive PPPs between the local currency and numeraire currency.[2]

In my studies, I have used the expenditure approach, following the techniques developed in the UN International Comparison Program (ICP) and production approaches, the "industry of origin" approach developed in the International Comparison of Output and Productivity (ICOP) project at Groningen University, Netherlands. The basic conclusion in my book *China's Economic Performance in an International Perspective* (OECD, 1997) is that, like other developing economies, there are huge deviations between the PPPs and exchange rate for China's economy as a whole as well as for its various industries. The empirical results for the overall PPPs are summarized in the following table:

* This paper is based on the findings derived from Dr. Ren's book "China's Economic Performance in an International Perspective" published in 1997 in English and French by the OECD Development Centre, and earlier studies (Ren, 1993, 1994, 1995, 1997). It also draws on some new findings derived from subsequent work. (Ren, 1998). This research was supported financially by the Visiting Research Fellow Program of CCER -- the World Bank, National Natural Science Foundation of China, National Social Science Foundation of China, OECD Development Centre, the World Bank, the Royal Dutch Academy of Sciences, the Institute of Economic Research of the University of Groningen and the World Economy Laboratory, MIT. Dr. Ren's contact information is as follows: 4th Floor Tongguang Jindu Office Building C/O, Shui Zhui Zi Post Office, Beijing, 100026, China. Telephone: 8610-82315433; Fax: 8610-62028356; and e-mail: ruoen@seec.com.cn.

[1] See Kravis et al. 1975, 1978, 1982

[2] Maddison, 1995.

Table 1
PPPs and the Exchange Rate Deviation Index (DI) using alternate methods, 1985 and 1986

	Chinese quantity weight		US quantity weight		Geometric mean	
	PPP	DI	PPP	DI	PPP	DI
1985 Real Exchange Rate: 2.9 yuan = US$ 1.00						
ICP Method	0.57	5.09	1.46	1.99	0.91	3.18
ICOP Method	0.85	3.40	1.33	2.18	1.07	2.72
1986 Real Exchange Rate: 3.5 yuan = US$ 1.00						
ICP Method	0.59	5.94	1.51	2.32	0.94	3.71
ICOP Method	0.86	4.05	1.35	2.60	1.08	3.24

Notes: The Deviation index = Exchange rate/ PPP. The ICP measurements are the price relatives based on market prices derived at various aggregated levels in an expenditure classification while the ICOP measurements are the price relatives based on ex-factory prices derived at various aggregated levels in a production classification.

The PPPs derived in the international comparison are the price relatives between the two economies or among the several economies, as the case may be. In the developed economies, the PPPs are at times very close to the nominal exchange rate, but at other times they are not. On the other hand, in the developing economies, the PPPs are quite different from the nominal exchange rate. There are some theoretical explanations for this difference, including the productivity differential theory associated with Balassa. The PPPs treated in this paper usually refer to the empirical results in the international comparisons, and are not to be confused with the real exchange rates derived econometrically in a macroeconomic framework (as, for example, constructed by the IMF).

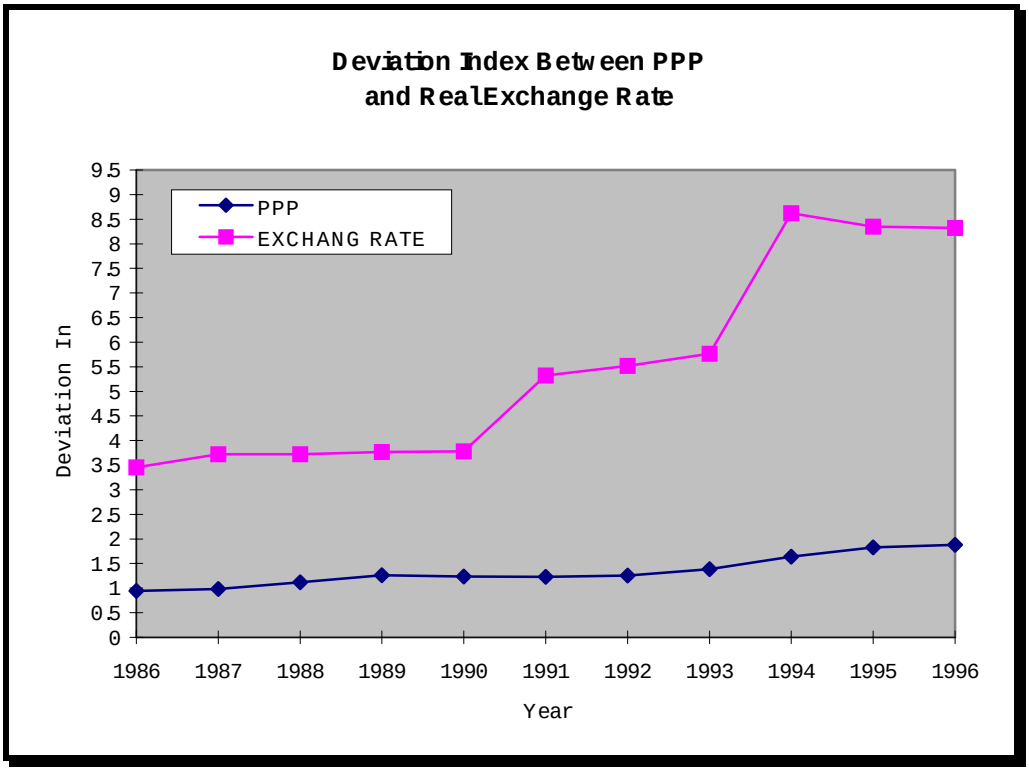
In the recent discussion on "the purchasing power parity puzzle",[3] some studies have shown that real exchange rates (nominal exchange rates adjusted for differences in national price levels) tend toward purchasing power parity in the very long run. Although it is not so sure that this is also the case for China, the PPP between the Chinese and the US currencies could be an important benchmark against which to compare the trend of the RMB/US$ exchange rate.

Based on the updates of the PPPs derived in my OECD study, I have calculated the deviation index between the RMB/US$ PPPs and RMB/US$ real exchange rates from 1985 to 1996 (see Figure 1). I have found that there are still big gaps between the RMB/US$ PPPs and the RMB/US$ exchange rate during this period. The biggest gap

[3] Rogoff, 1996; Goldberg and Knetter, 1997; MacDonald, 1997.

was found in 1994, with some narrowing thereafter. This finding seems to support the expectation that China's currency would have a tendency to appreciate in the coming years. In fact, the RMB/US$ exchange rate has been under pressure to appreciate, reflecting both a growing balance of payment surplus and as well the inflow of foreign direct investment.[4]

Figure 1



Notes: Upper line is the nominal RMB/US$ exchange rate. The lower line is the forecast PPP based on the benchmark year 1985, based on the movements of inflation and the exchange rate; it is derived from Ren (1997).

2. Currency Depreciation in Southeast Asia: Challenge to China's International Competitiveness

Since the early 1980s, China has undergone two restructuring processes: industrialization and the transition from a centrally planned to a market economy. Its successful, trade-driven development strategy has played a central role in both. The production-side (ICOP) estimates, rich in industry-by-industry detail, make it possible to explore the competitiveness of Chinese manufacturing by looking at relative price levels (the sectoral PPPs divided by the exchange rate), sectoral comparative productivity and unit labour costs.[5]

[4] China's currency devaluation in 1994 is a complicated issue. For more on the institutional aspect of this issue, see Hu, 1998.

[5] Ren, 1997, 1998

During the 1980s, Chinese manufacturing experienced improved price competitiveness, due largely to the depreciation of the yuan, which more than offset persistently high Chinese inflation. Relative prices for all manufacturing in 1994 stood at 37.2 per cent of the US level, well below the 49.4 per cent of 1985; absent yuan depreciation, the 1994 figure would have been 109.3. The relative price levels for six major manufacturing branches are shown in Table 2:

Table 2
Chinese Manufacturing Price Levels, 1980-1994 by Major Manufacturing Branches (USA=100)

	Food, Beverage & Tobacco		Textiles, Apparel & Leather		Chemicals & Related Products		Basic & Fabricated Metal Products		Machinery & Equipment		Other Manufact.		Total Manufact.		RMB /US$
	PPP	Price Level	PPP	Price Level	PPP	Price Level	PPP	Price Level	PPP	Price Level	PPP	Price Level	PPP	Price Level	
1985	1.32	44.96	1.37	46.52	1.50	51.15	0.99	33.77	1.78	60.53	1.17	39.91	1.45	49.38	2.94
1986	1.33	38.50	1.39	40.31	1.56	45.21	1.09	31.44	1.81	52.29	1.14	33.14	1.56	45.22	3.45
1987	1.44	38.65	1.49	40.06	1.77	47.54	1.15	30.99	1.87	50.23	1.35	36.24	1.64	44.12	3.72
1988	1.58	42.36	1.77	47.57	1.93	51.79	1.21	32.52	2.01	54.11	1.46	39.33	1.82	48.95	3.72
1989	1.74	46.34	2.12	56.21	2.27	60.29	1.46	38.74	2.35	62.39	1.56	41.54	2.06	54.67	4.77
1990	1.71	35.83	2.20	46.09	2.32	48.61	1.66	34.75	2.34	48.88	1.62	33.96	2.07	43.20	5.78
1991	1.77	33.26	2.27	42.60	2.39	44.95	1.97	36.95	2.37	44.43	1.68	31.59	2.18	40.96	5.32
1992	1.86	33.73	2.24	40.68	2.41	43.77	2.27	41.18	2.53	45.82	1.70	30.74	2.31	41.90	5.51
1993	2.06	35.81	2.33	40.41	2.61	45.23	3.54	61.48	3.02	52.49	1.84	31.99	2.82	49.00	5.76
1994	2.55	29.63	3.20	37.18	2.80	32.49	3.46	40.13	3.28	38.08	1.98	22.97	3.21	37.17	8.62

Note: The sectoral PPPs for 15 branch levels are taken from Szirmai and Ren (1995); the nominal exchange rate is obtained from IMF, International Financial Statistics, Washington DC, various issues.

Although Chinese labour productivity in manufacturing has grown substantially, by about 50 per cent between 1980 and 1992, it no more than held even with that in the United States; relative productivity was around 6.2 per cent of the US level in both years (see Table 3). Manufacturing labour productivity in China likely was about on the level of India's in 1985 – but while India showed a marked improvement in relative productivity between 1980 and 1986, China had no significant change over the same period in a comparative sense. Moreover, the productivity gap between China and the leading Asian economies is growing, notwithstanding that China has a very dynamic economy.[6]

Unit labour costs in Chinese manufacturing were about 90 per cent of the US level in 1980 before falling dramatically to reach their lowest level of 48.76 per cent in 1985. Subsequently unit labour costs began a strong rise. In 1990 unit labour costs in Chinese manufacturing were about 103 per cent of the US level, higher than in 1980. Labour costs are low in Chinese manufacturing but rising rapidly. In the face of such increases and because further substantial yuan depreciation seems unlikely, China's

[6] See Szirmai, and Ren, 1997

manufacturers appear to have only one way to maintain their cost competitiveness, namely to improve labour productivity.[7]

Table 3
Real GDP per Person Engaged in Manufacturing

	India	Korea	Japan	Indonesia	China	USA
1970	7.0	13.8	58.9			100
1971	6.3	15.8	57.8			100
1972	6.1	14.5	59.9			100
1973	6.0	15.4	61.6			100
1974	6.0	14.3	63.4			100
1975	5.8	17.6	64.1	7.7		100
1976	5.7	17.3	66.8	8.0		100
1977	5.8	17.8	67.7	8.0		100
1978	6.2	20.6	71.6	9.4		100
1979	5.7	18.4	77.7	9.0		100
1980	5.6	20.4	82.3	10.6	6.3	100
1981	6.1	22.7	84.3	11.5	6.4	100
1982	6.9	23.9	88.3	10.5	6.6	100
1983	7.1	24.4	83.6	9.3	6.2	100
1984	7.1	25.3	83.7	9.9	6.0	100
1985	7.7	24.5	85.0	10.5	5.7	100
1986	7.9	25.4	79.7	11.5	5.8	100
1987		26.4	81.8	10.0	5.5	100
1988		26.7	83.1	11.0	5.3	100
1989		28.9	87.1	10.5	5.5	100
1990			89.4	10.9	6.2	100

Table 4
Unit Labour Costs Levels by Major Manufacturing Branch
China as percent of the United States, 1980-1990

	1980	1984	1985	1987	1990
Food, Beverages & Tobacco	136.44	66.60	51.14	46.60	59.23
Textiles, Apparel & Leather	72.00	47.73	40.47	38.49	75.61
Chemicals & Allied Products	55.20	42.13	38.21	41.18	72.67
Basic & Fabricated. Metal Products	42.81	23.06	22.24	28.61	52.59
Machinery & Equipment	90.96	50.23	42.22	53.46	91.29
Other Manufacturing	71.05	44.47	39.14	44.21	88.46
Total Manufacturing	89.39	55.33	48.76	57.30	103.35

Sources: figures of labour productivity from Szirmai and Ren (1997).

[7] See Ren, 1998.

The PPPs and productivity measurements of Chinese manufacturing in a multilateral comparison framework were derived using the Geary-Khamis (GK) approach as well as using the generalized Theil-Törnqvist index based on the PPPs from the ICOP binary studies. These findings can be used to explore the trade performance of China with its main trade partners. These measurements are the building blocks for the measurement of international competitiveness of China's manufacturing in the framework provided by IMF's Competitiveness Indicators System.[8]

The GK method, first proposed by Geary (1958) and later pursued by Khamis (1970, 1972, 1984) has been most widely used as the principal aggregation method for international comparisons of real expenditure.[9] It is based on the two concepts of "purchasing power parities" of currencies and "international (average) prices" of commodities. The GK method derives these unknown parities and international prices using the simultaneous equations system; it satisfies the desired properties.

The generalized Theil-Törnqvist index was proposed by Caves, Christensen, and Diewert (1982a, b) for temporal and spatial comparisons of prices, output and productivity. This index is defined in two stages. The first stage involves the computation of the standard Theil-Törnqvist index (TT) for binary comparisons. This index was first proposed by Törnqvist (1936) and later discussed by Theil (1965, 1974). The Theil-Törnqvist index is a weighted geometric average of the price relatives with average value shares as weights. This index satisfies many desired properties as well; however it does not have transitivity. Caves, Christensen, and Diewert proposed to obtain a generalized TT index through the application of the EKS techniques. The EKS method[10] produces transitive multilateral comparisons from a matrix of non-transitive binary comparisons, maintaining a degree of "characteristicity." This procedure has been an alternative to the GK method in making international comparisons. The OECD has recently started to publish multilateral comparisons using both the GK and EKS methods.

Based on the PPPs calculated by the GK method, the PPPs between Chinese currency and other economy currencies are derived in Table 5:

Table 5
PPP All Pairs of Economies, 1987

	Japan Yen/Yuan	Germany DM/Yuan	Korea Won/Yuan	UK Pound/Yuan	US US$/Yuan
China	124.7	1.6	488.7	0.493	.709

[8] See Lipschits and McDonald, 1991, Marsh and Tokarick, 1994; and Ohno, 1990; Turner and Golub, 1997.

[9] See Kravis et al 1975, 1978, 1982.

[10] See Elteto and Koves, 1964; and Szulc, 1964.

Because the estimates derived by the GK method are transitive and invariant with respect to the base economy, it is legitimate to compare any pair of economies among the six economies in the multilateral comparison above. This is shown in Table 6:

Table 6
Relative Labour Productivity in Manufacturing
(Denominator economy = 100)

Denominator Economy	Numerator Economy				
	China	Korea	UK	Germany	Japan
Korea	24.59				
UK	12.18	49.54			
Germany	9.90	40.29	81.31		
Japan	7.49	30.45	61.46	75.58	
US	6.61	26.88	54.26	66.72	88.28

Since the onset of the Asian crisis, China's international competitiveness, especially in the manufacturing industries, has undoubtedly deteriorated to some extent because most of the currencies in the ASEAN economies have depreciated against the US dollar by over 30 percent, while the RMB has held steady. This can be seen from the recent data about China's exports and should be reconfirmed by export performance in the rest of this year.[11]

It has been argued, however, that "China's comparative advantage in low-cost, labour-intensive manufacturing goods is not yet seriously eroded relative to the region as a whole, …(because) China's labour costs are below the average of most of the ASEAN-4 nations".[12] It should be made clear that it is the unit labour cost comparison rather than the labour cost comparison that is relevant for assessments of international competitiveness. The data from Hu's paper showed that the labour costs in Korea will be 6.85 times as high as China's in 1998. At the same time, however, as can be seen from the labour productivity differential in 1987 in Table 6 of this paper, Korea's labour productivity in manufacturing is 4 times as high as in China. Considering the fact that the productivity gap between China and the leading Asian economies is growing (see Table 3 above), the gaps in the labour productivity between China and Korea would become larger than 4 times after 1987. So the gap in the unit labour cost between these two economies in 1998 would be expected to be quite small.

Generally speaking, price is only one aspect of overall international competitiveness; other factors, such as the labour and total factor productivity gaps, sales channels, distribution networks, marketing skills, and brand names, etc. must also be taken into account in analysis of international trade. The influence of these factors can only be seen in the longer time. But there is no doubt that China is going to suffer a significant decline in international competitiveness in the current circumstances by keeping its

[11] Note: the impact of the crisis on exports reflects of course a number of factors, including the contraction in demand in a number of partner economies as well as the exchange rate effects.

[12] Hu, 1998.

exchange rate stable against the US$ in the face of generally weaker regional currencies.

The ICP and ICOP estimates, which are central to my OECD study, support several analytic extensions. One of these is measuring the openness of China's economy: here trade is measured as half the sum of exports and imports, s a percentage of GDP. Use of the exchange rate converter shows this figure at 22.67 per cent in 1994, almost doubled from 11.40 per cent in 1985; this suggests a very open economy with high dependence on trade. Yet the same measure based on the ICP PPP converter puts the 1994 figure at a much more modest 4.33 per cent, compared with 3.45 per cent in 1985; the comparable figures based on the ICOP PPPs are 5.81 per cent and 4.31 per cent. Considering the fact that China is a big economy and has a huge domestic market, the measures of the openness of the Chinese economy based on PPPs seem to be more appropriate. This may provide some supporting evidence for the view that domestic aggregate demand is very critical and has substantial substitution effects.

3. Concluding Remarks

These results show that, as in other developing economies, there are huge deviations between the PPPs and the exchange rate for China's economy as a whole and for its different industries.

By examining the time series of real exchange rates and PPPs for China, there appears to be a trend of the real exchange rates moving toward purchasing power parity in the long run. This issue is worthwhile to be pursued further.

During the 1980s, Chinese manufacturing experienced improved price competitiveness, due largely to the depreciation of the yuan, which more than offset persistently high Chinese inflation.

The comparison of labour productivity is useful but only part of the story. An explanation of the huge gaps between China and other economies would certainly provide new insights into policies aiming to improve productivity levels. In this respect it would be very helpful to have estimates of the stock of capital in manufacturing sector by the perpetual inventory method. With the estimates of the stock of capital in manufacturing, the competitiveness of China's manufacturing sector could be explored by the TFP gaps approach. This would strengthen assessments of the international competitiveness of Chinese manufacturing.

On the one hand, labour costs, while rising rapidly, are still low in Chinese manufacturing. On the other hand, China has been experiencing declining cost competitiveness measured by relative unit labour costs. In the face of such labour cost increases and given that further substantial yuan depreciation seems unlikely, China's manufacturers appear to have only one way to maintain their cost competitiveness, namely to improve labour productivity.

China's international competitiveness, especially in manufacturing industries, has deteriorated substantially because most of the currencies in the ASEAN economies

depreciated by over 30 percent against the US$ dollar during the crisis while China has maintained its exchange rate stable against the US dollar, which has been an important stabilizing factor in the course of the crisis.

The measures of the openness of the Chinese economy based on the PPP converters show that China is not as open an economy as the measure based on the exchange rate would suggest. So domestic aggregate demand is critical for economic performance; moreover, there are substantial substitution effects.

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HOW DETRIMENTAL IS THE ASIAN CRISIS: ASSESSMENT BY MODEL SIMULATIONS

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Abstract

This paper assesses the economy-wide effects of the current Asian financial crisis by means of economic model simulations. A dynamic, multi-region, Computable General Equilibrium (CGE) model with international capital mobility was employed. The magnitude of the worldwide effects of Asian currency depreciation through international trade linkages is estimated not to be so large, although selected Asian economies would experience double-digit economic contractions. The economies outside the region would even gain rather than lose in terms of real GDP because of real income gains and capital inflows. Asian economies in question should stabilize home inflation in order to realize expected improvements in international price competitiveness. Foreign support for financing trade and investment would also be effective. Moreover, estimating the impact of several possible policy reactions including those of devaluation of Chinese yuan and expansion of Japanese domestic demand, it is stressed that Asia needs to remain committed to trade liberalization regardless of its current circumstances.

1. Introduction

Since the onset of the Asian crisis, the principle concern has been to stabilize the financial market turbulence, while at the same time identifying the past developments that might have caused the volatility. The main purpose of this paper is to evaluate the likely magnitudes of the worldwide effects of the Asian crisis that will be brought about in the future. The effectiveness of possible policy measures that could be taken in response to the current economic developments is also discussed. These aspects are thought to be particularly important for policy makers.

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* This paper is a revision of the JEXIM/RIIID Staff Paper Series 98-2 on this subject. It was presented at the APEC 1998 Economic Outlook Symposium, held in Xiamen in China on May 16, 17, 1998, and the first annual conference on Global Economic Analysis held at the Center for Global Trade Analysis, Purdue University on June 8 - 10, 1998. The views expressed here are the author's own and do not represent those of the Export - Import Bank of Japan (JEXIM). The author is grateful for comments received on earlier drafts, including those by Dan Ciuriak, Canadian Department of Foreign Affairs and International Trade. However, remaining errors are the responsibility of the author. Ken-ichi Kawasaki is Senior Economist at the Research Institute for International Investment and Development (RIIID), The Export - Import Bank of Japan (JEXIM). His contact information is as follows: Address: 1-4-1 Otemachi, Chiyoda-ku, Tokyo 100-8144, JAPAN; Tel: 81-3-3287-9494, Fax: 81-3-3287-9578, e-mail: kkawasaki@japanexim.go.jp

In this regard, economic model simulations can be quite useful in providing quantitative assessments to complement qualitative analyses. While economic models have limitations in analysis and, moreover, their properties vary among the several types, when used wisely they can provide helpful insights into some of the key mechanisms for possible economic developments, while indicating orders of magnitude of impacts, even those that we have not yet experienced and remain as yet unknown. Modeling can also provide a framework within which to identify more clearly the issues in areas where differences of views persist. The main purpose of this paper is to present some economic model simulations for these various ends.

A dynamic, multi-region, Computable General Equilibrium (CGE) model with international capital mobility is employed in this paper. It is a modified version of the standard Global Trade Analysis Project (GTAP) model[1]. One of the benefits of the GTAP model is that it deals with developing and developed economies with equal importance while showing developments in almost all Asian economies, in particular in those with which we are currently concerned. In the current model simulations, economies are aggregated into 16 groups, with the ASEAN-4 economies, China, the Asian Newly Industrialized Economies (NIEs) and Japan distinguished individually.

The analyses conducted here focus on the real side of the economy and on trade-linkage effects rather than on the currency market implications. This follows most of the studies by economic models currently available and reflects several considerations, including the fact that the economic effects of stock market volatility and/or asset price bubbles and their bursting are hard to predict[2] even in the developed economies, and the fact that macroeconomic models have some limitations in analyzing financial phenomena.

The simulations in this paper show magnitudes of the longer-term impact on steady state equilibrium. In the short-term, however, economic effects both in terms of direction and size can be different from their ultimate longer-run impact. In fact, the recent OECD Economic Outlook[3] has shown a possibility of a much more significant negative short-term impact of the crisis, particularly in Japan.

2. The Recent Asian Financial Crisis

Before presenting the model simulations, which are the main contribution of this paper, key features of current Asian economic developments are briefly discussed.

Depreciation of Currencies

A number of Asian economies have experienced rapid and significant depreciation of their currencies since mid-1997. Both the timing and extent of the depreciations, which

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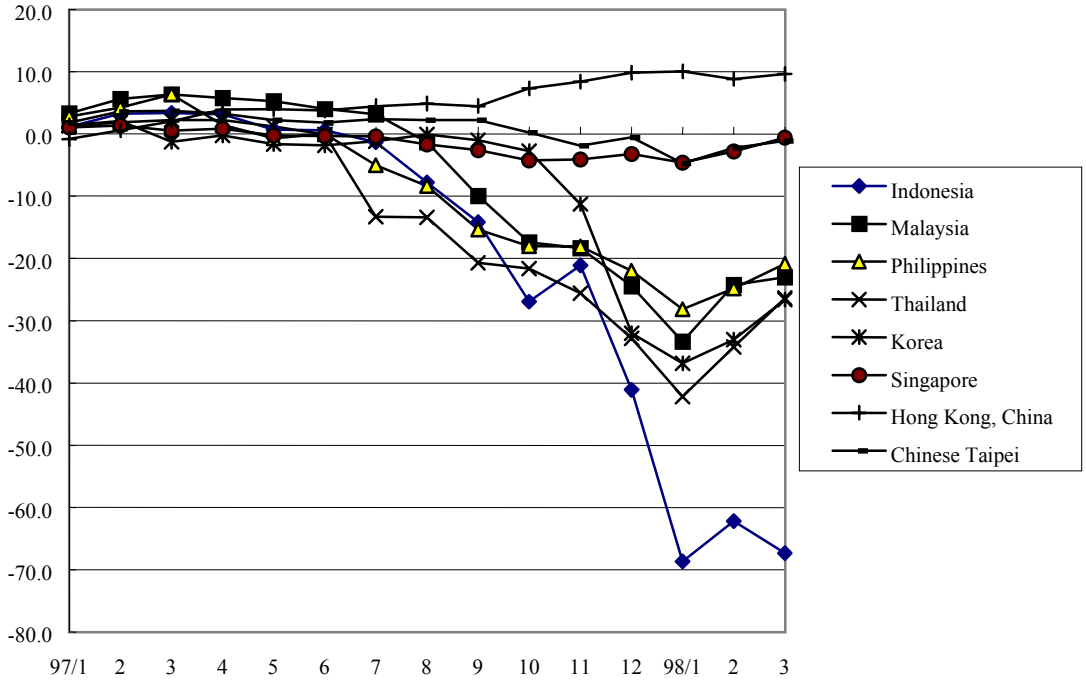
[1] See Hertel (1997) for an introduction to the GTAP framework.

[2] Using EPA World Economic Model simulations, Kawasaki and Tsutsumi (1996) estimate that the effects of capital loss due to the bursting of asset price bubbles in Japan in early 1990, which cumulatively amounted to more than a year and a half of Japanese GDP, lowered Japanese real GDP by only about 1 per cent in 1994.

[3] See OECD (1997) and OECD (1998).

were initiated by the fall of Thailand's baht, vary among the affected economies. Indonesia has been affected seriously when looked at in terms of changes in the real effective exchange rates.[4] Three other ASEAN economies (Malaysia, the Philippines and Thailand) and Korea have also been significantly affected. Moreover, these Asian economies in general have experienced a steep fall in stock and property prices and a sharp rise in interest rates.

Chart 1
Real Effective Exchange Rates for Asian Economies



Note : Original data are monthly averages, equal to 100 in 1990. Figures above show changes in per cent from the REER levels in December 1996 in the individual currencies.
Source : "Emerging markets: Economic indicators", JP Morgan

Exchange rate considerations are important for investors. Stable exchange rates promote production abroad through Foreign Direct Investment (FDI) while avoiding risks in exchange loss. According to the "EXIM Japan FY 1997 Survey"[5] in JEXIM (1998), which is an annual opinion survey for the outlook of Japanese FDI, among the most promising destinations for investment in the medium term (approximately three years), Thailand, which has experienced rapid currency depreciation, was ranked in fourth place in 1997 compared to second place in 1996. While the response ratio has

[4] Depreciation of the currencies in terms of real effective exchange rates is smaller than that in their nominal exchange rates, for example, against the US dollar. In addition to the fact that relative inflation is taken into account, it should be noted that many trading partners have also experienced currency depreciation against the dollar.

[5] The survey was carried out in July to September 1997. The responses did not reflect developments of currency depreciation which took place after that time, such as that in Korea and which became much more significant in the four ASEAN economies, particularly in Indonesia.

shown a declining trend in several Asian economies, China has kept the first position during the past four years.

Table 1
Promising Economies for Investment in the Medium-Term

(%)

Rank	FY 97 Survey	Ratio	FY 96 Survey	Ratio	FY 95 Survey	Ratio
1st	China	64	China	68	China	74
2nd	USA	36	Thailand	36	Thailand	36
3rd	Indonesia	28	Indonesia	34	Indonesia	33
4th	Thailand	25	USA	32	USA	32
5th	India	23	Vietnam	27	Vietnam	28
6th	Vietnam	19	Malaysia	20	Malaysia	22
7th	Philippines	14	India	18	India	17
8th	Malaysia	13	Philippines	13	Philippines	15
9th	Brazil	8	Singapore	10	Singapore	10
10th	Chinese Taipei	8	UK	7	UK	7
			Chinese Taipei	7		

Source: JEXIM (1998)

It has been argued that fixed exchange rate regimes may in general be accompanied by costs in economic development and macroeconomic policies. For example, domestic business expansion could be limited by a "ceiling of balance of payments." As well, import expansion induced by economic growth would need to be financed by foreign reserves, which are finite, to maintain the level of the exchange rate. Therefore, domestic fiscal and financial policies could be constrained. However, these arguments would not necessarily be relevant to Southeast Asia where it is thought that stable exchange rates created confidence for capital inflows as discussed above and led to higher economic growth.

Amongst the factors that have been suggested as possible explanations for the exchange rates depreciations in Asian economies affected by the crisis are speculative international capital flows and the worsening of economic fundamentals, including large external deficits, insufficient foreign reserves, loss of international competitiveness due to overvalued exchange rates under conditions such as lower labour productivity, the poor functioning of financial intermediation, and the bursting of asset price bubbles.

The relative significance of these factors varies in different economies. Moreover, the reason for the crisis cannot be attributed to any one of these factors individually, due to correlations among them. For example, the inflows of capital induced by current account deficits might have contributed to an increase in foreign reserves. In economies where sterilization policies are constrained by underdeveloped bond markets, which is typically the case in many Asian economies, this in turn may have contributed to expansion of the money supply through an increase in high-powered money. Bursting of monetary bubbles could have brought about significant effects in these economies.

Developments in Trade

As pointed out in APEC (1995), one of the typical features in the development of Asian economies was the association between higher economic growth and the deepening of economic interdependencies within the Asia-Pacific region. As a result, for individual economies in Asia, Asian economies as a whole now account for large shares of trade both in terms of destination of exports and origin of imports. This aspect has played an important role as concerns the impact of currency depreciations in the region on economic growth. The negative income effects have been amplified through the close trade linkages in the same manner that benefits of higher economic growth in the past were shared through the expansion of trade. On the other hand, price effects have been mitigated to some extent in terms of changes in relative exchange rates.

Table 2
Ratio of Intra-Regional Trade

	Oceania	Japan	ASEAN 4	China	Asian NIEs	US & Canada	Mexico & Chile
Oceania	11.9	21.7	9.1	3.9	19.9	8.5	0.4
Japan	2.2	-	12.1	5.0	25.1	28.9	1.0
ASEAN 4	2.0	18.1	5.7	3.0	23.8	21.3	0.4
China	1.3	19.1	3.7	-	33.1	17.5	0.4
Asian NIEs	1.9	9.7	10.3	16.0	14.4	22.5	0.6
US & Canada	2.0	9.4	3.3	1.8	10.2	36.1	6.5
Mexico & Chile	0.0	4.0	0.6	0.3	2.7	74.0	0.6

Source, IMF, Direction of Trade Statistics Yearbook, 1989-1995.

The imports of Asian economies from the world as a whole have shown significant declines. This reflects higher import prices in terms of national currencies due to currency depreciation (substitution effects) and lower demand because of shrinkage of domestic demand (income effects). The latter is partly due to tightened policy responses. Those trends are much more clearly seen in Korea, Indonesia and Thailand, the economies that were most seriously affected by currency depreciation.

As regards aggregate exports from the region, which had shown increasing trends until mid-1997 when the crisis hit, these are far from being further boosted by the improvements in international price competitiveness. In general, the recent trends in exports have been determined by economic developments in their destinations rather than in their origins. In this respect, it should be noted that exports in the region could be reduced more by the contractionary policy reactions within the region, which are important export markets of the region itself, as discussed above, as compared to possible developments in demand from economies external to the region.

Chart 2-A
Development of Asian Exports to World

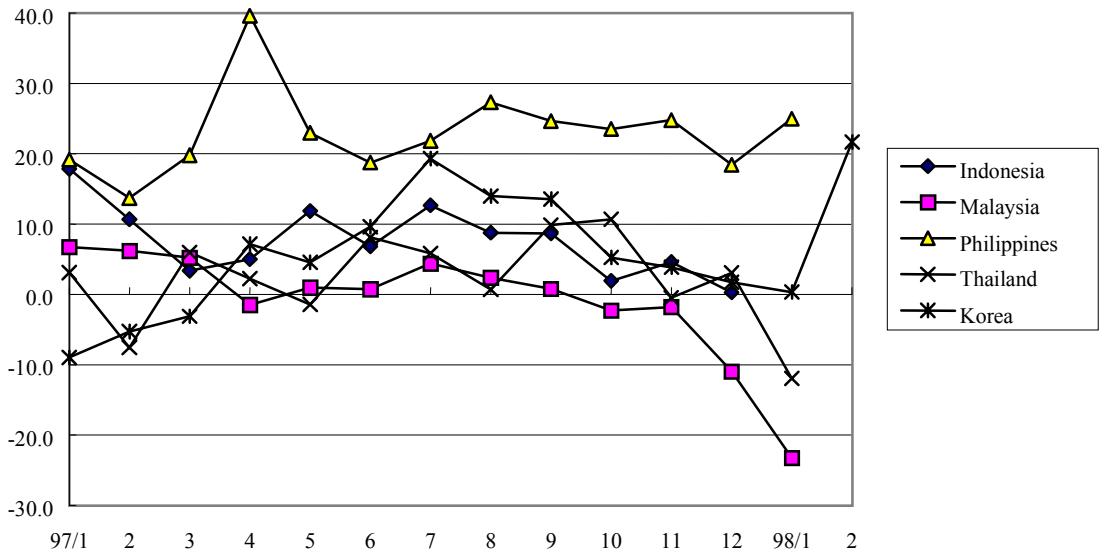
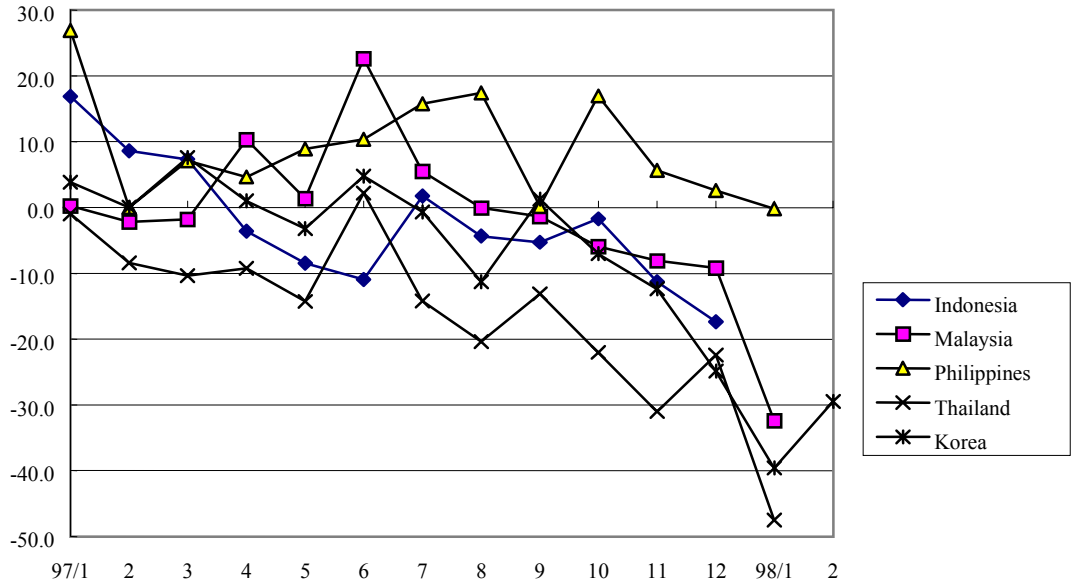


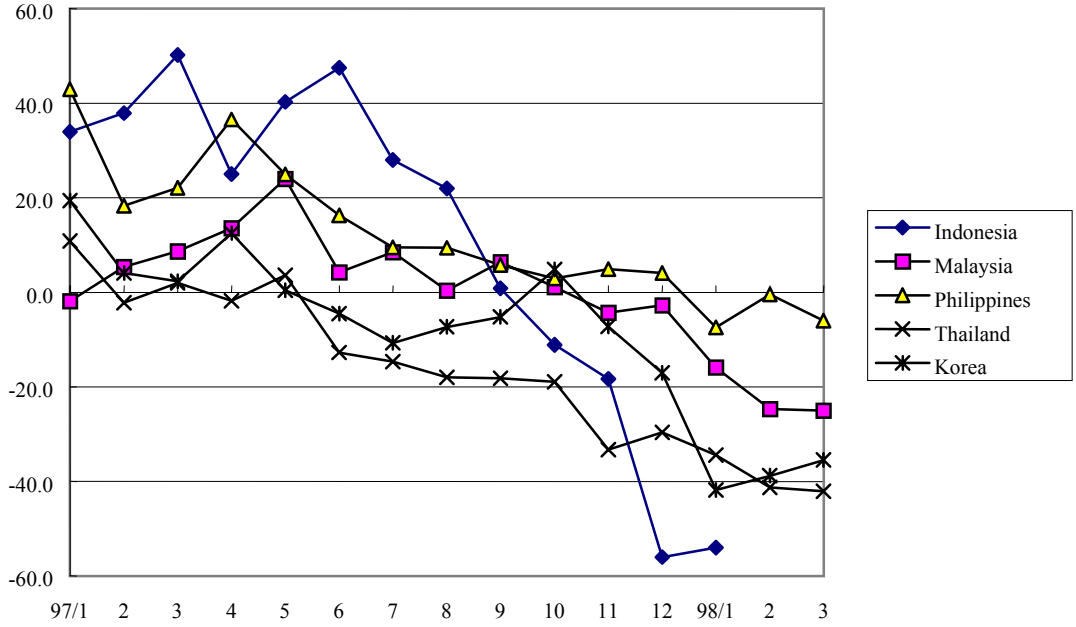
Chart 2-B
Development of Asian Imports from World



Note : Per cent changes over the previous year for those data in US dollars.
Source : "Foreign Trade Statistics ", Central Bureau of Statistics, Indonesia,
"Monthly Bulletin ", Bank Negara Malaysia,
"Merchandise Trade Statistics", National Statisitics Office, Philippines,
"Monthly Bulletin", Bank of Thailand,
and "Monthly Statistics of Korea", National Statistics Office, Korea
in "Kaigai Keizai Data (Overseas Economic Indicators) ", Economic Planning Agency

As regards the loss for economies outside the region of export opportunities to ASEAN and Asian NIEs, this is thought to be most significant for Japan, which has the biggest trade with those Asian economies among developed OECD economies. In fact, according to the recent "Merchandise Trade Statistics" by the Japanese Ministry of Finance, the decline of Japanese exports to the Asian economies in question is shown to be significant. However, it should be noted that the Japanese exports to the world as a whole have shown buoyant trends partly because of the weaker yen against the US dollar. Along with the recent stagnant trend in domestic demand, which could reduce the expansion of imports, this could result in a larger trade surplus in 1997.

Chart 3
Japanese Merchandise Exports to Asian Economies



Note : Per cent changes over the previous year for those data in Japanese yen.
Source : "Merchandise Trade Statistics", Ministry of Finance

Slowdown of Economic Growth

Tight economic policies have been taken in the economies in question in order to stabilize volatile financial markets. Budget expenditures are being reduced and monetary policy is being tightened. As a result, rates of growth in domestic demand in the crisis economies will substantially slow down. According to the economic outlooks published by international organizations, including the IMF (1998), economic growth rates in the four ASEAN economies (Indonesia, Malaysia, Philippines and Thailand) and Korea are forecast to decline significantly in 1997 and 1998 as compared to their rates of expansion of between 6 to 8 per cent in 1996 which corresponded to their recent average growth rates. A slowdown of economic growth is also projected for other Asian economies like China and Singapore, although to a lesser extent. It should be noted that most current projections have been revised growth rates downward from

those published at the end of 1997 in line with further depreciation of Asian currencies in early 1998. In Indonesia, Thailand and Korea, which are affected most significantly, economic contraction is now forecast in 1998.

Table 3
Economic Outlook for Asian Economies

(%)

	1996		1997		1998		1999
Indonesia	8.0	(8.0)	5.0	(5.0)	-5.0	(2.0)	n.a.
Malaysia	8.6	(8.6)	7.8	(7.0)	2.5	(2.5)	n.a.
Philippines	5.7	(5.7)	5.1	(4.3)	2.5	(3.8)	n.a.
Thailand	5.5	(6.4)	-0.4	(0.6)	-3.1	(0.0)	n.a.
China	9.7	(9.6)	8.8	(8.8)	7.0	(7.5)	n.a.
Korea	7.1	(7.1)	5.5	(6.0)	-0.8	(2.5)	4.1
Singapore	7.0	(7.0)	7.8	(6.2)	3.5	(4.8)	5.0
Hong Kong, China	4.9	(4.9)	5.3	(5.3)	3.0	(4.1)	4.3
Chinese Taipei	5.7	(5.7)	6.9	(6.7)	5.0	(6.4)	5.2
Japan	3.9	(3.9)	0.9	(1.0)	-0.0	(1.1)	1.3

Note : Figures in the parenthesis show those in the previous outlook in IMF (1997)
Sources : IMF (1997), IMF(1998)

It may be worth looking at past experiences in order to identify the likely magnitude of the crisis. In 1994, Mexico experienced a serious financial crisis. Its exchange rate, in terms of real effective exchange rate, depreciated by 48 per cent in 1995 and this level was sustained after that. Real GDP fell by 6.2 per cent in 1995 while inflation as measured by the GDP deflator accelerated to 38.0 per cent.

Table 4
Experience of the Mexican Crisis

	Effective Exchange Rate	Real GDP	GDP Deflator	Trade Balance
	1991=100	% Change	% Change	US$ billions
1994	89.5	4.4	8.3	-18.5
1995	46.6	-6.2	38.0	7.1
1996	39.5	5.1	31.5	6.5

Source: OECD

Although Mexico's growth rate recovered in 1996 partly due to an appropriate policy response, it should be noted that the Mexican case differs in several aspects compared with the Asian crisis. In particular, it took place just in Mexico and did not spread widely to other neighboring economies in Latin America. This could be because of lesser interdependencies in the region than among Asian economies as discussed above. Moreover, Mexico's close links to the United States is thought to have helped in the immediate recovery of Mexico.

3. Ultimate Effects of the Currency Depreciations

In addition to the magnitudes of short-term deviations of the economy due to the current financial turbulence, the magnitude of the longer-term impacts on the steady state equilibrium are also a matter of significant concern. Such ultimate effects can be estimated by a Computable General Equilibrium (CGE) model, which simulates numerically the general equilibrium structure of the economy. Several simulations are carried out mainly looking at price effects and income effects stemming from the Asian currency depreciations. Those outcomes are compared to identify the transmission mechanisms of the economic impact as well as their magnitudes.[6]

Among others, the Global Trade Analysis Project (GTAP) model, created on the basis of the version 3.0 database, is used for the model simulation in this paper. A standard version of the GTAP model was modified in respect of the capital formation features. First, international capital movements were allowed in the sense that the expected rate of return on capital is equalized.[7] Second, a "dynamic" income effect (in other words capital accumulation/decumulation) was incorporated. This linked changes in income to changes in production capacities through induced savings and investment effects.[8] It is thought that a capital formation mechanism is particularly important in Asian economic developments.

Effects of Changes in Terms of Trade

One of the key linkages to be explored is the impact of changes in terms of trade that resulted from the currency depreciation. It is expected that the crisis economies will experience improved international price competitiveness, which could help expansion of their exports while reducing their imports.

Nominal exchange rates of a number of Asian currencies against the US dollar started depreciating in July 1997.[9] As of December 1997, the monthly average level of the value of the Indonesian rupee was around half of that in June 1997. Significant currency depreciations were also recorded in Korea and Thailand as well as in Malaysia and the Philippines. Exchange rates of these economies reached historically low levels in early 1998 but subsequently recovered as of beginning of April 1998, except in the case of Indonesia. Therefore, model simulations were run evaluating the impact of currency depreciation in Asian economies observed until the end of the year 1997. It should be noted that this is just an assumption for the purpose of the simulations and should not be taken as a prediction of any future developments in these exchange rates.

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[6] As for other model simulations on Asian financial crisis, several recent studies shall be referred to. Those include Ianchovichina and McDougall (1998), Liu et al. (1998) and McKibbin (1998).

[7] In terms of the GTAP model framework, the parameter RORDELTA is set as one.

[8] In order to incorporate this mechanism, the methodology shown in François et al. (1996) is employed, while the savings ratio is still fixed.

[9] Source: IMF, International Financial Statistics (IFS).

Table 5
Magnitudes of Currency Depreciation in Asia

	Exchange rates against the US dollar			Import Prices	Export Prices
	June 1997	Dec. 1997	% Change [1]	% Change	% Change
Indonesia	2,446	4,995	104.2	104.0	-51.0
Malaysia	2.5	3.8	49.8	49.8	-33.2
Philippines	26.4	37.2	40.9	40.9	-29.0
Thailand	25.8	45.3	75.7	75.7	-43.1
Korea	889	1,484	66.8	66.9	-40.1
Singapore	1.4	1.6	15.5	15.5	-13.4
Chinese Taipei	27.9	32.5	16.5	16.5	-14.2

Source: IMF, International Financial Statistics
Note: a positive number indicates depreciation.

Given that the world price level of many commodities is largely determined in US dollar terms, steep depreciation of a currency against the US dollar leads to significant importation of inflation in terms of local currencies. According to the input-output structure of the economy and its general equilibrium mechanism, this inflation would eventually be passed through to price formation in the domestic markets of both factor endowments, which are land, labour, and capital, and commodities including supplies of services. As a result, significant domestic inflation would be observed without policy measures to stabilize prices.

Increases in import price inflation will potentially decrease imports of goods and services from abroad. However, there are wider effects. Domestic inflation in general would discourage demand for goods and services at home. In addition, insofar as inflation is passed on to output prices, exports would also be affected by higher costs in terms of local currencies. The current model simulations suggest in fact that export volumes would decrease rather than increase. As a result, real GDP in the Asian economies as a whole would shrink to a significant extent. In terms of individual economies, Thailand would be most seriously affected by price effects. The variation of the impact on individual economies could be a reflection of the variations in the structure of trade and industries in individual economies.

It must be emphasized that stabilization of domestic inflation will be one of crucial prerequisites for an export-led economic recovery in the Asian economies. Accordingly, tightening macroeconomic policy would be a reasonable response. However, as was underlined in the previous section, contractionary income effects in certain Asian economies would be transmitted to other economies through close interdependencies. Moreover, these economies may be suffering from a shortage of intermediate inputs from abroad due to deterioration of terms of trade and, therefore may not be able to fully benefit from the improvements in their international price competitiveness. As far as aid programs from outside the region are concerned, policy measures to support trade of the region should have the first priority.

Trade balances in Asian economies in general would be improved; however, this will largely be due to a decline in import volumes. The ultimate sizes of surpluses that will be generated over the longer term are estimated to be around US$ 7.9 billion in the ASEAN four and about US$ 8.9 billion in the Asian NIEs. These will be reflected in a deterioration of trade balances mainly in the largest three developed economies. The Japanese contribution is estimated to be the largest, amounting to US$ 8.0 billion. The European Union countries meanwhile would see a widening of their deficit by US$ 6.6 billion. However, the deterioration of trade balances in North America (the United States and Canada) could be significantly smaller, possibly limited to US$ 1.7 billion.

Table 6
Economic Effects of Currency Depreciation

	Percentage deviation from baseline					
	Real GDP	Price	Export Vol.	Import Vol.	DTBAL*	EV*
Oceania	0.1	-4.5	-0.5	-1.5	-0.2	-1.4
Indonesia	-23.4	58.5	-40.2	-49.0	3.2	-13.0
Malaysia	-20.0	35.1	-25.1	-29.1	1.6	-5.8
Philippines	-6.2	33.1	-23.9	-14.2	-0.3	-0.4
Thailand	-28.5	64.6	-44.9	-39.3	3.3	-10.6
China	0.1	-3.9	-0.8	-0.9	-0.5	-3.4
Korea	-10.2	42.1	-28.9	-29.6	6.3	7.0
Singapore	-7.1	11.8	-9.6	-10.5	1.1	-0.7
Hong Kong, China	0.2	-4.0	0.1	-0.5	0.6	-0.2
Chinese Taipei	-0.9	9.6	-3.2	-4.9	0.9	1.6
Japan	0.4	-4.0	-1.7	-1.8	-8.0	-23.6
South Asia	0.5	-3.7	-0.6	-0.2	-0.2	-0.3
North America	0.4	-3.8	-0.6	-0.8	-1.7	0.5
Latin America	0.9	-3.9	0.5	0.4	0.0	5.6
Western Europe	0.5	-3.8	-0.3	-0.2	-6.6	-1.4
Rest of the World	0.5	-3.8	0.2	0.1	0.4	1.2
World	-0.2	-2.4	-2.9			-44.9

Note : Deviations in Trade Balance and Equivalent Variation in billion US dollars.
Source : Author

What is striking in these results is that economies outside the region in question are expected to gain rather than lose in terms of real GDP. This would firstly be a result of real income effects, reflecting weaker price developments. World trade prices and GDP deflators would decline by 2 to 3 per cent.[10] This development should be welcome to economies where inflation risks exist, as it would extend economic growth longer than usual while also creating greater possibilities for alternative macroeconomic management. Moreover, the general equilibrium effects of the capital outflow from Asia are to boost capital formation in other economies, which works to offset lower export growth. The magnitudes of these effects vary among the economies

[10] It is shown in simulation outcomes that such disinflation is much more significant in primary commodities like agricultural and food products.

reflecting differences in the economic structures including trade dependencies.[11] Export loss in Japan is shown to be approximately three times larger than those in North America or the EU economies. In any event, this is a good example of how model simulations can offer an opportunity to review alternative scenarios while looking at economic developments in a more comprehensive manner rather than focusing on specific aspects.

Table 7
Decomposition of Changes in Real GDP

	North America	Japan	EU
Components of GDP			
• Consumption (Households)	0.15	0.10	0.24
• Consumption (Government)	0.03	0.01	0.04
• Investment	0.16	0.29	0.25
• Exports	-0.07	-0.19	-0.05
• Imports	0.09	0.15	0.03
GDP	0.36	0.36	0.51

Note: Figures for the components of GDP represent the percent contributions to real GDP growth.
Source: Author

The magnitude of the worldwide effects of the Asian currency depreciations are estimated not to be so large in terms of world output and trade. World real GDP as a whole would decrease by only 0.2 per cent, although the Asian crisis economies would experience double-digit economic contractions. The volume of world trade is estimated to be 2.9 per cent smaller than it otherwise would have been.

It should be noted that this order of income/output loss is significantly smaller than that shown by macro econometric models like the OECD INTERLINK model, which also incorporate international trade linkages. At the same time, the magnitudes of changes in trade and substitution effects do not vary significantly between the two sets of estimates. These differences stem partly from the fact that the model simulations reported here focus on the economic impact over the longer term, in which initial influences, which tend to be much larger, would already be absorbed.

It has been often argued that real GDP suffers as an indicator of economic welfare, as it does not include terms of trade effects. This is a relevant critique for the purposes here since quite significant changes in terms of trade are likely as a result of changes in the values of currencies. Region-specific differences emerge when economic welfare is looked at by the equivalent variations in GDP levels. Among the three economies affected by serious currency depreciation, welfare losses in Indonesia and Thailand would be significant, amounting to more than US$ 10 billion in each economy. In contrast, welfare gains might be expected in Korea. What is striking is that the most

[11] Similar results are also shown in McKibbin (1998) attributing currency depreciation to a rise in risk premium.

significant losses in terms of equivalent variation would be in Japan, amounting to more than US$ 20 billion.

One of the significant benefits of sectoral models, including many CGE models, is that they can provide detailed information concerning economic developments affecting particular commodities and industries. The currency depreciation in many Asian economies is likely to result in significant changes in the worldwide structures of industrial production; this can result in impacts on individual industries that may be much more serious than economy-wide impacts.

On balance, declines in production would be relatively significant in the mining sector and in the machinery and other equipment sector in Asian economies in general compared with output losses in terms of real GDP. Meanwhile, declines in agricultural and food products would tend to be smaller. In textiles and wearing apparel, production cuts in Korea, Indonesia and Philippines are remarkable. In chemicals and metals, the production share of Singapore would decline. In transport equipment including automobiles, Korea and Singapore would reduce production. In the other manufacturing industries, production would decline the largest in Thailand.

Table 8
Changes in Industrial Structures in Asia

Percentage deviation from baseline

	AGR	MNG	PFD	TXL	CHM	MTL	TRN	OME	OMF	EGW	CNS	T_T	OSP	OSG
Oceania	-1.1	2.5	-0.1	2.7	0.2	-0.8	1.6	1.4	0.9	0.0	0.4	0.2	0.1	-0.2
Indonesia	-4.7	-38.6	-8.4	-38.2	-21.6	-20.7	-13.5	-67.5	-26.1	-24.2	-32.5	-26.0	-24.0	-4.0
Malaysia	-4.4	-23.5	-9.4	-19.7	-17.1	-18.5	-19.4	-33.4	-16.7	-20.3	-24.8	-20.5	-15.5	-5.3
Philippines	-1.0	-13.3	-1.2	-20.0	-6.7	-14.7	-5.8	-32.2	-9.5	-5.1	-9.3	-6.4	-5.2	-0.8
Thailand	-8.3	-29.0	-16.1	-32.8	-27.1	-31.2	-25.4	-50.4	-38.9	-27.9	-34.7	-30.0	-26.5	-10.9
China	-0.2	1.2	0.0	2.5	0.3	0.1	-0.3	0.5	0.5	0.3	0.5	0.3	0.0	-0.1
Korea	2.9	12.3	-3.4	-20.9	-10.5	-10.0	-17.0	-10.0	-12.3	-9.1	-15.4	-10.6	-7.7	-2.9
Singapore	0.3	-10.9	-8.5	-9.6	-12.9	-12.6	-18.6	-11.0	-5.2	-8.3	-14.3	-3.2	-2.5	-0.7
Hong Kong, China	-0.5	1.0	-0.4	2.7	-0.3	0.0	1.0	-0.2	1.1	0.6	0.1	0.1	-1.1	-0.9
Chinese Taipei	0.2	2.0	-0.1	1.0	-0.5	-1.0	-1.5	-2.0	0.5	-0.9	-1.5	-1.2	-0.7	-0.7
Japan	0.2	2.6	0.2	1.0	0.2	0.0	0.8	0.4	0.7	0.3	0.8	0.3	0.4	0.1
South Asia	0.1	0.7	0.1	2.0	0.7	1.0	0.9	1.3	0.9	0.8	1.0	0.6	0.4	0.2
North America	-0.4	0.6	0.2	1.8	0.4	0.5	-0.1	0.9	0.9	0.4	0.7	0.3	0.3	0.1
Latin America	0.2	1.1	0.5	2.0	1.1	0.9	1.2	2.0	1.4	0.9	1.5	1.0	0.9	0.5
Western Europe	0.1	0.6	0.2	1.9	0.5	0.7	0.4	0.9	0.9	0.5	1.0	0.5	0.5	0.1
Rest of the World	0.0	0.7	0.4	2.4	0.7	0.6	1.1	1.3	0.9	0.6	1.0	0.5	0.5	0.2

Note : Mnemonics stand for industries as follows;
AGR: Agriculture, Forestry & Fishery, MNG: Mining, PFD: Food & Beverages,
TXL: Textiles & Wearing Apparel, CHM: Chemicals, MTL: Metals,
TRN: Transport Equipment, OME: Machinery & Equipment, OMF: Other Manufacturing,
EGW: Electricity, Gas & Water, CNS: Construction, T_T: Trade & Transport,
OSP: Other Services (private), OSG: Other Services (government)
Source : Author

Influences of Lower Growth

Estimated output losses in Asian economies due to the price effects of currency depreciation are shown to be relatively large. This is firstly because the model

simulation above shows the ultimate effects in a cumulative manner. However, these should not be considered as the likely outcomes in an economic forecasting sense, since they do not reflect the influence of possible policy reactions, which are reflected in forecasts.

In this regard, in order to estimate the likely magnitudes of the short-term economic effects of the Asian crisis, further simulations were carried out. Table 9 shows the impact of the crisis on Asian growth on annual growth in 1997 and 1998 and cumulatively over these two years. The calculations are based on the assumption that, without the financial turbulence, Asian economies would have maintained their 1996 economic growth rates.[12] In other words, it is assumed for the purposes of the model simulation that the cumulative amount of slowdown in Asian economic growth in 1997 and 1998 (as estimated using the IMF projections for growth in 1997 and 1998) is attributed to the impact of the Asian crisis. In terms of modeling, these particular simulations focus on income effects that work through trade linkages, which highlights the economic effects outside the region. This then allows comparison with the price effects simulated above, based on the impact of the currency depreciations.

Table 9
Slowdown of Asian Growth

	GDP Growth (%)			Cumulated Changes in GDP Level
	1996	1997	1998	1997-1998
Indonesia	8.0	5.0	-5.0	-14.5
Malaysia	8.6	7.8	2.5	-6.3
Philippines	5.7	5.1	2.5	-3.6
Thailand	5.5	-0.4	-3.1	-13.3
China	9.7	8.8	7.0	-3.3
Korea	7.1	5.5	-0.8	-8.8
Singapore	6.9	7.8	3.5	-2.4

Source: IMF (1998)

Two alternative scenarios can be used to estimate the economic effects of lower economic growth. One is to assume a shift of Aggregate Demand (AD Curve); the other is to assume a shift in Aggregate Supply (AS Curve). In this paper, in order to estimate the economic impact of a downward shift of the AD curve, regional investment is reduced so that the level of GDP will be lower by a certain amount, which is shown in Table 9. The aim here is to investigate the role of capital formation, which was found in the previous section to be one of the key factors in differentiating the economic impact across economies. Meanwhile, the economic impact of a downward shift of the AS Curve is estimated by lowering Total Factor Productivity (TFP) so as to adjust the GDP level, as is the case of the AD Curve shift. In this case,

[12] Lower economic growth is also projected in China in addition to Asian economies where currency depreciation already occurred. Therefore, its slowdown is included in the assumption for model simulations.

the aim is to look at Asian production structures that have been highlighted during the dialogue on the so-called "Asian miracle".

Reduction in Investment

One of the notable features in this simulation is that the lower investment in Asian economies leads, through capital outflow to acceleration of capital formation outside the Asian economies. This leads to an expansion of production and incomes outside of Asia which more than offsets the slowdown in Asian economic growth and in fact results in an increase in world GDP as a whole by 0.2 per cent.

In this simulation, the lower income in Asia leads to a reduction in demand for imports, which corresponds in magnitude approximately to the extent of the decline in income. On the other hand, import volumes in economies outside of Asia increase, contributing to larger Asian export volumes. Overall, the simulation shows a reduction in the volume of world trade that is limited to around 0.3 per cent, or only a tenth of that estimated from the price effects of currency depreciation above.

Table 10
Economic Effects of Reduction in Investment

Percentage deviation from baseline

	Real GDP	Price	Export Vol.	Import Vol.	DTBAL*	EV*
Oceania	0.4	-0.2	0.2	0.2	-0.2	0.7
Indonesia	-14.5	0.4	-11.3	-15.5	1.6	-15.2
Malaysia	-6.3	0.9	-5.4	-6.0	0.3	-3.0
Philippines	-3.6	0.8	-3.3	-3.6	0.3	-1.3
Thailand	-13.3	2.7	-10.1	-13.0	2.6	-11.6
China	-3.3	-0.8	-0.2	-4.4	4.4	-9.5
Korea	-8.8	-0.8	-0.9	-10.1	8.4	-21.9
Singapore	-2.4	0.3	-2.5	-2.8	0.5	-0.5
Hong Kong, China	0.6	-0.4	0.3	0.3	-0.2	0.2
Chinese Taipei	0.5	-0.3	0.0	0.2	-0.3	0.6
Japan	0.5	-0.0	-0.9	0.4	-5.3	11.5
South Asia	0.6	0.0	-0.0	0.7	-0.4	1.5
North America	0.5	-0.0	0.1	0.5	-2.9	20.5
Latin America	1.1	-0.2	0.9	1.1	-1.0	10.3
Western Europe	0.6	-0.0	0.1	0.7	-6.0	34.6
Rest of the World	0.8	-0.0	0.7	0.8	-1.8	10.1
World	0.2	-0.0	-0.3			27.0

Note : Deviations in Trade Balance and Equivalent Variation in billion US dollars.
Source : Author

Output prices in Asian economies would rise or decline according to the degree of the *ex post* AS Curve shift. In the ASEAN 4 economies and Singapore, lower investment would result in increases in prices because of less capital stock, which results in smaller production capacity and thus higher costs. On the other hand, in Korea and China, less demand for investment could lower prices. These features would distinguish the relative price competitiveness of the economies in the international export markets. In

this regard, as far as tightening economic policy is concerned, an expenditure/demand cut should be achieved by reducing consumption rather than investment.

While economies outside the region see a reduction in their export volumes to Asia, declines are not seen in the exports of the Asian region itself as a whole. In this regard, Japan stands out as nearly the single exception, with a slight decrease in exports. The loss in export markets would mainly be allocated within the Asian economies in question through the close interdependencies in the region, which has often been pointed out.[13]

Lower Total Factor Productivity (TFP)

In this simulation, the Asian economies see higher inflation because of a reduction in supply capacity. Export prices go up and result in a decline in export volumes through price effects. Meanwhile, Asian imports decrease due to lower incomes.

Table 11
Economic Effects of Lower TFP

Percentage deviation from baseline

	Real GDP	Price	Export Vol.	Import Vol.	DTBAL*	EV*
Oceania	0.0	-0.2	-0.1	-0.3	-0.0	-0.2
Indonesia	-14.5	2.2	-14.3	-12.4	-0.3	-15.6
Malaysia	-6.3	1.4	-6.1	-5.2	-0.3	-3.1
Philippines	-3.6	1.0	-3.8	-3.0	0.1	-1.6
Thailand	-13.3	3.7	-13.2	-10.6	0.5	-11.9
China	-3.3	0.5	-3.2	-2.7	0.2	-10.3
Korea	-8.8	1.5	-7.8	-7.3	0.9	-22.3
Singapore	-2.4	0.1	-2.6	-2.7	0.1	-0.8
Hong Kong, China	-0.3	-0.3	-0.4	-0.7	0.1	-0.3
Chinese Taipei	-0.1	-0.2	-0.3	-0.5	-0.1	-0.3
Japan	-0.0	-0.3	-0.3	-0.8	-0.4	-3.5
South Asia	0.0	-0.0	-0.1	-0.1	-0.0	0.0
North America	0.0	-0.1	-0.2	-0.3	-0.2	-0.7
Latin America	0.1	-0.1	0.0	-0.0	-0.0	0.4
Western Europe	0.0	-0.1	-0.1	-0.2	-0.4	-0.7
Rest of the World	0.0	-0.1	-0.0	-0.0	-0.1	0.4
World	-0.3	-0.1	-0.9			-70.7

Note : Deviations in Trade Balance and Equivalent Variation in billion US dollars.
Source : Author

In comparison with the former simulation, the influence of lower productivity is limited. Changes in Investment-Saving (IS) balances and therefore trade balances would be marginal both in the Asian economies and outside the region. One of the distinguishing features in this case is a common decrease in exports and imports throughout the regions all over the world. As a result, magnitudes of shrinkage in

[13] See APEC (1995).

world trade as a whole would be larger (0.9 per cent) compared with the case when slower growth is generated by reduction in investment.

On the other hand, these simulations do not show any income gains through capital accumulation outside the Asian economies; inflation outside the region would also be minimally affected. The world real GDP would be smaller by 0.3 per cent, which corresponds to the weighted average of the slower growth in the Asian economies. In terms of equivalent variation, welfare loss in the world as a whole would amount to US$ 71 billion. This is compared with a gain by US$ 27 billion in the case of a demand shift where welfare gains in other economies more than offset the welfare losses in Asian economies. These simulations suggest that the development of economic welfare outside the Asian economies would be dominated by capital movements and accumulation in addition to trade linkage effects.

4. Effectiveness of Possible Policy Reactions

From a policy perspective, it would be useful to estimate the likely orders of magnitude of impact of policy measures that could be taken by various authorities in response to the current economic difficulties in Asia. In this regard, the effectiveness of three representative scenarios is discussed in this chapter on the basis of model simulations. Those are the impact of a) devaluation of the Chinese yuan, b) domestic demand expansion in Japan, and c) a trade liberalization initiative in the Asia-Pacific Economic Cooperation (APEC).

Devaluation of Chinese Yuan

The significant extent of currency depreciation in the crisis-hit Asian economies has altered their international price competitiveness significantly not just with respect to economies outside the region but also with respect to those Asian economies that have not devalued their currencies. In this respect, attention is focussed on the future developments in the Chinese yuan[14] and Hong Kong dollar, which have not yet depreciated.

One experimental simulation was carried out concerning Chinese currency depreciation. It is assumed that both the Chinese yuan and the Hong Kong dollar would be devalued by 30 per cent against the US dollar, in conjunction with depreciation of Asian currencies, which are already simulated in the previous chapter. This means that their import prices would be higher by the same amount in national currencies given the world price levels of the US dollar, and their export prices in terms of the US dollar would be lower by around 23 per cent compared with domestic price formations. It should be noted that this simulation discusses the impact of such currency depreciation but it does not predict the likely degree of currency deprecation nor suggest its possibility itself.

[14] It is concluded in Liu et al. (1998) that while China did experience a large nominal depreciation, the Chinese yuan has actually appreciated during the 1990s in real terms.

China and Hong Kong, China would be seriously affected by currency depreciation. Import volumes would decline by around 15 per cent in both economies, which corresponds to about half of the magnitudes in import price rises. On the other hand, the impact on export volumes is estimated to vary widely between the two. Hong Kong, China would experience more serious losses in export markets.[15] In comparison with the price effects of currency depreciation in the other Asian economies (see Table 6), the trade balance would deteriorate by US$ 1.5 billion in Hong Kong, China while it would improve by the same amount in China. As a result, economic damage in terms of both real GDP and the equivalent variation would be much more significant in Hong Kong, China. The output loss in China would be relatively smaller compared with those in the other Asian economies.

Table 12
Impact of Devaluation of Yuan

Percentage deviation from baseline

	Real GDP	Price	Export Vol.	Import Vol.	DTBAL*	EV*
Oceania	0.0	-5.7	-0.6	-1.8	-0.2	-1.9
Indonesia	-23.5	56.8	-40.2	-49.0	3.2	-13.3
Malaysia	-19.9	33.6	-25.0	-29.1	1.5	-6.0
Philippines	-6.3	31.7	-23.9	-14.3	-0.3	-0.5
Thailand	-28.6	62.9	-44.9	-39.4	3.3	-11.0
China	-3.8	18.0	-14.5	-14.2	1.0	3.6
Korea	-10.2	40.8	-28.8	-29.5	6.3	6.5
Singapore	-7.4	10.4	-9.7	-10.8	1.1	-0.9
Hong Kong, China	-9.3	28.9	-25.6	-16.4	-0.9	-1.7
Chinese Taipei	-0.9	8.5	-3.2	-4.9	0.7	1.2
Japan	0.4	-5.1	-1.8	-1.9	-8.9	-31.6
South Asia	0.5	-4.6	-0.6	-0.2	-0.1	-0.6
North America	0.3	-4.9	-0.7	-1.0	-1.4	-4.1
Latin America	0.9	-4.9	0.4	0.3	0.3	4.7
Western Europe	0.5	-4.9	-0.4	-0.3	-6.8	-9.9
Rest of the World	0.5	-4.9	0.1	-0.1	1.0	-0.9
World	-0.3	-3.0	-3.7			-66.4

Note : Deviations in Trade Balance and Equivalent Variation in billion US dollars.
Source : Author

Macroeconomic effects outside the two economies would be limited. World real GDP would decrease by around 0.3 per cent compared to a decline of 0.2 per cent in the case of currency depreciation in other Asian economies. However, this further decrease is largely due to income losses within the two economies. Trade volumes outside the two economies would not be affected. Devaluation of the two currencies would primarily lead to deterioration in economic conditions within the two economies. International competitiveness outside the economies is shown to be least affected.

[15] This does not necessarily mean that China is a product market for manufactures of Hong Kong, China. It is well known that most exports from Hong Kong, China are re-exports of imported goods from other economies including China.

Domestic Demand Expansion in Japan

Stabilization of the situation in the crisis-affected Asian economies would clearly be facilitated by international cooperation, in particular from the developed economies. In this regard, Japan, as one of the major Asian economies, would be expected to play a major role by increasing its own demand. However, effectiveness of expansion of government investment to stimulate a stagnant economy is one of the key issues in macroeconomic theory.[16] Moreover, in Japan's particular case, "efficiency" of fiscal policy measures would be required in addition to their "effectiveness" given that Japan faces the rapid aging of its population in the coming decades.

The impact of domestic demand expansion in Japan was simulated using the CGE model by increasing Japanese domestic investment by one per cent of its real GDP. This corresponds to a stimulus of around 5 trillion yen, i.e. US$ 40 billion in 1997. It should be noted that this does not mean to suggest an appropriate size of economic stimulus. The calculation in this section is made simply to provide an estimate of the simple multiplier.

Expansion of Japanese domestic investment expenditures is shown to result in an increase in real GDP by more than one per cent, which is the size of the initial impact. This is because induced savings and investment due to the initial increase in income in turn impacts positively on production capacities which causes a further increase in income. Japanese import volumes would increase through income effects by 1.6 per cent, while export volumes are shown to decrease by 1.8 per cent because of price effects. As a result, the Japanese trade balance would deteriorate by US$ 11.6 billion.

What is important to note in this simulation is that improvements in the trade balance in Asian economies are limited. Those amount to US$ 0.5 billion in the ASEAN 4 economies, US$ 0.4 billion in China and US$ 1.2 billion in the Asian NIEs. This ranges just one to three per cent of the size of the Japanese domestic demand expansion. This outcome is intuitively self-evident regardless of model simulations: although Japanese import ratios from Asian economies are higher (more than 40 per cent) than with respect to other economies, the import share of GDP is quite small (around 10 per cent).

Given the current trade structures in the world economy, the lion's share of the benefits would be enjoyed by the EU. North America could also benefit significantly. It should be noted that improvements in Asian external balances as a whole would be small not just in absolute amounts but also in terms of their ratios in the world. In addition, it must be emphasized that such benefits in improving the trade balances are not always larger than the size of financing programs offered by the IMF and developed economies including Japan. Meanwhile, the cost of policy measures is significantly larger than those programs.

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[16] Empirical studies by macroeconomic model simulations, including those by the EPA World Economic Model, have tended to reject significant crowding-out effects at the least in Japan. Moreover, introducing the Scandinavian wage and price behavior to a smaller econometric model, it is shown in Kawasaki (1997a) that external crowding-out effects would disappear in Japan.

Table 13
Impact of Japanese Expansion of Demand

Percentage deviation from baseline

	Real GDP	Price	Export Vol.	Import Vol.	DTBAL*	EV*
Oceania	-0.4	-0.0	-0.3	-0.4	0.1	-0.7
Indonesia	-1.1	0.1	-0.9	-1.2	0.1	-1.1
Malaysia	-1.0	0.1	-1.0	-1.1	0.0	-0.5
Philippines	-0.6	0.0	-0.6	-0.7	0.0	-0.2
Thailand	-1.5	0.2	-1.2	-1.6	0.3	-1.4
China	-0.4	-0.2	-0.1	-0.6	0.4	-1.2
Korea	-0.7	-0.2	-0.1	-0.9	0.7	-1.9
Singapore	-0.6	-0.1	-0.7	-0.8	0.1	-0.2
Hong Kong, China	-0.8	0.0	-0.7	-0.8	0.2	-0.4
Chinese Taipei	-0.5	-0.1	-0.4	-0.7	0.2	-1.0
Japan	1.1	0.2	-1.8	1.6	-11.6	28.8
South Asia	-0.5	-0.2	-0.1	-0.8	0.3	-1.3
North America	-0.4	-0.1	-0.2	-0.6	2.4	-18.1
Latin America	-0.9	-0.0	-0.7	-0.9	0.8	-8.4
Western Europe	-0.5	-0.1	-0.2	-0.7	4.6	-29.9
Rest of the World	-0.6	-0.1	-0.5	-0.6	1.3	-7.5
World	-0.2	-0.1	-0.5			-45.0

Note : Deviations in Trade Balance and Equivalent Variation in billion US dollars.
Source : Author

Another interesting result in this simulation is that, taken together, all the economies outside Japan would lose rather than gain both in output and economic welfare. Although Japan would gain substantially, world real GDP as a whole would decline by 0.2 per cent and the world equivalent variation would also decrease by US$ 45 billion. Thus, while Japanese domestic demand expansion would be effective to stimulate the stagnant Japanese economy, this would not necessarily be always beneficial to the other economies.

This aspect could be a reflection of one of the notable features of the GTAP model. The model extends the Walrasian general equilibrium structure by equalizing global investment and global savings. Although additional demand in certain regions would stimulate incomes in the other regions through trade linkages, an autonomous increase in investment in certain regions would accompany reductions of savings/investment in the other regions. The mechanism for this is the international capital movements that are generated by changes in expected rates of return on capital among the regions. This occurs even when the dynamic capital accumulation mechanism is incorporated as these two effects may offset each other. Therefore, outcomes in particular economies would entirely depend on relative significance of the two mechanisms, which may vary both over time and across economies. It should be noted that the latter macroeconomic closure is not always satisfied in most macro econometric models that focus on economic developments in the short term. Such models tend to deviate from steady state equilibrium. All in all, these results suggest an important role for Japan in

providing sufficient capital in the world economy. Investment in the other economies rather than in Japan would also be suggested to be much more efficient.[17]

Trade Liberalization Initiative in APEC

The recent rapid devaluation of currencies in Asian economies has been attributed at least in part to large deficits in external balances. There have been signs of several movements in those economies to protect the market and/or to postpone the implementation of market opening measures. However, trade liberalization is beneficial, not harmful, to liberalizing economies, particularly where significant liberalization measures are taken. By most projections,[18] Asian developing economies are expected to be among those making the largest economic gains due to the implementation of trade liberalization measures under the APEC initiative.

According to GTAP data, implementation of the Uruguay Round (UR) agreement, would result in import protection declining by an average of 3 per cent worldwide by the year 2005, which accounts for around one-third of current protection level. Meanwhile, abolition of export restraining measures would result in decline in trade protection for exports by around 1 per sent on average, which amounts to abolishing almost entirely this type of trade protection. With the implementation of the Bogor Declaration, import protection would be entirely eliminated in the APEC member economies, resulting in a global decline of another one-third of current import-based protection levels.

Trade liberalization measures including tariff reduction will stimulate world trade due to reduction of export and import prices. World trade would expand by 16.8 per cent by full trade liberalization measures according to the Bogor Declaration,[19] half of which would be attributed to the implementation of the UR agreement. Reduction in import prices would result in increases in national output while increasing access to the markets of trading partners. In addition, domestic production resources would be used more efficiently when domestic distortions are reduced. These combined effects would result in the expansion of production and an increase in income and economic welfare. World real GDP would increase by 1.5 per cent, in which the net contribution of the Bogor measures would amount to 0.4 per cent. These gains would be significant in the Asian member economies in general, with the largest gains realized in China and ASEAN.

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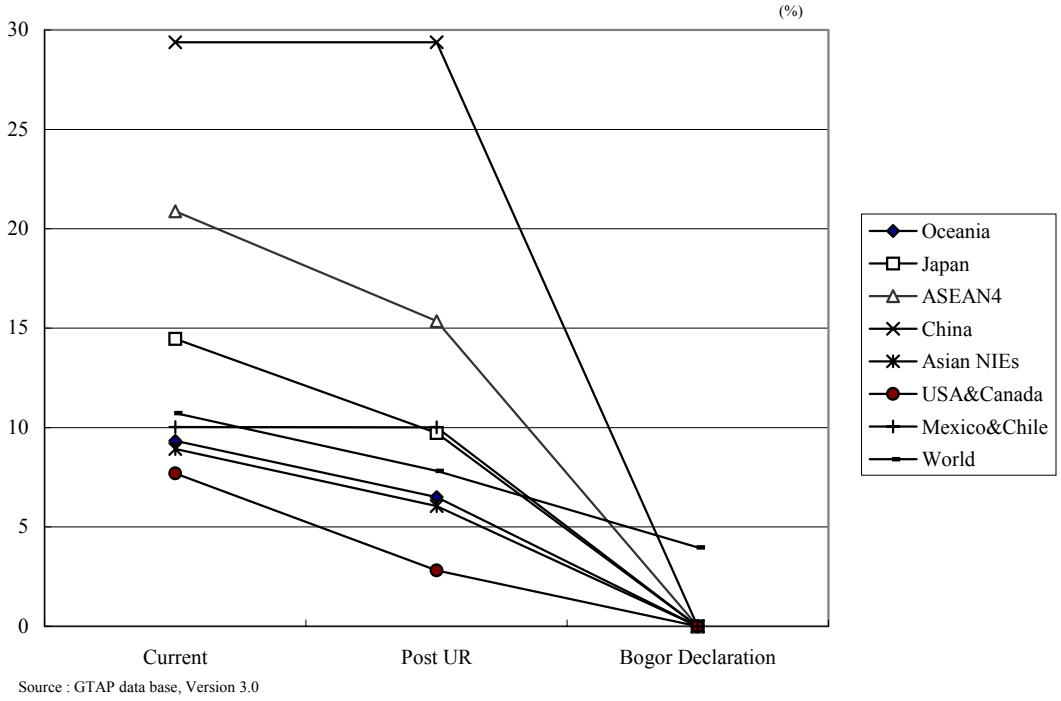
[17] It is shown that additional investment, for example, in Western Europe and North America would result in an increase in the world real GDP as a whole.

[18] Former studies on this subject are discussed in such papers as Dee et al. (1996), Kawasaki (1997b) and APEC (1997). The simulation outcomes in those studies vary to some extent because of differences in a) framework of the CGE model used, for example, either static or dynamic version and b) scope of coverage, either limiting liberalization measures in merchandise trade or extending those to service trade, and whether trade facilitation measures are included or not.

[19] This includes the implementation of the UR agreement. A "net" contribution of the Bogor Declaration measures should be attributed those taken beyond the UR commitments.

Chart 4
Changes in Trade Protection (APEC Economies)



Source : GTAP data base, Version 3.0

Table 14
Impact of APEC Trade Liberalization ("Net" Bogor Declaration)

	Percentage deviation from baseline					
	Real GDP	Price	Export Vol.	Import Vol.	DTBAL*	EV*
Oceania	2.1	1.2	11.6	13.4	-0.0	6.0
Indonesia	9.1	-4.0	24.6	24.5	-0.6	7.0
Malaysia	21.5	-6.2	33.3	31.5	-1.0	7.5
Philippines	16.5	-7.3	60.2	42.2	-0.6	4.5
Thailand	53.4	-15.7	88.6	73.9	-6.8	33.5
China	10.6	-4.9	47.6	43.0	-6.2	18.1
Korea	6.4	-0.6	22.1	23.3	-4.0	15.1
Singapore	5.9	3.7	6.7	9.7	-0.8	3.4
Hong Kong, China	3.3	5.6	6.2	10.8	-1.5	4.4
Chinese Taipei	8.4	-2.0	21.9	24.3	-0.8	14.8
Japan	0.5	-0.5	12.6	16.2	2.8	29.4
South Asia	-1.6	-0.3	-0.9	-3.1	0.8	-4.2
North America	-0.7	1.7	1.1	2.1	5.1	-14.9
Latin America	5.4	-3.9	28.9	22.4	-1.5	40.1
Western Europe	-1.1	1.6	0.7	0.6	12.3	-41.3
Rest of the World	-1.4	1.2	-1.4	-1.5	2.8	-16.4
World	0.4	0.6	8.2			107.1

Note : Deviations in Trade Balance and Equivalent Variation in billion US dollars.
Source : Author

Moreover, it is stressed in Kawasaki (1998) that, in the world where international capital movements are flexible to changes in expected return on capital, capital formation will be accelerated in Asian economies since investments in those economies are attractive. Although those economies will tend to experience a trade balance deficit on one hand, further accumulation of capital will bring about impressive economic gains compared with other economies.

In order to realize benefits of capital inflows and accumulation, one of the required elements will be the solid functioning of domestic financial intermediation. In this respect, it is expected that structural reforms and policy measures that are currently being implemented in Asian economies would play an important role in improving the soundness of financial sectors. Foreign support for financing trade and investment would also be effective in developing economies.

But clearly, Asia needs to remain committed to trade liberalization regardless of its current circumstances. However, in promoting liberalization measures, it would be required to introduce certain measures, for example, those encouraging stable capital inflows in the longer term in order to avoid volatile fluctuations in capital inflows and outflows in the short term, which have been cited as one of crucial factors that caused the current financial crisis.

5. Summary and Policy Implications

This paper has attempted to assess some of the economy-wide effects of the current Asian financial crisis by means of economic model simulations. The stylized features of simulation outcomes and their policy implications could be summarized as follows.

a) The magnitude of the worldwide effects of Asian currency depreciation is estimated not to be so large in terms of world output and trade. World real GDP as a whole would decrease by 0.2 per cent, although the Asian economies directly affected by the crisis would experience double-digit economic contractions.

b) Stabilization of domestic inflation is one of the crucial prerequisites for economic recovery in the Asian economies. Tightening macroeconomic policy would be reasonable. However, contractionary income effects in certain Asian economies would be transmitted to other economies through close interdependencies. Expenditure/demand cuts should be achieved by reducing consumption rather than investment. Foreign support for financing trade and investment would also be effective in supporting recovery in developing economies.

c) The economies outside the region in question are expected to gain rather than lose in terms of real GDP. This would reflect real income effects as a result of weaker price developments. Moreover, the capital outflow from Asia would be reallocated outside the Asian economies and offset the declines that these economies would experience in terms of export growth.

As regards the effectiveness of alternative policy responses, the economic analysis discussed above has the following implications:

a) Devaluations of the Chinese yuan and Hong Kong dollar would be harmful to the two economies, particularly to Hong Kong, China. However, macroeconomic developments, including international competitiveness effects, outside these two economies are shown to be minimal.[20]

b) The contribution of Japanese expansion of demand to improve Asian external balances would be quite small not just in absolute amounts but also in terms of global ratios. Moreover, because of global savings/investment constraints, all other economies outside Japan combined are estimated to lose rather than gain both in output and economic welfare.

c) Asian developing economies are expected to be major beneficiaries in economic gains due to the implementation of the APEC trade liberalization measures. Further accumulation of capital associated with international capital inflows would bring about impressive economic gains compared with other economies. In order to realize those benefits, one of the required elements will be the solid functioning of domestic financial intermediation.

One of the distinguishing benefits of model simulations is that, utilizing the common framework of the analysis, those outcomes are comparable among the different scenarios. It is interesting to note that the effects on world GDP of the Asian crisis, which is negative, is quantified as being only half of the positive amount generated by the APEC trade liberalization according to the Bogor declaration.

Table 15
Comparison in Simulation Outcomes (World Economy)

Percentage deviation from baseline

	GDP	Price	Trade	EV*
Currency Depreciation (Asia)	-0.2	-2.4	-2.9	-44.9
Currency Depreciation (Asia & China)	-0.3	-3.0	-3.7	-66.4
Lower Growth (AD)	0.2	-0.0	-0.3	27.0
Lower Growth (AS)	-0.3	-0.1	-0.9	-70.7
Japanese Demand Expansion	-0.2	-0.1	-0.5	-45.0
APEC Trade Liberalization	0.4	0.6	8.2	107.1

Note : Deviations in Equivalent Variation in billion US dollars.
Source : Author

[20] These estimates, it will be recalled, did not include any possible impacts from further financial market turbulence that such devaluations might cause, and which could lead to larger effects externally.

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PART 2

KNOWLEDGE, TECHNOLOGY AND ECONOMIC GROWTH

KNOWLEDGE, ABSORPTIVE CAPABILITY, AND ORGANIZATIONS

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1. Theories of Economic Growth

Let me begin by borrowing a distinction that Nelson and Pack (1996) have made with respect to theories of economic growth. These authors distinguish between "accumulationist" and "assimilationist" theories of growth. Accumulationists are those who stress the role of "moving along the production function," that is, of accumulating ever greater stocks of inputs in order to generate higher output. The institutional assumptions in such theories are minimalist at best: so long as an economy gets relative prices right, accumulation should translate into higher output. By contrast, assimilationists see the role of institutions, including business institutions and capabilities, as more subtle, more complex, and more important. To an assimilationist, growth is not about moving along an existing production – which assumes a given state of knowledge – but rather about moving to new and different production functions. Assimilationists thus stress the importance of learning and innovation.

In order to understand the requisites for economic growth from the assimilationist perspective, we need to step back a bit and take a look at the theory of learning as it is being developed today by scholars of innovation and technological change. There are three main points I wish to touch on.

- Knowledge as tacit, sticky, and localized.
- The need for absorptive capacity.
- The importance of institutions and organizations.

I will discuss each of these in turn, and then attempt to link them back to the problem of economic growth.

2. Tacit and localized knowledge

According to one popular story, technological knowledge is a peculiar kind of good. Because such knowledge is inherently slippery – it can be replicated and transmitted at essentially zero marginal cost – its generation contributes a positive externality to society. Knowledge "spills over" easily from its creator to benefit others, much as

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passers-by receive the esthetic and olfactory benefits spilling out from a well-tended private garden without having to pay for them.

This set of propositions has arguably constituted the central core of the neoclassical microeconomics of technological change for some decades. More recently, however, discussions of spillovers have shifted to a more aggregated venue, namely the so-called New Growth Theory (NGT) and New Trade Theory (NTT). As elaborated in several contexts, the basic argument of this theory is a simple syllogism: technological change leads to growth; increases in knowledge lead to technological change; and formal research and development (R&D) activities at the level of business firms lead to increases in knowledge. As a consequence, policy should focus almost entirely on creating incentives for an optimal amount of formal R&D at the firm level.

However, research on the nature of innovation and technological change has begun to call into question the picture of knowledge and its creation that underlies this theory of growth. There is a growing body of literature on behavior and organization that adduces quite different presuppositions. In the evolutionary theory of the firm (Nelson and Winter 1982) and the related literature on dynamic capabilities (Teece and Pisano 1994; Langlois and Robertson 1995), economic actors are not "profit maximizing and far-sighted entrepreneurs," as Grossman and Helpman (1991, pp. 517-8) put it, but are, in Herbert Simon's well-known phrase, "boundedly rational." The import of this limitation is not that entrepreneurs do not try to do the best they can with what they have; rather, the point is that what they have to work with is qualitatively different from what the neoclassical picture suggests.

Invoking Michael Polanyi (1958), Nelson and Winter argue that much of what economic agents know is actually tacit knowledge, an inarticulate kind of knowledge that cannot be easily codified or transmitted in explicit form. Such tacit knowledge is in the nature of a skill, something acquired only through a costly process of imitation, apprenticeship, and trial and error. Clearly, knowledge of this type is far less "slippery" than explicit knowledge. To the extent, then, that resources devoted to the production of knowledge (R&D) are actually directed at producing knowledge that is tacit in this sense, spillovers are far less of a problem (Cohendet, Héraud, and Zuscovitch 1993). Knowledge becomes far more of a private good.

Far from being slippery, indeed, knowledge may be "sticky," both because of its tacit character and because there may be transaction costs of communicating even valuable (and relatively explicit) knowledge to others across markets and within organizations; and there may even be costs of persuading those others of the value of the knowledge once communicated (Silver 1984; Langlois and Robertson 1995). Furthermore, if knowledge is dispersed and sensitive to context, then firms will likely learn different things even when searching for the same things; that is, R&D effort will lead to relatively localized knowledge.

3. Absorptive capacity

Cohen and Levinthal (1990) argue, moreover, that, rather than receiving new knowledge as a free gift, firms must invest resources in the "absorptive capacity"

necessary to understand the results of the R&D spilling in from others. They contend that an organization's absorptive capacity for external knowledge is a function of its existing knowledge. Thus organizations that already have some background in a given area may find it quicker and cheaper to acquire new related knowledge than do organizations with no prior experience in the area. Cohen and Levinthal point to basic, or generalized, R&D activities as an important way to improve a firm's chances of spreading its external nets widely in acquiring useful knowledge from its surrounding environment. But, as it is not feasible to have a basic background in all areas, the problem is still to determine which fields are likely to prove sufficiently fertile in the future to justify an investment in basic background knowledge now. In the words of Cohen and Levinthal (1990, p. 138):

> "A firm without a prior technological base in a particular field may not be able to acquire one readily if absorptive capacity is cumulative. In addition a firm may be blind to new developments in fields in which it is not investing if its updating capability is low. Accordingly . . . firms may not realize that they should be developing their absorptive capacity due to an irony associated with its valuation: the firm needs to have some absorptive capacity already to value it appropriately."

Furthermore, as Penrose (1959) noted, some organizations have better initial learning capabilities than others. Each organization – and by implication, each economy or region – is unique, and its ability to acquire the knowledge necessary to adopt a significant innovation successfully differs from that of existing or potential competitors.

4. Social institutions and business institutions

It may be worth recapping the argument so far. I have argued that, contrary to the view of knowledge articulated in neoclassical accounts (including the New Growth Theory), the knowledge essential to economic growth is not slippery and easily transmissible but is in fact often sticky and tacit. Moreover, those to whom knowledge is transmitted (or to whom it "spills over") cannot easily utilize that knowledge unless they possess the capabilities (including existing stocks of knowledge) to receive and "absorb" that knowledge. The final part of the argument is to observe that social and business institutions are storehouses of useful knowledge that provide precisely the source of "absorptive capacity" necessary for growth. The research agenda of economic growth, then, should focus less on the "optimal" production of R&D by unexamined units called firms and far more on the nature and role of institutions in generating – and receiving and using – productive knowledge.

At the base of virtually all formulations of the concept of a social institution lies the notion of rule-following behavior. Institutions reflect behavior that is highly organized, in the sense that the behavior represents a relatively predictable or non-random pattern. And such patterns emerge as the result of the following of rules: they are, as Hayek (1967) puts it, systems of rules of conduct.

Sometimes the rules seem to be a property of the human agents themselves. Agents follow rules unconsciously as if, in effect, programmed to do so. Writers who take an evolutionary perspective on social institutions often incline to this interpretation, even though most are aware that rules have other meanings as well (Hayek 1967; Nelson and Winter 1982). These writers stress the skill-like nature of behavior, which implies that the rules guiding behavior are often necessarily inexplicit or tacit (Polanyi 1958). Sometimes, however, social institutions seem to consist of rules external to individuals. Such rules are more in the nature of side-constraints that channel the behavior of individuals whose operating principles may not be the following of rules in the first sense. In both cases, the rules generate an orderly pattern of behavior. There is not necessarily a conflict between these two meanings of rule-following, and one can imagine both types to be operating, to varying degrees, in a system of social institutions. For example, consider what is probably the canonical example of a social institution in the modern literature: the convention in many economies that one drive on the right-hand side of the road. This institution is an explicit rule of law that one can be punished for violating; but it is also an unconscious predisposition of native drivers. Indeed, as Hayek and others would point out, the following of unconscious rules obviates attention to many of the details of behavior, which frees up attention and thus actually facilitates conscious action (constrained or otherwise).

Another important aspect of social institutions, one closely related to their order-producing and rule-like aspects, is their capacity to economize on knowledge or information.

An institution provides a means of orientation to a large number of actors. It enables them to co-ordinate their actions by means of orientation to a common signpost. ... The existence of such institutions is fundamental to civilized society. They enable each of us to rely on the actions of thousands of anonymous others about whose individual purposes and plans we can know nothing. They are nodal points of society, co-ordinating the actions of millions whom they relieve of the need to acquire and digest detailed knowledge about others and form detailed expectations about their future action. (Lachmann 1971, pp. 49-50.)

Thus, by making the behavior of others more predictable, institutions reduce the amount of information we need in order to behave effectively in society. To make this point clearer, consider again our canonical example. Because of the convention that everyone drive on the right, I do not need information about the lane preference of each driver who confronts me head on.

Indeed, there is a more general point relevant to the argument I am making here: institutions – viewed as rules, customs, routines, habits, or conventions – contain or embody knowledge about effective behavior. In an important sense, then, institutions are very much repositories of absorptive capacity. They are the antennae that allow organizations or regions to receive knowledge from elsewhere and to use it productively.

Douglass North (1990) makes a sharp distinction between "institutions," which are the abstract background rules of society, and "organizations," which are the actors upon that background. Langlois and Robertson (1995), however, consider an intermediate

set of organizational forms and structures they call "business institutions." The term is intended to refer both to the pattern of capabilities within an economy and to the systems according to which those capabilities are organized, with the latter running the gamut from decentralized markets (broadly understood) to highly integrated firms. Rosenberg and Birdzell (1986, p. 115) have noted the importance for the economic growth of Western Europe of a number of innovations in business institutions, including bills of exchange and banking; insurance; economic association without kinship; double-entry bookkeeping; and the mercantilist partnership. One could easily name some more recent ones, including those managerial innovations chronicled by Alfred Chandler (1977).

The productive knowledge embodied in such innovations has very much the properties hoped for in the New Growth Theory: it is template knowledge that is widely applicable and reusable. But such knowledge is not typically, if at all, "produced" in the way R&D is supposed to produce knowledge. "Ironically," writes Howard Pack (1994, p. 60), "the new generation of growth models relies on externalities and R&D at precisely the time a sense is emerging that one of the important factors determining intermediate and perhaps long-term productivity growth is organizational."

But it is not merely that institutions represent a kind of knowledge in addition to strictly technological knowledge. It is that the structure of background and concrete business institutions in a society largely determines the way in which the society generates and uses more purely technological knowledge. This is in part what Nelson (1993) and Lundvall (1992) mean when they speak of national systems of innovation.

5. Institutions and Economic Growth

As Douglass North (1981, 1990) has persistently argued, theories of economic growth that rely on movements in aggregate stocks like capital, labor, or even knowledge "beg all of the interesting questions" (North 1981, p. 5). Such theories either assume institutions to be unimportant or, as is usually the case, tacitly assume that institutional questions reduce to questions of relative price: institutions are just a matter of "getting the prices right."

Much could be said on this point. But I would like to focus on the role of institutions in the creation of the knowledge that – all are agreed – is conducive to economic growth. At one level, institutions are important for growth because they create incentives; and, if those incentives channel behavior into the creation of new wealth rather than into the redistribution of existing wealth, they are favorable to growth. This is an idea dating back at least to Smith. At another level, however, institutions are important to growth because they are themselves embodiments of knowledge. Thus one might "produce" knowledge not only about how to produce goods and services more effectively (holding institutional structure constant) but also about how to change institutions themselves in a manner more conducive to economic growth.

Obviously, institutional change at the most abstract level – that is, change in basic institutions of government, law, and culture – is an extremely complex process of "coevolution" that is not well described as a progressive search for more efficient forms

(North 1981). However, if we consider institutions at a more concrete level, including the kinds of organizational forms and contractual structures that emerge within an abstract system of law and policy, then we might reasonably think that more-or-less cumulative productive knowledge might well be embodied in such institutions in much the same way that it can be embodied in technological innovations.

6. Conclusion

In short, a country cannot simply accumulate inputs, even knowledge inputs as those are conceptualized in the New Growth Theory, without the proper set of background and business institutions to permit learning – to permit the assimilation of the knowledge others have spilled over onto them. Economies as well as firms need absorptive capacity.

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TO LEARN TO INNOVATE: LEARNING IN TECHNOLOGICAL PROGRESS AND A NEW PRODUCTION PARADIGM IN DEVELOPING ECONOMIES

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Abstract

This paper presents a suggestive rather than exhaustive analysis of the strategies for technological progress in developing economies. As latecomers, developing economies do enjoy the advantage of being able to learn from advanced economies; therefore the process of technological progress can be compressed. The primacy of learning is emphasized, and the implicit dimension of this learning process is brought to the attention of readers. In the information age, the prevalence of information and communication technology (ICT) has radically changed the learning environment, thus making it possible for developing economies to advance their technological development by fully integrating various technologies available. By citing the examples of the emergence of the VCD industry and the agricultural vehicle industry in China, it is argued that technological progress for developing economies may well take a different course from those of the advanced economies. By allocating resources to technological innovations, which start from modification and improvement of existing technologies according to local factor endowments, new trajectories of technological development can be created. The development of ICT has provided a unique chance for developing economies to integrate available technologies in a creative way so that product as well process innovations can be generated. Four basic principles are outlined as the essential components of the new technological strategies for developing economies in the age of information. It is believed that a new production paradigm can emerge from the developing economies that adopt these new technological strategies.

1. Introduction

During the height of Asia's economic boom four years ago, the American economist Paul Krugman called the attention of researchers as well as policy makers to the quality

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of economic growth in Asian economies (Krugman, 1994). One argument he put forward in the paper states that the Asian economic growth is fuelled by the increase of factor input rather than the increase of total factor productivity (TFP). The subsequent Asian currency crisis seems to prove that there is some truth to Krugman's statement, although we all agree that what is behind this crisis is much more complicated than just a productivity problem.

Long-term economic growth is driven by technological progress and this is a well established tenet in economics, especially in the current economic literature centred around the so called new growth theory (Romer, 1986; Grossman & Helpman, 1991). On the surface, technological innovations are mainly generated by forward-looking and profit-seeking agents through investment in industrial research, be it in developed economies or developing economies. Fundamentally, all technological progress is derived from breakthroughs in scientific research. This requires governments' input in the form of investment in education, basic research in science, and as well institutional settings that promote public and private R&D. While advanced economies are normally at the forefront of scientific research and technological innovations, developing economies, constrained by their level of technological development, are mainly in a position to import technologies from advanced economies. Developing economies must learn from advanced economies as well as from their own experiences. However, since even imported technologies sometimes need modifications to suit local conditions, developing economies are also engaged in technological innovation activity.

The importance of learning in technological progress for developing economies is a much-studied topic (Humphrey, 1985; Kim, 1997; Kagami et. al, 1998). In this paper, we stress the importance of learning in technological progress for developing economies, especially in basic industries, although in the age of ICT, technological leapfrogging is possible for developing economies (Soete, 1985; Hobday, 1994). In stressing the learning process, it is meant to say that learning is not only important for developing economies to acquire new technologies, but also of vital importance for them to gain the experience of developing marketable technologies. Implicit learning and tacit knowledge are dimensions that are often neglected in discussions explicitly dealing with learning and knowledge acquisition in the dynamic learning process for developing economies. As a matter of fact, in creating an adequate learning environment, tacit knowledge can be conveyed by learning through practice and experiences, i.e., in an implicit way.

Successful late industrialized economies such as Japan and South Korea all started from being good learners (Amsden, 1989, Kim 1997). They have quickly transformed themselves from active learners to aggressive imitators, and then to successful innovators. In achieving this, they have quickly assimilated imported technologies and modified them according to local conditions. The rise of ICT since the 1980s has provided even greater opportunity for other developing economies to imitate the success of Japan and South Korea in terms of technological development. By producing

technological innovations that incorporate existing technologies, home factor endowments and domestic market structure, developing economies can create their own competitive advantages.

This paper is organized as follows. To summarize the many studies on learning in technological progress, section 2 stresses the primacy of learning for developing economies to acquire advanced technologies as well as to build up absorptive capacities, especially for transition economies such as China. The implicit dimension of the dynamic learning process is especially emphasized here. In section 3, two examples of combinatory innovations, i.e. the VCD industry and the agriculture vehicle industry in China, are described to illustrate that developing economies may create different trajectories of technological development. In section 4, some key principles of technological strategies for developing economies in the age of information are discussed. These four principles, i.e., the just-in-time investment strategy, the incremental and progressive way of technology development, a human integrated manufacturing system, and the systematic integration of existing technologies based on modern ICT, are the key ingredients of an emerging new production paradigm for developing economies. It is concluded that the competitive advantages can be built in developing economies by adopting these new technological strategies and a new production paradigm may well emerge.

2. The Primacy of Learning

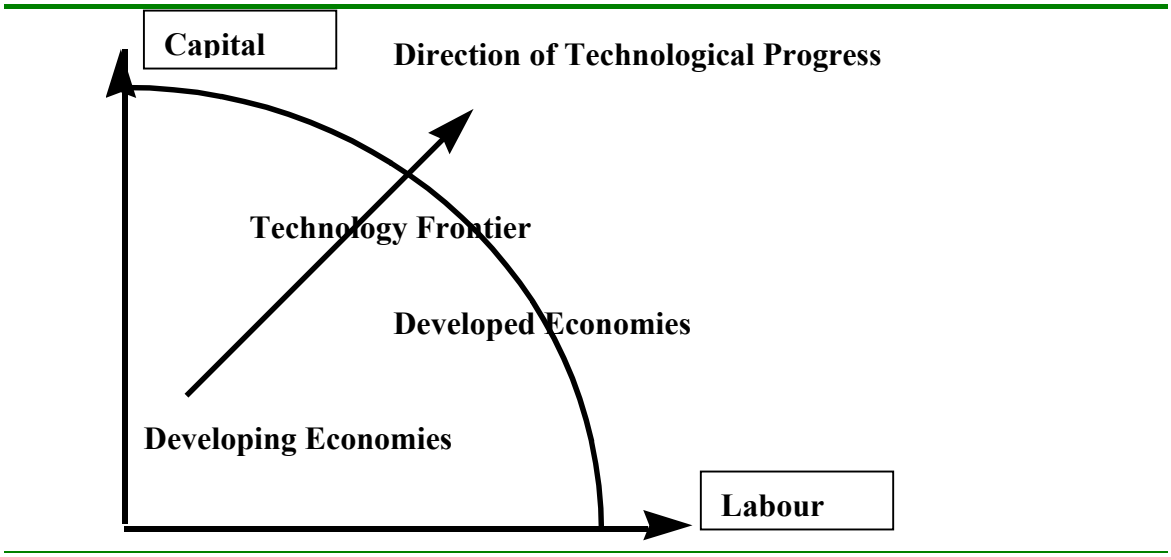
The importance of learning to economic growth and technological development has been extensively studied in economics (Arrow, 1966; Atkinson & Stiglitz, 1969; Stiglitz, 1987). For developing economies, learning means to learn from others (technologically advanced economies) as well as from their own experiences (learning by doing). It is almost tautological to say that developing economies have to learn technologies from developed economies, since developed economies have achieved high GDP per capita level by creating and employing advanced technologies to increase productivity. Figure 1 illustrates the relative position of developing economies and developed economies in the technology space.

As a matter of fact, the economic exchange between developed and developing economies takes on the form of the former exporting technological products to the latter. International trade is one of the routes that embedded technologies can be transferred to developing economies.

Normally technology transfer between developed and developing economies can happen in many ways. As summarized by Kagami (1998), developing economies can acquire technologies from developed economies through the following major routes.

- Technology transfer by multinational corporations (MNC) through FDI. Attracted by low labour cost and growing market in developing economies, MNCs will invest there and bring with them new technologies as well as new management practices to the host economies

Figure 1
Relative position of developed and developing economies in the technology space.



- Purchasing new technologies by paying royalties or licensing fees. Here, technology takes the form of disembodied knowledge. This will become a more common practice for developing economies since the tightening of international intellectual property right laws. However, this requires the economy making the purchase to have necessary absorptive capacity to realize the full potential of the purchased technologies.
- Purchasing new tools containing new technologies. To import capital goods with embodied technologies, developing economies may need to make some modifications to the equipment so that they could be better suited to the local environment. This type of activity, based on the full understanding of how the imported tools work (i.e., "reverse engineering"), is the beginning of innovation aimed at developing appropriate technologies for developing economies.
- Technological co-operation between domestic firms and foreign firms. When an economy has the basic technological capacity to innovate, international co-operation in technological innovation will become more important and pervasive.
- Domestic technological innovations through R&D and education. When developing economies have accumulated enough experiences in technology development, they will increasingly rely on domestic R&D to develop technologies that suit domestic needs as well as to build international competitiveness. This will be the ultimate goal for developing economies to achieve technology independence.

In technology transfer, the transfer of "know-how", a kind of knowledge which can not be wholly formalized, nor transmitted solely through written documents, should receive more attention (Senker, 1995). Thus enters the often-neglected dimension in technological learning – the dimension of tacit knowledge and implicit learning in contrast to explicit knowledge and explicit learning.

Explicit learning refers to knowledge that can be articulated and codified, and thus can be transmitted in formal and systematic language. In terms of technology transfer and technological learning, explicit knowledge can be acquired explicitly by reading science books, technical manuals and taught by instructors in a systematic way. However, according to Polanyi, "we know more than we can tell" (Polanyi, 1966). This statement catches the essence of tacit knowledge which is rooted in the human mind and the primacy of all human knowledge (Reber, 1989). Implicit knowledge is difficult to articulate and communicate with other people, it can only be accessed and acquired through practicing and experiencing. Procedural knowledge is a kind of implicit knowledge.

The process to acquire implicit knowledge is called implicit learning and it means that knowledge, mostly implicit, is gained without the subject being aware of it. In the psychology literature, the study of implicit knowledge and implicit learning has attracted more attention, partly because it has touched up the often-neglected dimension of the learning mechanism in humans (Reber, 1989). According Barry and Dienes (Barry & Dienes, 1992), the working characteristics of implicit knowledge can be summarized as follows:

- Implicitly gained knowledge shows specificity of transfer in that it is relatively inaccessible with free recall and forced-choice tests and it is also shows limited transfer to related tasks
- Implicitly acquired knowledge tends to be associated with incidental learning conditions, and therefore can be mostly obtained in unnoticed situations
- Implicitly acquired knowledge gives rise to a phenomenal sense of intuition, since a subject can not accurately tell you how he/she has reached a decision
- Implicit knowledge remains robust in the face of time, i.e., it can be maintained long after the learning process has completed.

Technological learning involves both explicit and implicit learning. Learning through using and practicing is imperative for firms to acquire technology know-how that can only be gained by experiencing it. Some literature on technology development has claimed that Japanese companies are quick learners in technology development because they deliberately created an environment that facilitated the learning process in which knowledge can be transferred implicitly between instructors and among workers.

Therefore, the primacy of learning in technological development for developing economies derive not only from the advantage of being latecomers that can have the process of technological progress compressed, but from the necessity of affective acquiring the know-how as well.

In some sectors, for service industries as an example, imported technologies or the purchase of "Embodied R&D", in such forms as imported ICT equipment (computers, machinery, telecommunications equipment) appears to earn a higher rate of return than domestically acquired technology (OECD, 1997). However, for developing economies, technological progress in basic industries such as machinery, electronic, chemical and materials, cannot be bought. They must learn from first hand experience about how to conduct R&D and how to improve technologies.

Technological progress is slow, technology must be accumulated through a gradual process of learning. Even at the corporate level, learning is incremental, painstaking, long-term, and cumulative. At the social level, it is even more so, as the progress of technology level for a nation as a whole depends on the gradual and systematic accumulation of industrial, educational and infrastructural capability.

For China, it is especially true because there is another dimension of learning in China that it is in a transition from a planned economy to a market economy and the market experience is a more relevant issue to China economic development. The market readiness and social capability is lacking to support technological innovation. Learning is imperative for China to catch-up in economic development as well as in technology development. What the government can do to promote technological progress in developing economies is to create an institutional setting and favour policy environment to facilitate learning. The realistic choice is to be a learner first and an innovator later.

3. From Imitator to Innovator

To build up their own competitive advantages in a globalized world, developing economies should not solely rely on imported technologies. As discussed above, the task of learning for developing economies is not just aimed at learning to master one particular technology or production process; the most important issue is to learn how to use the technologies and then to create new technologies.

In discussing Korea's technological progress, Kim (1997) summarizes the dynamic learning process at the firm level in developing economies into three major stages, i.e., technology acquisition through transfer, knowledge assimilation, and technology improvement. To absorb imported technologies, firms must have the necessary physical capital as well as human capital, i.e., workers that have received minimum education so that they can be trained to use the imported technologies. Normally, technology transfer starts from the training of technicians and workers. With the imported technologies, knowledge can be acquired by using technical equipment. The next step is to assimilate technologies by creating a suitable environment to enhance learning, so as to realize import substitution of personnel, engineering, and components. Finally, the firms will try to improve the imported technologies to make it run at the maximum efficiency, make incremental advancement on imported technology and apply to new production process.[1]

However, the present external conditions for developing economies to acquire imported technologies have become less favourable than those that Japan and Korea, the model learners, enjoyed during their industrialization process. Under the new rules of international trade prescribed by the World Trade Organization (WTO), developing economies will face more restrictions in protecting the domestic market for infant industry to learn. At the same time, developed economies have become more and more

[1] See also Kim 1997, p. 209.

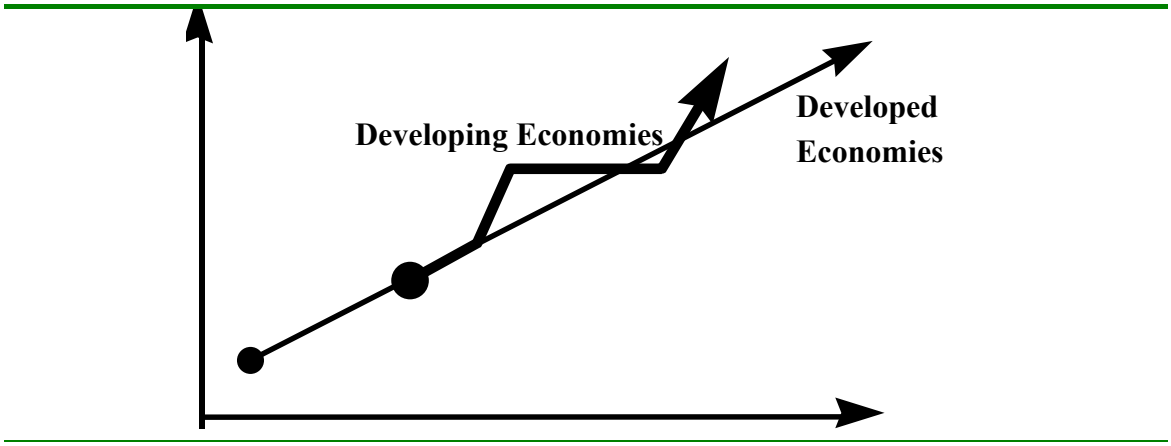
reluctant to transfer technologies to developing economies through FDI. The tightening of international intellectual property right laws puts more constraints on creative imitations by developing economies such as reverse engineering. Also, the surging protectionism in developed economies will also hold back developing economies' efforts to adopt an export-orientated strategy in economic development. Developing economies must therefore seek to produce their own technological innovations quickly and rely on domestic and regional markets for product development. Being late-comers means that they have wide choices of technologies when it comes to the technological and production process innovation. Being developing economies means that the technological changes can progress in line with the growth of domestic markets. Therefore, developing economies could have their own trajectories of technology development.

The majority of the economic literature dealing with technological innovations is concerned with innovations at the technological frontier, and is more relevant to describing technological progress in developed economies than in developing economies (Freeman, 1990). The uncertainties faced by innovators at different stages of technological development are of different kinds. For developed economies at the technological frontier, the uncertainty of innovation is mainly decided by that inherent in technology itself. However, for developing economies, located behind the technological frontier, technological innovations will be mainly about production process innovations rather than original and generic innovations based on radical breakthroughs in science and technology. Most of the existing literature dealing with technological change in developing economies admits that the possibility exists for innovations derived from the recombination of existing technologies to suit local endowment conditions. The uncertainties of innovations in these economies derive mainly from uncertainties of market demand. The constraints of market structure on technological changes will be the main concern.

As illustrated in Figure 2, developing economies can re-combine existing technologies to produce new technologies or create new production processes which may be different from those used by developed economies. This conclusion is based on the following observations.

- Any technical products are the results of the integration of many different technologies. They can be re-combined to form new products or new production processes
- The adaptation of technology may require some modifications to suit local conditions. This kind of modifications may lead to different products or more likely different production processes.
- At each stage of technology development, there may co-exist many technologies that may have the same potential to be employed in production.
- Technology development illustrates strong characteristics of path-dependence, therefore any deviation from the existing trajectory of technology development can be preserved (examples include the US design and French design of nuclear reactors).

Figure 2
Trajectories of technological progress for developed and developing economies



Therefore, given that developing economies have at their disposal a large stock of technologies, they may combine them creatively to produce new products or production processes that are more in line with the factor endowment and market structure in home economies.[2]

The development of China's consumer electronics industry and auto industry can serve to illustrate this point of view. China's consumer electronics industry started from early 1980s by importing production lines and technologies from developed economies. In the years that followed, it enjoyed fast development due to the large and expanding domestic market. A group of large consumer electronics companies has emerged and by the end of 1997, the annual production of colour TV reached 20 million units. The top selling TV brands in China are produced by domestic TV producers. Starting from assembling lines and imported CRT production lines, these companies have gained production experiences as well as design expertise. Now these leading TV producers have established their own R&D teams and begun to turn out new products with proprietary designs.

Although the Chinese government devoted much effort to nurture a successful VCR industry, China VCR firms failed to achieve the same kind of success as TV manufacturers did. By the end of 1997, the combined total production capacity of VCR of Chinese producers was 3.5 million units per year; this compares with annual production of 1.2 million units. Foreign brand VCRs from Japan and South Korea still dominate China market.

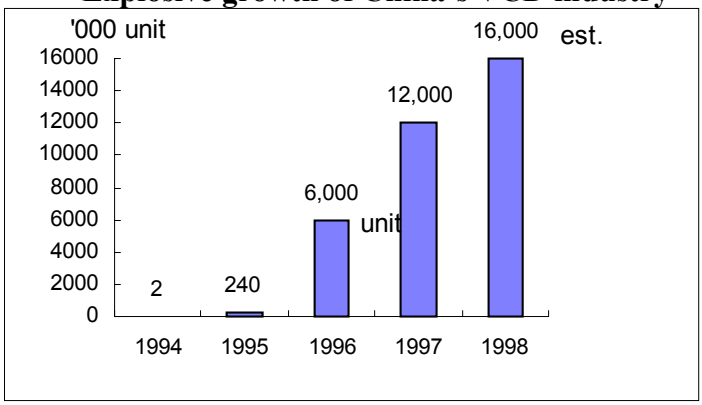
However, starting from 1995, a new type of consumer electronics product named VCD (Video Compact Disk) has emerged in China. Built on the concept of CD-ROM mounted on PCs, the VCD machine was invented as a home appliance that can replace/complement the VCR. It is a type of digital audio-visual system that

[2] For more detailed technical argument, please refer to Gao & Xu, 1998.

compresses image and voice data using the MPEG-1 technology. The new VCD industry has swept China by storm and taken the world by surprise. By the end of 1997, the total production of VCD machine reached 12 million units in China, far surpassing that of the VCR production (see figure 3).

The core component of a VCD player, i.e., the decoder, was not produced by Chinese firms, but Chinese VCD manufacturers have learnt to form alliances with electronics firms in developed economies such as C-Cube of the USA and Philips of Holland. The price is affordable to most Chinese families (half the price of a VCR), the library of VCD programs is abundant (feature films, Karaoke programs, and educational software), and the machine is compatible with existing home appliances (TV and audio-visual systems). All these factors combined together have made the VCD system a huge success in China. But only in China.

Figure 3
Explosive growth of China's VCD industry



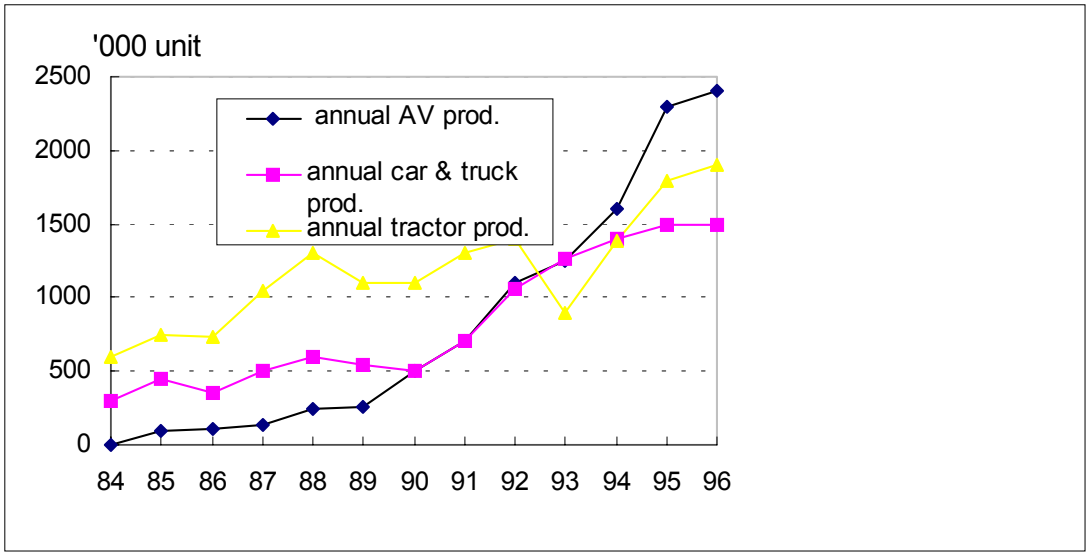
Sources: China Electronics News (Various issues of Home Appliance Special Issues) 1997-98. Cheng, "1998: three questions about the VCD market", Business world, August 1998, pp 26-29.

The emergence of the VCD industry is a unique Chinese phenomenon and it could potentially have significant implications to the future development of China's consumer industry. In developed economies, the audio-visual product industry has experienced the development stage of black-and-white TV, colour TV, VCR, CD, CD-I sequentially and is now heading for DVD and DTV/HDTV. VCD has never been received in other economies except some Asian economies and probably it never will. Now big players in the consumer electronics, such as Philips, Sony, Matsushita etc, are battling for the standard of DVD, the next "killer product" in home appliances. China's TV and VCD manufacturers are competing for the standard of SVCD (super-VCD) of CVD (Chinese Video Disk) – a next generation of VCD that stands between the first generation of VCD and DVD. SVCD adopts MPEG-2 decoding technology that DVD uses, has a better display quality than VCD (357 - 400 horizontal lines versus 268 lines of VCD), provides more editing functions, and is sold at the same price of VCD which is much cheaper than DVD. If China VCD/TV producers can play it wisely, they may well have the Chinese market to themselves and build up their unique competitive advantages for DVD and future generation of audio-visual products. We have a different trajectory of technological progress here.

The growth of China's agricultural vehicle industry is another illustrative example about how the trajectory of technological progress in developing economies could be different from those of developed economies.

Agriculture Vehicle (AV) is a type of cheap car specially designed for transporting passengers and goods over bumpy roads in the countryside. It is similar to pickups in developed economies but much simplified. It uses a small diesel engine and thus runs slower than normal passenger cars. However, it has a strong chassis and thus can be overloaded. As it omits many necessary features of a car, it is much cheaper, priced at one third to half of the price of a normal truck of the same loading capacity. Accordingly, farmers in the countryside can buy one for passengers as well as goods transportation. While the development of China's passenger car industry is constrained by the level of household income as well as the development of national infrastructure, AVs are affordable to farmers and can be used in the vast countryside. Primarily, AV serves as a production tool rather than simply a personal transportation tool, thus it can bring farmers income while provide them with the freedom of travelling. AV is thus called "the machine that could change China's country" (Xu, 1996). Figure 4 shows the growth of China's car industry versus AV industry. The biggest AV producers can produce and sell 300,000 units of AVs annually while the largest car makers only produce and sell 200,000 units per year.

Figure 4
Explosive growth of China's Agricultural Vehicle (AV) Industry



Source: Report on China Agricultural Vehicle Development Strategy, Ministry of Machinery Industry, 1997, pp 3.

While China's major car manufacturers are losing money because of limited demand and excessive investment, China AV producers have a healthy balance sheet. With farmers' income level increases, the demand for 3-wheel AVs decreases and for 4-wheel AVs increases. It is possible that AV producers upgrade 4-wheel AVs to become proper pickups and even passenger cars as the market structure changes. It could well

be that some of the present AV producers would grow to become major carmakers in China in a few years time.

These two examples are cited to show that, constrained by the market structure and level of technology development, the development of products and technologies can take a different path from those experienced by developed economies. Incorporated with the condition of factor endowment, new products and production processes may well be created

4. An Emerging New Production Paradigm

Atkinson and Stiglitz argue that, it may pay developing economies to develop 'Intermediate technology" which requires less capital than those required for developed economies. Whether or not it will in fact do so depends on the extent to which the technique is dominated by the advanced technique, on the resources required to improve it, on the time horizon of the planners and so on."[3] The message is clear that allocation of resources should not be biased towards most advanced technologies, but rather towards affordable and appropriate technologies that can sell. We will now elaborate on this and argue that a new production paradigm can emerge and is emerging in developing economies based on the new technology strategies.

What differentiates developing economies from developed ones is that they are at different stages of development in that the basic economic conditions and technological environment are different. One important aspect is that they have different basic goods markets.[4] To a large extent, the basic goods market is the one that domestic firms can rely on to maintain market share in the face of competition from foreign firms. For developing economies, the basic goods market requires the development of affordable or low and intermediate technologies. The emphasis is on the accumulation of industrial experience, improvement of management practice, and the build up of R&D capability. Therefore, the rationale of employing affordable technologies can be briefly stated as follows.

1. By employing affordable technologies in product and production design, domestically provided production equipment can be adopted. This reduces capital costs and at the same time helps domestic Original Equipment Manufacturers (OEMs) gain necessary production experience and achieve necessary profits for further R&D.

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[3] See Atkinson & Stiglitz, 1969, page 577.

[4] The concept of basic goods market is defined as one that has large market size and the product has a wide application. Take semiconductor as an example, DRAM can serve as the basic good. In the sector of DRAM, the products can be divided into product generations of 64K, 256K, 1M, 4M, 16M, 64M, 256M and 1G etc. Each time a new generation of product is introduced, the manufacturing technology will be upgraded and the production process improved. For developed economies such as USA and Japan, the market for 16M and 64M can serve as the basic goods market, while for developing economies that have newly entered the semiconductor market, the market for 64K to 256K is the basic goods market.

2. By employing low-tech equipment, a large number of less-skilled labours can be employed to substitute for capital that is normally scarce in developing economies. By introducing factor price differentials, production costs can be reduced.

3. In the process of designing and producing low-tech products, the production process can be improved, management enhanced, industrial experience amassed and human capital accumulated. This learning process is of vital importance for firms in developing economies to move to the next stage of development. It is especially so for economies in a transition from planned economy to market economy, because through this learning process, firms can learn to organise R&D and turn out products according to market demand.

4. Since production costs using these technologies are lower than those using imported technologies, products produced will have cost advantages, especially in the domestic market. Domestic firms can build their competitiveness on profitability at every stage as the domestic market grows. Technologies can be upgraded gradually.

5. For economies with a large domestic market, domestic firms and industries can grow as market grows, without being heavily burdened by the financial costs resulted from using imported technologies which is more advanced than can be fully utilised.

Based on the aforementioned technology strategies for developing economies, we propose in the following discussion four principles that can help to nurture the emergence of a new production paradigm.

A new production paradigm based on the integration of comparative advantages

It is fair to say that what developing economies can learn from developed economies are simply not the advanced technologies that they use but the way that these economies integrate their various comparative advantages to form their profit-making ability. It is the latter that is difficult for developing economies to imitate. Therefore, for developing economies to develop their own comparative as well as competitive advantages, it is more important to systematically integrate their existing comparative advantages than just to import technologies from developed economies and adopt the production paradigm of developed economies. It is envisioned that based on the following principles for the choice of economic and technological strategies, a new production paradigm can emerge in developing economies.

A "Just-in-Time" investment strategy

Doubtless, mass production is the dominant mainstay production paradigm in modern industry and, at the same time, large-scale investment is the way to achieve desired production scale. On the account of technical economic factors, mass production still enjoys visible advantages. However, what is crucial in determining the profitability of an investment project and the stable development of an industry lies in that there exists an appropriate level of market demand rather than in whether the designed production

capacity meets that required by scale economy and mass production. If we over stress the need to comply with international standards in technologies and production scales, large scale investment projects can hardly be profitable in a market where the consumer demand is very limited or is growing slowly due to the level of income.

For each single project, the unit production cost is a decreasing function of the utilization rate of the designed production capacity, no matter how perfectly designed the project is. Since the investment required to achieve scale economy is usually huge, the proportion of fixed cost (depreciation, wages and management fees etc.) in the formation of total cost is large, the utilization of production capacity becomes more prominent in deciding costs. At the same time, the elasticity for cost reduction through economies of scales is quite limited and generally not enough to offset the cost increase caused by low utilization rate of equipment. When the utilization rate of production capacity is lower than a certain threshold, the unit cost of product produced by a factory built according to the scale economy through large scale investment can actually be higher than the unit cost of a project not built at the minimum efficient scale economy but with smaller investment. In addition, if we also take into account the fact that the construction period required for a large project will be longer than smaller projects, the financial cost will be much higher for large projects. In increasing the scale of production, the fixed cost of unit production is also increased, thus the advantages of large-scale production is reduced.

On these accounts, we believe that, in terms of the enhancement of competitiveness, the rational choice in deciding investment will be based on market demand. The investment and thus the production scale can be increased incrementally as market demand grows. In this way, no redundant production capacity will be formed. In keeping production capacity in line with growth in market demand, the fixed cost resulting through excessive investment will be reduced and the profitability and the competitiveness of the project increased.

Corresponding to the “just in time” (JIT) investment strategy is "delayed investment" in technology renovation and production expansion. The prevailing practice in China is to expand production when market demand comes close to existing capacity and the immediate consequence is that the newly added production capacity might become redundant when market fluctuations occur. The JIT investment strategy stresses that investment in production expansion will be made when market demand exceeds existing capacity substantially and for a period of time. In between, the shortage of production capacity will be made up for by employing extra labour or by extending working hours. Investment in technology upgrading and renovation will be made in a similar way.

Technology development: sequential engineering [5]

In modern manufacturing technologies, most of the technologies and production processes can be broken down to some interrelated technologies or components. These technologies can more or less develop independently along their own trajectories, but they can form a modern technology system when integrated.[6] In terms of technological progress, each of these technologies has their own development history and can be divided into different stages. The trajectories of development of all these technologies define the world's technology space. Therefore, developing economies will have different choices of technologies and equipment at each stage of development, therefore they can chose and combine these technologies creatively. To some extent, developing economies are in a position to choose and even create new trajectories of technology development.

Influenced by the patterns of technological progress in developed economies, developing economies are tempted to go directly to adopt the most advanced technologies. In this way, the necessity of learning and the time required to build up competitiveness gradually is neglected. Most importantly, these economies will miss the opportunity to engage domestic industries. As discussed above, thanks to the fast development and wide spread of ICT, modern technologies are in a transformation from mass production of standard products to automatic, flexible and integrated production of small batch and diversified goods. This type of production must be based on various kinds of advanced technologies. Developing economies that hope to use advanced manufacturing technologies have to rely on costly imported technologies and equipment. The result is that the amount of investment for unit production capacity is increased, the start up of production delayed, the time for learning and mastering the equipment prolonged, and opportunity to support domestic equipment industries missed. Ultimately, the cost hence the price of products is increased. Since these products are priced higher than those produced using domestically provided equipment, the competitiveness against domestic producers as well as foreign competitors is reduced.

Therefore, a rational choice is to use low to intermediate technology as a start, and then move to upgrade and develop technologies sequentially. Roughly, the idea of sequential engineering is characterized by the following features.

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[5] In technology literature, "sequential engineering" refers to a method of product development in which product design, manufacturing, and marketing are arranged sequentially. In contrast, the recent development in engineering design is called "simultaneous engineering" or "concurrent engineering" which stresses the co-ordination of design, production, quality control and marketing strategy. Please refer to Gao & Xu, 1998 for details.

[6] For example, in the auto-industry, the major technologies and production processes include press, wielding, painting and assembly line each use different types of equipment. In the semiconductors industry, the major processes and technologies include gas-purification, lithography, stepper, and wafer etc. Each type of technology can develop independently and each major production process can be improved separately while they can be kept compatible in a production system.

1. The initial choice of manufacturing technologies and equipment will be decided by whether the domestic industries can effectively use them, not whether they are the most advanced in the world.

2. Since the experience of developed economies has shown the direction of technological progress, the choice of technologies and major technical equipment must be based on a planned trajectory or envisioned direction. At each stage of development, firms making investment in these technologies and equipment must be able to make profit.

3. In any two adjacent stages in the trajectory of technological progress, the major technologies and equipment should be compatible so that most of them can still be utilized when limited technology renovations/innovations are introduced or some new equipment adopted.

4. Technologies and equipment chosen should be mainly domestically produced to make sure they are fully utilized. Upgrading of technologies should be co-ordinated with technological progress in the relevant domestic equipment industry.

Sequential engineering, defined as above, is a technology strategy compatible with the JIT investment strategy. To guarantee the compatibility of equipment, the sequential engineering strategy will make sure that all investment are made under a planned investment sequence and a unified technological progress plan.

Human integrated manufacturing systems

For most developing economies, especially China, the abundant supply of cheap labour remains the basic source of comparative advantage. Any technological innovation must be based on this fact. In large-scale mass production, to intensively employ labour depends on the following conditions:

1. Labour can substitute equipment in major production process. To substitute labour for capital goods and to expand production by employing more labour, two conditions must be met. First, major production equipment must be able to run steadily when intensively used so that the working hours can be extended if necessary. Second, the operation must be simple and labours can be easily trained to use this equipment and even perform various operations.

2. The supply of labour must be very flexible and firms can easily adjust the number of labour when the market demand fluctuates.

3. Labour cost must be low.

In production, production technologies and equipment will be adjusted so that labour can be intensively used.

1. By intensively using labour and equipment, the utilization rate of production equipment will be increased, capital goods can be depreciated quickly.

Therefore, the time required for equipment renewal shortened and technological progress quickened.

2. By changing the number of workers employed and varying the working hours, the production can be expanded under a given designed production capacity, so that the short term market fluctuation can be effectively met, production maintained at a high level, therefore a JIT investment strategy can be supported. The substitution of capital with labour can assure market adaptability.

System integration based on modern ICT

The breathtaking development of ICT during the 1990s has significantly reduced the cost of computing and communication for industries globally, greatly facilitating the widespread application of computers in developing economies. Because of the great potential of applying computers in product development, material management, cost control, quality assurance and profit lifting, it is very important and profitable for developing economies to pay special attention to the applications of computer integrated technological systems. Priorities should be given to the following fields.

1. By adopting a top-down strategy, computer tools similar to MRP II can be employed to effectively manage materials and control costs. Starting from production process management, computer integration should gradually be extended to production development, process design, marketing and automation of processing platform. For developing economies, they can employ cheap computing power to achieve industrial management and resource optimization.

2. In terms of product development, technologies such as CAD and CAPP should be vigorously promoted so that products may have good "manufacturability" and modularity as well as be produced cheaply. In this way, companies can achieve flexibility in producing new products in response to market changes.

5. Conclusions

In this paper, we stress the primacy of learning in technological progress for developing economies, in terms of accumulating technological knowledge, know-how, and industrial experience. The importance of learning is partly due to the nature of tacit knowledge resided in technologies. With the development of modern ICT, developing economies can shorten the process of technological progress, and may also create distinctive trajectories of technological development. To some extent, the emergence of the American production paradigm represented by the Ford assembly line and the Japanese production paradigm centred on the lean production philosophy also shows that the long lasting competitive advantages of a nation can only be built on the unique combination of technologies and factor endowment. Therefore, it is hopeful that new production paradigm may emerge in developing economies on which competitive advantages can be built and maintained.

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THE NATIONAL INNOVATION SYSTEM: GOVERNMENT, INDUSTRY, UNIVERSITY ROLES

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1. Introduction

This note focuses on two studies that were recently completed by the Science and Technology Policy Program of SRI for the U.S. National Science Foundation that illustrate the importance of knowledge exchange in the innovation process and that shed some light on the importance of the relationships between government, industry and universities in the national innovation process.

Together, these studies emphasize three themes about these relationships:

- the importance of the relatively easy flow of ideas, knowledge, technology and people across institutional boundaries;
- the widely varying and frequently unpredictable roles of government, industry, and universities; and
- the overarching significance of first-class technical education and training for company and national industrial competitiveness.

But first, let me put this in a bit of context in terms of the National Innovation System in the United States.

2. Overview of the National Innovation System in the United States

In the United States, the R&D enterprise is scattered throughout a number of different kinds of institutions, which differ in their goals, mechanisms of financing and major functions. In general terms, as in most countries, we categorize the national research and innovation system as comprised of government, industry, and universities. In actuality, however, the system includes a fair amount of diversity.

There are government-owned/government-operated research labs and there are government-owned/contractor-operated research labs, which may be operated by universities, private industry or even non-profit organizations.

The university sector itself is diverse, consisting of public and privately owned institutions, which again vary in terms of the level of their research intensity, degree of specialization, and other factors.

In the industry sector, there are small and medium sized manufacturers that conduct R&D and there are large corporate R&D labs, as well as product development labs at the corporate division level.

And finally, we should also distinguish between those private companies that seek to make a profit and those that instead are chartered as what we call non-profit organizations, operating in the public interest. For example, SRI International is a non-profit organization – which doesn't mean that we don't like to make some bottom-line net earnings, it just means that we call it operating income rather than profit and that we plow it back into the organization for internally sponsored R&D or new facilities and equipment rather than distributing it to share holders. SRI would fall over in the industry category when you are simplifying things into these three broad sectors.

Accordingly, notwithstanding the overall simplistic picture of the actual innovation system, in actuality, the relationships between the individual organizations that comprise this system are multidimensional and varied.

3. Impact of government support for engineering

The first study examines how government support for engineering has contributed to the development and commercialization of recent, significant engineering innovations. This project has been led by David Roessner, the Associate Director of our Science and Technology Policy Program, who has kindly consented to lend me some of his briefing materials to share at this APEC Symposium.

The project is in some ways similar to studies conducted around 1970 known as Hindsight and TRACES, which tried to identify the scientific origins and underpinnings of a number of significant innovations. In our study, six innovations have been examined to date:

1) magnetic resonance imaging (MRI);
2) reaction injection molding of polymer composites (RIM);
3) the Internet;
4) computer-aided design applied to electronic circuits (CAD/EC);
5) optical fiber for telecommunications; and
6) the cellular telephone.

This note describes some of the principle generic findings. For more technical details, the first three cases are currently on the SRI Web page and the second three will be shortly at www.sri.com/policy/stp/inov.

Broadly speaking, we wanted to learn more about the processes by which significant engineering innovations evolve and how the various activities of government R&D funding agencies influenced those processes. Patterns were looked for across the six innovation cases in three categories:

1) The interplay of government, industry, and universities as the innovations evolve
2) The role of, and interaction between, fundamental research and technology development
3) The role of intellectual property rights protection

We also looked in detail across the cases at the specific ways in which the following activities of government agencies have influenced the evolution of these engineering innovations:

- Education;
- Support of research;
- Contribution to the knowledge base;
- Contribution to the research infrastructure;
- Contribution to supporting technology;
- Organizational leadership.

As Dave Roessner has noted in the study report, the cases illustrate what is becoming common knowledge: a significant factor in technological innovation in the United States in the latter decades of the twentieth century is the interplay of contributions by, and interaction among, all three sectors: government, industry, and academia. In some cases, this interaction takes place primarily through the flow of key contributors – people – across institutional boundaries (e.g., the Internet, CAD/EC, RIM). In other cases, the interplay consists primarily of the unimpeded flow of knowledge across these boundaries (e.g., optical fiber, the cellular phone, MRI). As Dave has also pointed out "the cases reveal clearly the importance of 'invisible colleges': scientists and engineers who share results and know-how via networks that span both cooperating and competing institutions. Isolation appears clearly as the enemy of innovation." In terms of intellectual property rights protection, the six case studies reveal that the innovations evolved successfully despite, rather than because of, such protection. The Internet, which is now yielding substantial private profits as well as social benefits, was until a few years ago an entirely public innovation, the diffusion of which was facilitated by the public character of its intrinsic technologies.

In nearly all six cases support for research and technology development by government, especially agencies of the Defense Department, played major roles. Without exception, the cases reveal the essential role that government support of education and training, especially graduate education, had on engineering innovation. It is this support of education and training that emerges most consistently across all six cases as a significant influence on the evolution of engineering innovation. Among other government activities, support of university research infrastructure emerges as the likely candidate for second place as most influential. Direct support of research by government agencies led directly to successful innovation in just one case: CAD/EC, and I refer you to that case for the details on why that occurred in that instance. There is no doubt, however, that government support of research produced the knowledge that was essential to – or that underlay – the successful evolution of the other innovations studied.

4. Engineering Research Centers Program: Interactions with Industry

The second study, which relates to the impact on industry of interactions with the U.S. University-based Engineering Research Centers, reinforces some of the findings from the innovation study. The Engineering Research Centers (ERC) program was established in 1985 by the National Science Foundation (NSF) to create long-term collaborations between universities and industry, to create industry-relevant knowledge at the intersections of traditional disciplines, and to prepare a new generation of industry leaders who are more capable of engaging in team-based, cross-disciplinary engineering practice. The program was designed as a three-way partnership: universities, in addition to receiving government support from NSF for the establishment of the Centers, were to recruit industrial firms as ERC members or partners that would provide additional financial support and maintain close ties with ERC activities. Ultimately the program was aimed at increasing U.S. economic competitiveness by strengthening the linkages among those sectors.

As part of an ongoing effort to examine the impact of the ERC program, now in existence for over a decade, NSF asked SRI to conduct a study examining one important aspect of the ERC program: the *patterns* of interaction between Centers and industry, and the overall *impact* of those interactions on the participating firms. That is, we were primarily looking at the *type*, *frequency* or distribution, and *value* of ERC interactions with industrial firms that participate.

I can only touch on some of the broadest findings from the study. The report itself, however, offers a wealth of detail. It is available on SRI's Web page, at www.sri.com/policy/stp/erc.

At the time that this study was initiated, there were 18 ERCs in existence, with more than 700 industrial partnerships, involving approximately 550 different firms. Areas of research conducted by the ERCs covered a broad spectrum, including biotechnology/bioengineering, design and manufacturing, energy and resource recover, materials process engineering, and electronics/telecommunications.

How do companies typically interact with ERCs? The most common interactions were participation in seminars and workshops conducted by the ERC, review of ERC research results or publications, and receipt of technical advice or consultation from ERC researchers. A much lower percentage reported participating in *joint* projects with ERC researchers and even fewer had co-authored a publication or developed an invention jointly with an ERC researcher.

Why do companies participate in ERCs? Among the most important reasons are access to new ideas, a match between the research interest of the ERC and the company, access to ERC expertise, and an opportunity to keep abreast of university-based research. About a third of the firms considered access to ERC students very or extremely important in their initial reasons for participating. Relatively few joined an ERC to conduct joint projects or to license ERC inventions or software.

What do companies say they obtain by participating in ERCs? The outcomes *most* commonly reported, generally relate to what might be called "knowledge exchange". They include access to new ideas, technical assistance, influence on a company's R&D agenda, increased interaction with other firms, and technical information for customers and suppliers. Those outcomes which are *least* frequently reported by participating firms, all relate to more tangible, concrete product or process oriented outcomes. They include, for example, the development of a new product or process, or the adoption of an ERC technology, licensing, patenting or copyrighting of an ERC-based technology or software. The point is that the most *frequently* reported results of interactions with ERCs relate to the firm's exposure to knowledge and information at the ERC, while the *least* frequently reported relate to the transfer of research results that are more or less directly translatable into new products or processes introduced or commercialized by the firm. In the middle – use of ERC facilities and equipment and hiring of an ERC student or graduate – are outcomes that in some ways might be considered as involving both knowledge exchange and the more concrete product or process-oriented exchange.

Among the firms who experienced the outcomes, some reported valuations of the outcome a moderate amount or a great deal. Of particular interest is the fact that the knowledge exchange types of outcomes are generally valued every bit as highly, and in some cases more so, than the more process-product oriented outcomes. With the exception of the hiring of ERC students, to which I will return in a moment, the next most valued outcomes are direct technical assistance, exposure to new ideas, know-how and technologies, and improved information for their customers or suppliers.

While in all cases, over half of the firms found at least some value to the outcome reported, the value attached to the hiring of ERC students or graduates is especially high. Eighty-one percent reported valuing this a moderate amount or great deal, much higher than any other outcome and close to 60 percent of the firms reported valuing the hiring of an ERC student a great deal. This is roughly double the percentage who reported this level of value associated with any other specific outcome. Companies reported that ERC graduates were better than their peers without ERC experience in many ways, including their overall preparedness to work in industry and the amount of company funded training required before becoming a net contributor to the firm.

How do companies explain the benefits they obtain? The most important factors appear to be the match between the ERC's and the company's technical focus, the ERC's responsiveness to company needs and effort to stay in contact, and the receptivity of company technical staff to ERC ideas and results. On the other hand, the company's ability to establish proprietary rights to ERC-based technology, and the commercial potential of ERC research made little difference to most firms. Further, relatively few companies considered either a low commercialization potential of ERC research or that that ERC research was not sufficiently applied to be barriers to benefiting from their participation.

What this shows is that knowledge exchange is at the heart of the ERC-industry interaction. It is access to the ideas, know-how and core research at the universities – as well as the students trained in a center that interacts closely with industry – that industry basically desires, gets, and highly values when it occurs in its interactions with ERCs. Industry is neither going to ERCs directly seeking more tangible

product/process types of outcomes nor does it generally get that type of outcome, although, of course, it is appreciated very highly when, although unanticipated, it does occur. What we are also finding, however, is that government's role in this process is equally important – it is difficult for firms to assign a monetary value to this relatively intangible flow of knowledge and ideas, and therefore the ability to leverage government funds is viewed as an especially important factor in this relationship.

5. Conclusion

The two studies reported here show the importance of the links among the three broad categories of organizations involved in the national innovation process. Without the relatively easy flow of ideas, knowledge, technology and *people* across those institutional boundaries, innovation would not occur, or at least would be extremely hampered. The studies also both clearly point to the overarching significance of first-class technical education and training for company and national industrial competitiveness.

A NEW TECHNOLOGY LANDSCAPE IN ASIA? COMMENTS ON EMERGING NEW STRUCTURES AND CAPABILITIES

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1. Introduction

The information and comments of this paper should be understood in the light of technological globalization, the effects of which are summarized below. Technologies act as a powerful instrument for the diffusion of information and provide the underpinning of many aspects of globalization, e.g. trade, financial markets, and a host of services. This in turn feeds the process of generating and diffusing new technologies and a number of important questions arise.

- To what extent are National Systems of Innovation (NIS) affected by the globalization of technology?
- Will National Systems of Innovation become increasingly identical in different countries?
- To what extent are national policies for NIS being circumscribed?

Large firms operating in an international environment control a very substantial proportion of all industrial research, and today many of them constitute a firm-based system of technological development, which interact with national systems of innovations (NIS). However, these linkages are not yet well understood although it is becoming increasingly clear that they strongly impinge on NIS, and diminish the effectiveness of national policies within state borders.

Available evidence although scanty, indicates that large multinational firms are increasing their influence on national systems of innovation. Often this takes place simultaneously in a number of countries, which individually are providing critical inputs for technological development carried out within a particular company. Thus, the resources for technological development used by many multinational companies become embedded in a number of NIS. Multinational companies have in the past been

* The information and comments contained in this paper are partly extracted from two recent publications:

- Jon Sigurdson and Olle Persson "The New Technological Landscape in Pacific Asia: An Inquiry into the Dramatic Changes in Patenting and Scientific Publishing and its Underlying Forces and Effects", Research Evaluation (UK), volume 7, number 2 (August 1997), pp. 1-9
- "Knowledge Creation and Innovation in Geographically Dispersed Organisations", conference paper submitted to Asia-Pacific Journal of Management
- "The Role and Bounds of National Science and Technology Policies", paper prepared for Taipei Workshop for OECD Project on National Innovation Systems in Catching-up Economies April 20-22, 1998, Taipei

quite reluctant to locate technological operations away from home countries - if such activities were directly related to core competencies. However, cross-national mergers and acquisitions will dramatically shift this perspective. Such changes have already been preceded by the forced globalization of large multinational companies that had their origin small countries like Sweden, the Netherlands and Switzerland. Thus, it is to be expected that manufacture and related technological development, based on knowledge-intensive operations, will in the future be less geographically circumscribed than has been the case in the past. However, centres of excellence arise only over time and require certain conditions to become attractive.

Countries want to promote their national interests while firms have to exploit markets to gain a competitive advantage. The critical responsibility for national policy makers is to grasp the balance between available technology policies that affect national and regional change on one hand while stimulating and utilizing the globalization efforts of actors outside their national boundaries on the other. However, location-specific advantages remain in spite of globalization, which is partially a reflection of agglomeration of skills and acquisition of knowledge, which is closely linked to the local/national education and research structure. Furthermore, sectoral specialization arises in countries, although seldom of a permanent nature in the age of globalization.

2. Visions in Northeast Asia and in ASEAN Countries

Korea has been transformed from an agrarian economy into a newly industrialized economy in the span of little more than three decades. Indonesia in the Southern region of Asia Pacific has also shown a remarkable development success, as it was in the mid-1960s one of the poorest economies in the world. China has since its open-door policy, initiated in 1978, joined the league of the most rapidly developing economies and has changed from an earlier period of autarky to become a major host to foreign direct investment (FDI) in the global economy. Similar changes have taken place in most other economies in the region.

Technology policy has in its entire dimension become one of the most discussed political issues in many economies in the region. This is obviously the case in Indonesia where the Minister for Research and Technology has, since the mid 1980s launched a number of widely publicized initiatives to accelerate that economy's entry into the leagues of economies with broad capabilities in advanced science and technology.

Korea, being in a more advanced stage of development, has since the early 1990s been active in providing a new platform for future generation technologies which include multimedia electronics, personal communication systems and a new type of nuclear breeder reactor. Japan is already a technological superpower but has increasingly come to realize that its science and technology system lacks in creativity and efficiency which is particularly true for most of its government research institutes and for the university system. Changes are now implemented, based on major policy decisions in 1996, and to be accompanied by very substantial increases in the state budget for science and technology.

China has since the early 1950s been committed to developing a very broad range of technological and scientific capabilities, although poorly linked to economic development, and is now gradually probing into more suitable approaches for its development of science and technology. China, in fact, provides a full spectrum of technology development approaches each of them having distinct similarities with those of individual economies in the Asia Pacific region.[1] First, China is consolidating some of its major state-owned enterprises into technology-based corporations with early characteristics that resemble those of *chaebols* in Korea or the large diversified companies in Japan. Second, China is also promoting small and medium-sized technology-based companies, which show distinct similarities with such companies in Chinese Taipei. Third, China is maintaining a large sector of government research institutes through which it intervenes in pursuing national technology programs similar to those in Indonesia and Vietnam. Finally, China has attracted large amounts of foreign direct investment to encourage industrial and technological development, which particularly corresponds to policies in Singapore and other ASEAN countries.

Throughout the Asia Pacific region, science and technology is perceived as being, or becoming, the key factor that will fuel the region's continued economic development. There can be no doubt that the criticism of Paul Krugman has highlighted shortcomings, sharpened the analysis and triggered more forward-looking approaches.

3. Scientific research papers and patents

A debate is raging whether the rapid economic development in Pacific Asia has a solid basis and is not only relying on the use of more capital and labour. Available data show substantial increases in patenting by Asian companies in the major market for industrial products – the United States. Pacific Asia overtook the European Union already in the mid-1980s and has expanded dramatically in sectors like telecommunications, computers and data processing systems. This may indicate that Pacific Asia is more stirred than EU to protect their intellectual property rights in the US. However, the increase in the number of scientific papers indicates a substantial expansion in research activities, which are likely to strengthen the support for future innovative activities in Pacific Asia. In addition, the US is ahead of the EU in establishing closer links in both joint research and in joint patenting with the region.

Statistical data indicate that Pacific Asia economies are stronger in patenting activity than in scientific research. Furthermore, the US is far ahead in establishing joint relations with Pacific Asia countries – both in patenting and scientific research. The statistical data also support the notion that scientific research, particularly in certain sub-fields, is rapidly expanding in Pacific Asia. This would indicate that a technological shift in science-based activities might be underway.

There are various interpretations of the rapidly expanding number of patents in the US system assigned to Pacific Asia companies. One argument suggests that the US market

[1] John Mathews, to whom I am indebted, has suggested the classification of ongoing technology policies in China.

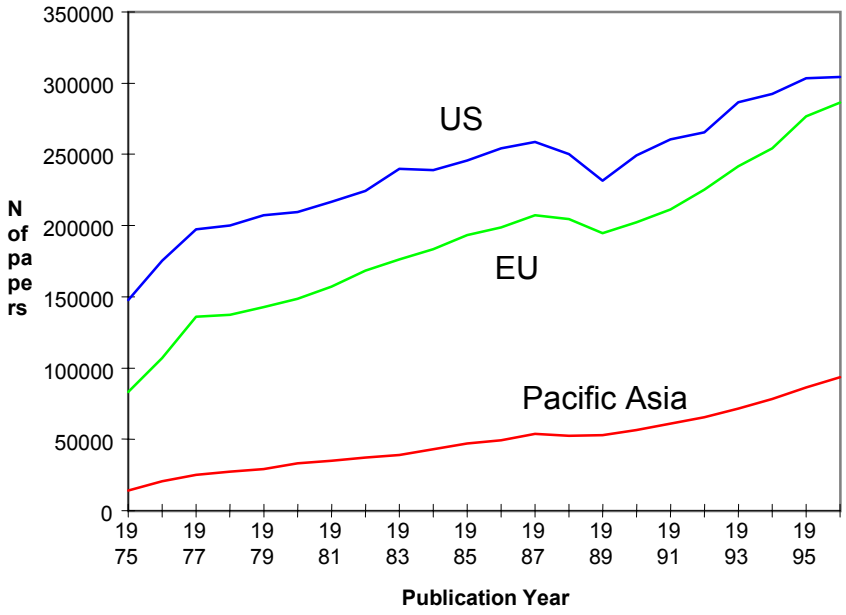
is much more important to Asian companies than it is to EU companies while another maintains that Asian patents only protect low value-added products. Another view suggests that the EU is better in research than in innovative activities, the latter usually resulting in patents. The integration in Europe has created the notion of an economic bloc, which may have fostered a temporary sense of self-sufficiency, which does not exist in Asia. The ongoing expansion of research in Pacific Asia, if closely linked to innovative activities, will provide additional strong support in establishing a strong position in intellectual property rights.

In the following, I will illustrate the dynamic changes that have taken place in Pacific Asia economies by using statistics on patenting activity and publication of scientific papers. Major changes in a national R&D-system should be reflected in the amount and composition of knowledge outputs. When it comes to basic scientific activity, publication in scholarly journals is the main channel for presenting and evaluating results. In a similar fashion, patenting is one of the main signs of technological activity. Using the 3,300 journals covered by Science Citation Index™ should be enough to reveal major changes in a nation's research system. Similarly, the patent system of the US is a relevant database for studying the dynamics of national innovation systems. Of course, there are papers and patents that are not covered by these databases, and there are as well other forms of outputs. Furthermore, the publication and patenting strategies may differ among economies. Still, it is reasonable to believe that significant changes will show up on these central, but limited, segments of the knowledge market.

4. Overall growth of the number of papers and patents

Let us first find out how the pattern of publishing scientific papers has evolved over the past 20 years, covering the period 1975-1996 in the US, the EU and Pacific Asia. The results, which are illustrated in Figure 1, clearly indicate that the US is leading although closely trailed by the EU. The combined publication of scientific papers in Pacific Asia is still at a much lower level, although the annual increase is much higher than in the US and EU. A substantial share of scientific papers originates from researchers in a limited number of economies. However, the figures indicate that the region is in a catch-up phase, which is also revealed in science and technology policies and increased allocations to R&D in state budgets. It should be noted that increased attention to the scientific sector through increased budgets and other measures would not result in increased scientific activity, as measured by published papers, until several years later. Thus, we can expect that the gap between Pacific Asia and the other two regions will dramatically narrow over the next 20 years.

Figure 1.
Number of papers in Science Citation Index (SCI), by Region 1975-1996



However, when obtaining statistics on the level of patenting activity, as revealed in the US Patent System, a completely reverse picture emerges. During the period 1976-1995, patenting by foreign assignees has increased considerably in the US and more than threefold for the EU. However, the patenting by assignees from economies in Pacific Asia has increased much more dramatically and actually overtook the EU in the mid-1980s. See figure 2.

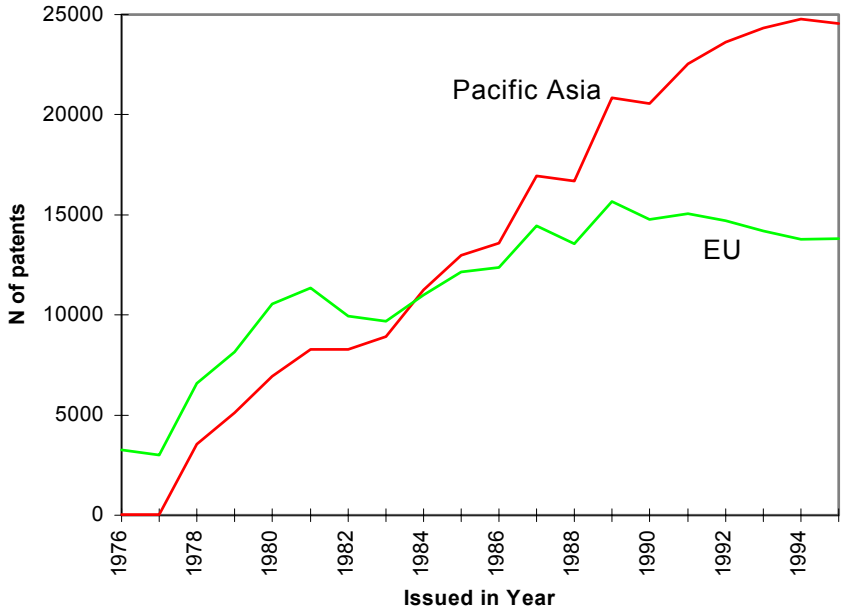
5. Growth of papers and patents in sub-fields

Naturally the aggregate figures discussed above do not reveal what has taken place in specific sectors, which may vary considerably from one field to another. Patenting in telecommunications reveals a general pattern of considerable increase for the EU and a dramatic increase for Pacific Asia, which has overtaken the EU at a much earlier stage and maintains a considerable lead over EU – a lead that appears to be widening.

A similar but even more dramatic change has taken place in patenting activity in electrical computers and data processing systems. The number of patents attributed to EU assignees has hardly increased while those of Pacific Asia has registered a tremendous jump leaving EU far behind.

However, there are sub-fields, which show a very different pattern, which is exemplified by biotechnology and microbiology. In this sector both the EU and Pacific Asia have registered considerable increases of their patenting activity in the US, basically in parallel throughout the period of 20 years.

Figure 2.
Patents in US-System, by region 1976-1995



6. Collaboration in technological innovation and basic science

Globalization also has the effect that inventions and papers are increasingly jointly patented and jointly published, respectively, by assignees and authors in different regions. Let us first look at joint region patents; the figures in Table 1 show very substantial increases over the period covering a majority of patents taken out by EU-US assignees. However, the number of joint EU-Pacific Asia and US-Pacific assignees has increased more rapidly. It should also be noted that the joint US-Pacific Asia patenting is several times higher than that of EU-Pacific Asia.

Table 1
Co-invented patents, by region

Region	1981-85 Numbers	Proportion Of 1981-85	1986-90 Numbers	Proportion of 1981-85	1991-95 Numbers	Proportion of 1981-85
EU-Pacific Asia	72	100	201	279	474	658
EU-US	1157	100	2141	185	4002	346
US- Pacific Asia	316	100	809	256	1892	599

A very similar picture emerges from comparing co-authored papers with authors in different regions. The increases are substantial over the period covered, although lower than those for patents with a very significant dominance of EU-US co-authorship. Similar to co-patenting the US-Pacific Asia relationship is considerably stronger than that of EU-Pacific Asia. See table 2.

Table 2
Co-authored papers, by region

Region	1981-85 Numbers	Proportion of 1981-85	1986-90 Numbers	Proportion of 1981-85	1991-95 Numbers	Proportion of 1981-85
EU-Pacific Asia	3671	100	7320	199	15745	429
EU-US	39653	100	60629	153	100864	254
US- Pacific Asia	8095	100	14310	177	29620	366

7. The Changing Character of National Innovation Systems (NSI)

The OECD Booklet on National Innovation Systems states[2]:

> "The concept of national innovation systems rests on the premise that understanding the linkages among the actors involved in innovation is key to improving technology performance. Innovation and technical progress are the result of a complex set of relationships among actors producing, distributing and applying various kinds of knowledge. The innovative performance of a country depends to a large extent on how these actors relate to each other as elements of a collective system of knowledge creation and use as well as the technologies they use. These actors are primarily private enterprises, universities and public research institutes and the people within them. The linkages can take the form of joint research, personnel exchanges, cross-patenting, purchase of equipment and a variety of other channels. There is no single accepted definition of a national system of innovation."

The objective to control and guide the NIS is to improve technology performance. This requires an adept understanding on how the various actors relate to each other in a system of knowledge creation. The argument in the following is that the changing character of actors and their relations have in recent decade(s) undergone fundamental changes which have only partly been grasped by national policy makers and translated into new national, supra-national policy structures.

Michael Borrus and John Zysman provide significant illumination on the character of Cross-national Production Networks (CPNs).[3] They argue that:

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[2] P. 9 National Innovation Systems, OECD-STI, Paris 1997, 48 pp

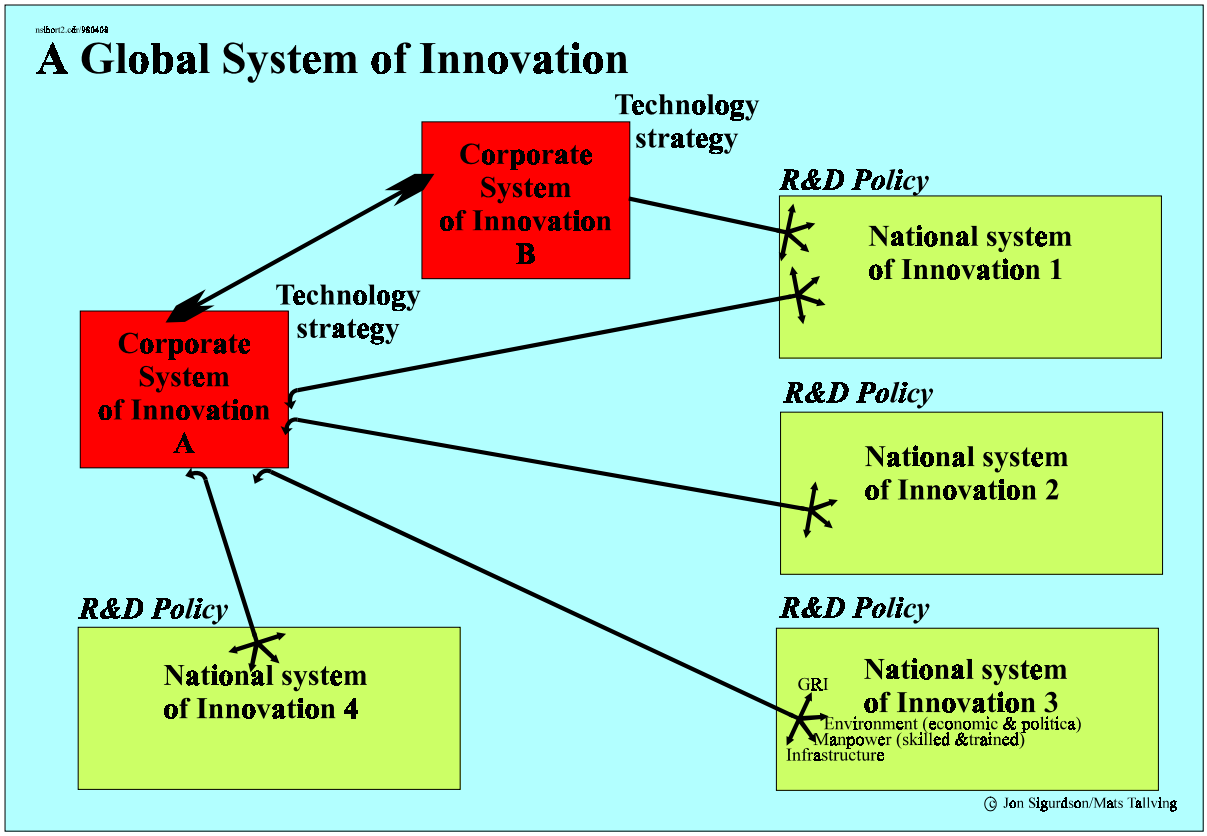
[3] Borrus, Michael and Zysman Borrus, "Globalization with Borders - The Rise of Wintelism and The Future of Global Competition", in Industry and Innovation, Vol. 4 No. 2 (December 1997)

"CPNs permit and result from an increasingly fine division of labor. The networks permit firms to weave together the constituent elements of the value-chain into competitively effective new production systems, while facilitating diverse points of innovation. But perhaps mot important, have turned large segments of complex manufacturing into a commodity available in the market."

What is the character of these ties, what patterns do they form and what are their significance? The ongoing globalization takes place in a world economy that has several centres, each with a different endowment and capacity for innovation and development. This diversity is reflected in competing strategies where nations, group of nations, a single corporation or a group of corporations strive to seize advantages under rapidly changing circumstances.

Let us first look at some major structural changes. First, actors in a small group of economies control the majority of all global R&D, basically the OECD-Group, which the G-7 countries dominate. Secondly, the private sector dominates R&D in basically all advanced industrialized economies, which constitute the OECD-Group. Third, large corporations dominate in R&D. Fourth, large corporations are increasingly global actors. In sum, large corporations, with primary bases in OECD-countries dominate the control and use of R&D resources in an increasingly global economy, which poses critical challenges in most economies whether these have reached an advanced industrial status or not. These potential threats to nations are modified by the fact that R&D resources are only one important source for technological progress. See Figure 3.

Figure 3
A Global System of Innovation



However, it is useful to suggest a classification of innovation system where the focus presently has remained on the national system. It has become obvious that corporations often or generally transcend the national system. One response to this challenge is the creation of the EU Framework for R&D that has also come into existence to meet demands for critical mass in R&D and for support for the industrial and technological community in Europe.

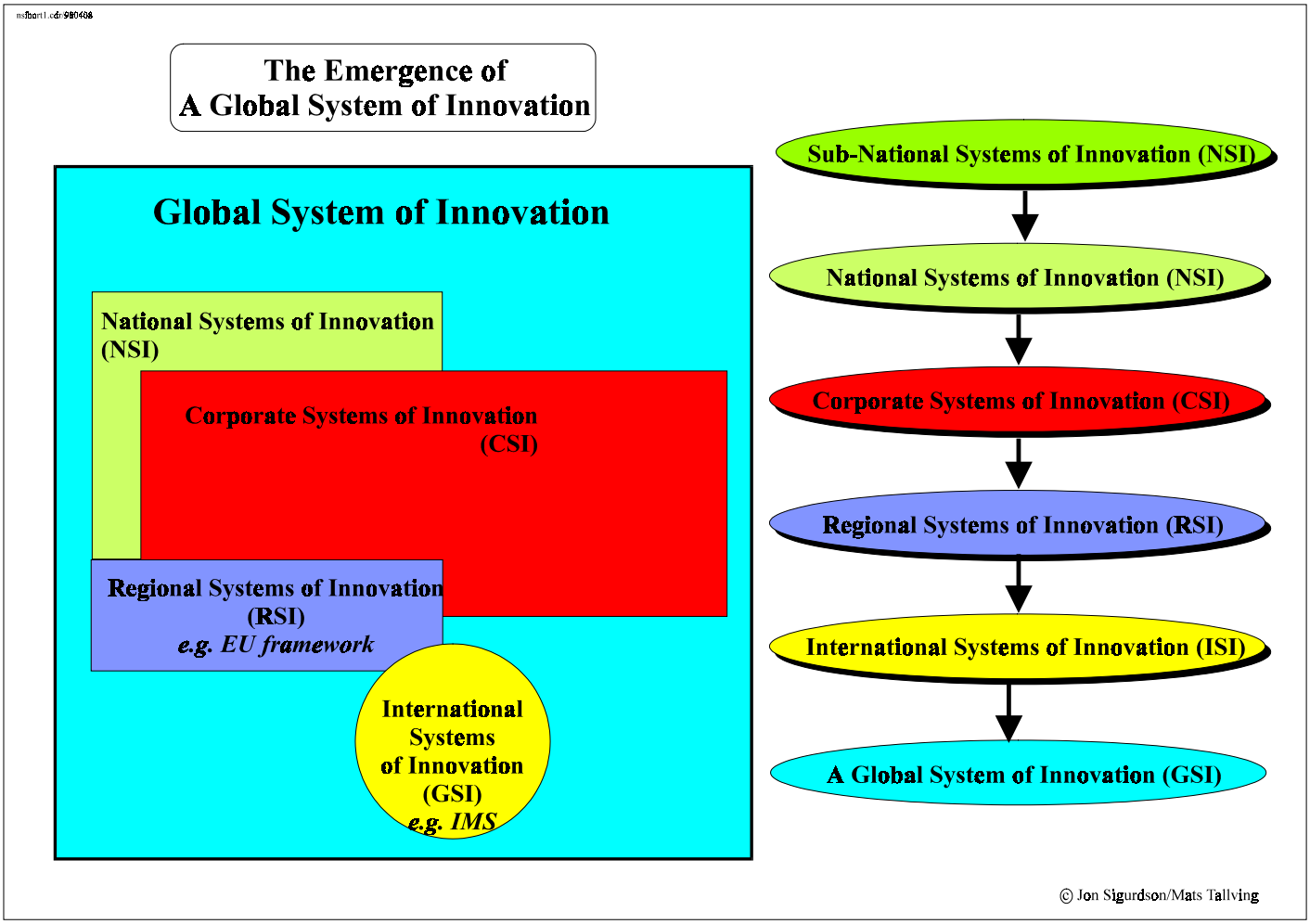
Other responses include the creation of R&D networks within international organizations such as the UN's Food and Agriculture Organization (FAO), supported by governments and more recently international industrial innovation networks, which are supported by both nations and corporations. Furthermore, in many economies, and not only the largest, one finds sub-national regional systems of innovation which may have become more pronounced in economies which are large and have a federal structure.

All five different systems which have been identified are likely to remain, although their relative importance is likely to undergo substantial changes over the coming decades. Assuming continued integration of the global economy, as exemplified in transportation, IT infrastructures, financial services and last but not least in manufacturing, it may be increasingly practical to identify a global system of innovation to represent the structure and environment in which technological change and technological progress take change.

Foreign firms can be involved not only in the long-term development of the national technological base but also in national short-term commercial applications of technologies. The national base is operationalised by companies to strengthen their competitiveness in a global economy, and national support for the pertinent technological and skill base is often essential if company operations are to remain within a particular country. Thus, the dynamic character of global competition forces nations to pursue policies that provide significant elements that are critical for a firm's competitive advantage. A company pursuing a competitive advantage in the global economy would look for access to skilled and trained manpower, good infrastructures, good political and economic environment and access to government research institutes (GRIs). This might indicate that global companies have actually taken hegemony in setting the relations between corporate technology strategy and national R&D policy. See Figure 4.

The OECD report states that there are many different approaches to analyzing national innovation systems and mentions innovation surveys directed to firms, and cluster analysis with a focus on the interactions between particular types of firms and sectors. Furthermore it is suggested that innovation systems can also be analyzed at different levels, sub-regional, national, pan-regional and international, and argues that the national level may be the most relevant due to the role of a host of country-specific interactions. It is obvious that globalization has not created a borderless global economy as national systems of production although with an increasingly strong regional structure, which is shaped by history, and political and economic institutions.

Figure 4
The Emergence of A Global System of Innovation



8. Asian Specialization and Global Competition

The heterogeneity of innovation systems in Asia Pacific derives from a series of developments that has characterized the region and created four levels of technological systems with Japan at the top. The next level consists of Korea, Chinese Taipei, Singapore and Hong Kong, China – a group that industrialized shortly after W.W.II through technology catch-up and export-led growth. The next level consists of the major economies in Southeast Asia, which includes Indonesia, Thailand, Malaysia, Philippines, and more recently Vietnam, as well as the coastal provinces of China. Cross-national production networks have played a very important role in the economic and industrial development of these economies, as they do not contain the local manufacturing prowess that has been so significant in Japan as well as in Korea and Chinese Taipei. Thus their strategies must evolve from a division of labour that is controlled by firms in other parts of Asia Pacific, in Europe or in Asia. The final level is large-population economies which includes China as well as India. They may be able to pursue far-reaching indigenous strategies, which are only partly export-led and where network-led development will be less pronounced.

A matrix of production networks involving all four levels has gradually evolved through stages of industrial dis-aggregation. However, the dis-aggregation of electronics production and outsourcing in Asia Pacific did not become a major force until the mid-1980s, after which it increased dramatically. Today the electronics CPN constitutes more than US$ 50 billion in sales and estimates suggest that this represent 10-20 per cent of total product-level electronics manufacturing.[4]

Simplistically it can be argued that the earlier vertical structures of electronic production, still prevalent in car manufacture, have disintegrated or rather been transformed into horizontal structures in which marketing and design still remain in "home countries". This has offered new possibilities for host economies in Asia Pacific that have captured large portions of the value-added chain and are increasingly being able to control essential components that go in the final product

Borrus and Zysman argue that the move to CPNs and contract production services permits systems firms to concentrate on product definition and market strategies while conserving capital and gaining production flexibility. As well, the new CPN possibilities provide small producers with a cost-effective production strategy to exploit the new market opportunities.

The recent decade has seen a distinct shift in the electronics industry away from final assembly and toward exceptional value-added products that are supported by standards strategies in which US innovations and entrepreneurs have been extraordinarily strong. Subsequently, US CPNs have created strong bases for component technologies and manufacturing capabilities in Asia Pacific, outside Japan. The rapid and successful development of electronics CPN raises the question if they are likely to become broad

[4] Borrus, Michael and Zysman Borrus, "Globalization with Borders - The Rise of Wintelism and The Future of Global Competition", in Industry and Innovation, Vol. 4 No. 2 (December 1997), p 158

features of the global economy that reach considerably beyond the electronics industry. Borrus and Zysman argue that:

> "Electronics may be originating sector, the development test-bed, for the new approach to competition and production. But the enormous possibilities for creating distinctive products and new product segments, and for increasing the functionality of existing products, suggest that the new approaches will diffuse more widely to other industries."[5]

The shift in industrial research in the US and other industrialized countries indicates that IT R&D may soon dominate industrial. Furthermore, biotechnology, or more broadly industrial research in drugs and medical areas also show a dramatic shift. See table 2. This concentration of industrial research in IT and "biotechnology" poses new challenges to the national systems of innovation in Asia Pacific and elsewhere.

Table 3
Information/Electronics and Drugs/Medicines dominate Industrial R&D in the U.S.[6]

Share of Industrial sector R&D	1981	1988	1995
Information and Electronics R&D	32%	42%	44%
Drugs and Medical R&D	7%	9%	16%
Subtotal	39%	51%	60%

Another, possibly even more serious, challenge comes from the emergence of the digital economy where firms in the US and other advanced industrialized economies are at the forefront and are not only setting the pace but also the direction for future change. One of the most notable economic developments in recent years has been the rapid increase in the share of computing and communications (IT) in investment activity and in GDP. The US Department of Commerce mentions in a recent report that the share of IT grew from 4.9 per cent of the economy in 1985 to 6.1 per cent as the PC began to penetrate homes and offices. The next outburst started in 1993 with the burst of commercial activity driven by the Internet. From 1993-1998, the IT share of the US economy will have risen from 6.4 per cent to an estimated 8.2 per cent. With such rapid expansion the share of IT in the total US nominal economy has been running almost double its share of the economy, at close to 15 per cent.[7]

It is argued that the pace of technological development and the borderless environment created by the Internet drives a new paradigm for government and private sector responsibilities.[8] Funding for research and development on future Internet and high performance computing technologies will come from government budgets - maybe primarily in the US. However, most of the capital to build the computing and

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[5] ibid. p. 163

[6] The Global Context for U.S. Technology Policy, p.9

[7] The Emerging Digital Economy, US Dept of Commerce, April 1998

[8] ibid.

telecommunications infrastructure is being provided by the private sector, and it is expected that Internet should function as a seamless global marketplace with no artificial barriers erected by the government. So far, its seems that it is only Singapore and to a lesser extent Malaysia that has risen up the challenge of an impending digital economy.

The US report says that growth could accelerate in the coming years not only in the IT sector itself, but across all sectors of the economy as the number of people connected to the Internet multiplies and its commercial uses grows - primarily in the following four activities. First, the Internet will expand from presently around 100 millions throughout the world to an estimated 1,000 million by 2005. Such an expansion will drive dramatic increases in computer, software, services and communications.

Second, electronic commerce among business, which started only in 1996, is likely to expand rapidly. Third, he digital delivery of goods and services will rapidly increase as software programs, newspapers, and music CDs will no longer need to be packages and delivered to stores, homes and kiosks, as they can be delivered electronically over the Internet. Such transactions are already common among airlines and security companies. The sale and transmission of goods and services electronically is likely to be the largest and most visible driver of the new digital economy. Finally, the Internet can also be used to order material goods and services, which are produced, stored and physically delivered, and sales of certain products such as computers. Software, cars, books and flowers are already growing rapidly.

9. Concluding remarks

Long before the financial crisis struck in Asia there was a preoccupation with the role of technology and exploitation of R&D resources although with varying results from economy to economy. However, the countries in Asia Pacific, with the possible exceptions of Japan and Korea, have already been influenced by rapid changes in the global economy, which has drastically reduced the prospects for establishing truly national innovation systems. The reasons are threefold. First, following from global markets and global production, corporate R&D has also become taken on the character of a global resource. Second, as a sequel large product segments, particularly in electronics, have become integral parts of Cross-National Production Networks (CPNs). This is also revealed when looking into the composition of the flow of foreign direct investment (FDI). Third, services and other commercial activities, based on digital technology, have recently and rapidly emerged as crucial and momentous parts of national economies, particularly in the US. Thus, national innovation systems in Asia Pacific, and elsewhere, have to accommodate and adjust to this threefold challenge.

Opportunities for technological development and research are opening up on a global scale and can be seen as paralleling and complementing opportunities in manufacture. Thus, large global companies develop new organizational practices in order to fully exploit the opportunities for decentralized technological development and research.

Notwithstanding, national objectives exist but have to be formulated in light of global changes.

It is suggested in this paper that the confines of national innovation systems have become increasingly determined by global changes, and that national policies for science and technology are becoming subordinated to corporate technology strategies, which sustain Cross-National Production Networks.

However, it has become apparent that the intensity of global competition in many industries, clearly exemplified in the electronics sector, has forced even innovation-oriented companies to forcibly pursue efficiency in production. Subsequently, there is a tendency for global companies to let their subsidiaries abroad take on a larger responsibility for competitiveness. This would often require a high degree of responsiveness that will be better served by using local creative resources. In the process there may occur opportunities, within sub-national regions, of creating fundamental and indispensable technologies, to be combined with more basic scientific resources, in such a way that a clustering of corporate activities may appear in certain locations.

The key to improving technology performance dwells in the understanding of the linkages among the actors involved in innovation. This understanding requires broad and systematic knowledge of the domestic innovation system, of systems in other countries, and a keen understanding of the increasingly interlocking character of large global companies. Without such intelligence realistic national objectives cannot be formulated, but still have to be constantly modified in the light of changes within an innovation system which is increasingly taking on global characteristics.

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INTERNATIONALIZATION OF SCIENCE AND TECHNOLOGY AND ITS IMPACT ON INTERNATIONAL COOPERATION

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1. Introduction

In a sense, the title of this note is a misnomer at best, misleading at worst. Some clarification of its context is needed. When the subject of international cooperation in science and technology (S&T) is discussed, it is usually thought of as representing research and development (R&D) activities that involve personnel from more than one economy involved in research that crosses or transcends national borders. It may represent a "big science" operation in which scientists from several economies collaborate on an experiment using large-scale facilities, such as a nuclear accelerator, large telescope, or internationally developed satellite. Joint international projects take place under special international agreements – the United States was somewhat notorious during the Cold War for concluding various summit meetings in which no serious issues could be resolved by establishing an agreement for international scientific cooperation. Or it may take place in industry, where a large and/or multinational corporation locates a laboratory outside its headquarters country, staffing it with both local and international personnel.

However, it must be recognized that R&D represents only a part of S&T activities that can be internationalized. Science, itself, usually does represent research aimed at the creation of new knowledge, but the research is also often a part of the process of higher education, in which many international borders may have been crossed. On the other hand, "development" has been increasingly recognized as a process that involves both science and technological development. We still do not know enough about the innovation process that develops new technologies. However, the "linear model," in which innovation represents a direct pipeline that passes from scientific research, through engineering development, testing, and pre-production phases, to end with the introduction of a new product or process, has pretty well been abandoned. Whatever is in the "black box" of the innovation process, it is a complex process that involves constant feedback and iterative interaction between the research and development processes.

These points serve to emphasize the potentially complex nature of any discussion of international scientific cooperation. This note sheds light on this issue drawing on empirical data available on cooperation – the databases of the Institute for Scientific Information (ISI) in "bibliometric" studies.

2. Why Cooperate?

Why do nations engage in international cooperation in S&T? A number of reasons or motivations can be suggested, and instances of cooperation often embody more than one of these.

First, science has always been culturally international in nature. Researchers make an effort to disseminate the results of their work by publication, by preference in journals that enjoy an international reputation, will be read by their colleagues abroad, and predominantly in the English language. International exchanges, meetings, publication, travel and exchange represent the *modus operandi* of a community that knows that its specialized interests are often more shared abroad than at home. And in recent years, technology has become internationalized in the context of the global economy. Rapid transportation, information technology, multinational corporations and the internationalization of competitive forces move technology across borders. Staying on top of innovation requires a nose for international developments: competitive advantage is increasingly "created" from S&T, rather than being derived from resources in the ground or agriculturally productive environments.

Second, the best vehicle for technology transfer is people: cooperation breeds interaction and facilitates discovery and innovation. It is a social process that involves the minds of men – and women, who bring their individual knowledge to bear on solving problems and end up transferring technologies.

A third reason for cooperation is that the need for access to instrumentation, other special equipment and systems may require mobility and cooperation. Fusion reactors, accelerators, specially instrumented and capable telescopes, gene sequencers, and the like are not to be found on every street corner, nor in every economy. The need to share costly instrumentation provides a strong incentive for cooperation.

A related fourth reason is that research may location sensitive. There are access requirements for things like the Northern or Southern Hemisphere of the sky (plus an appropriately instrumented telescope), or tropical or geological environments (e.g. potentially natural ingredients, earthquake research under particular seismic conditions, or specialized ecological systems).

Finally, there are humanitarian reasons for cooperation that can range from solving local or global health problems to the desire to strengthen a developing economy's infrastructure, whether directly in S&T, in education, or economically.

3. What's Happening?

Developments are generally favorable for increased international cooperation in science and technology, especially that involving developing economies.

In science, research activity in developing economies is increasingly visible in the international literature, which is to say that it is competitive in terms of being published in the type of peer-reviewed, internationally-circulated journals that are indexed by ISI.

An increasing share of the database is represented by papers that include authors from Mexico, Brazil, and China, while India has remained at a relatively level over the past decade. Increasing visibility (See Table 1) is also evident for most of the newly industrializing or emerging economies (NIEs) that are members of APEC. While the numbers for many economies remain small, it is important to recognize that, in a global, knowledge-based economy, the ability to sustain a visible presence in the international scientific community is a critical part of economic development.

Table 1
Internationally Co-Authored Articles
(In Percent)

Economy	1981-87	1988-93	Change in %
United States	6.7	10.3	3.6
Japan	6.6	10.5	3.8
Canada	18.5	24.5	6.4
Australia & New Zealand	14.7	21.6	6.9
India	7.0	11.5	4.5
China	23.7	27.1	3.4
Asian NIEs	25.4	22.9	-2.5
Other Asia	38.3	43.7	5.3

There is also evidence of increasing international collaboration on the part of many economies, as represented by international co-authorship of ISI-indexed publications (Table 1). Most of the Pacific Rim economies shown in the table have increased the proportion of papers indexed by ISI that have multi-country authorship. Note, however, the decreases that occurred among several of the NIEs. This is not necessarily an adverse trend, at least in the short run: the propensity of developing economies to collaborate is often stimulated by the need to make up for a lack of local infrastructure. A brief downturn that reflects national self-confidence could therefore represent a healthy sign.

There are similar trends in more technologically oriented activities. There is a movement toward the internationalization of industrial R&D. While the most extensive nets of overseas research facilities are concentrated in Europe, the USA, and Japan, many companies are locating laboratories in developing economies. For example, Mitsubishi's air conditioning research is conducted in Malaysia, Intel usually carries out a substantial amount of R&D at major overseas manufacturing installations, and software for Texas Instruments is written in Bangalore and sent by satellite to Texas.

Cooperative agreements also convey technology across borders. Developing economies have taken an increasingly aggressive posture in their insistence on access to advanced technologies. Examples of such agreements include China's cooperative agreements with airframe manufacturers, and Merck's arrangements to collect potential natural products in Costa Rica. However, while such arrangements bring a great deal of exchange of technical information, any of these agreements can, depending on viewpoint, be characterized as continuing to favor the interests of the multinational corporation or industrialized country partner. Finally, any foreign direct investment

inevitably brings a substantial amount of maintenance, engineering, and development with it of necessity that results in further technology transfer.

Not all trends are favorable in terms of international cooperation in R&D. There is not a great deal of clear data on funding trends, but the European Community's resources devoted to cooperative efforts have tended to focus on Central Europe and the former Soviet Union countries. Countries like Canada and Sweden continue a deep commitment to technical assistance, but represent limited amounts of money. U.S. industry has been reducing its R&D capabilities, and, while it is outsourcing some R&D and turning to other sources of new knowledge, most takes place within the country. U.S. government agencies are watchful of R&D spending and most available funding is for mission-oriented research.

Many developing economies are poorly prepared to support international cooperation in S&T. There is a general lack of local S&T infrastructure. Industries have often not developed a culture of research and the ability to cooperate with research institutions, at home or abroad. Brazil represents a case in which there is little tradition of industry-based research, and a relatively weak base in the universities. In Korea, industry was encouraged to get into R&D and now supports more than half the national R&D effort, while the universities are in need of being strengthened in their ability to support the R&D system with fundamental research. Neither of these environments is very conducive to international cooperation.

There is also the fact that cooperation is hard to do. There are cultural issues, both national and institutional – it is very hard to recruit U.S. scientists to do cooperative projects in Japan because of the language problem. There are potential professional jealousies – how is the data to be shared; who gets to publish, where, and when? And efforts to establish international agreements are fraught with concerns about who benefits most. The U.S. Congress insists on "mutual benefit" in any U.S.-funded cooperative agreements.

A major barrier is the potential loss of commercial advantage. Agreements must deal with intellectual property rights (IPR). Who gets the IPR, and *is* there an IPR regime that is acceptable and facilitating? In the long run, cooperative relationships may go well and never have an IPR issue arise of any import, but the perception that one or more countries involved in cooperation lacks a world standard IPR regime can prevent an agreement from ever being reached.

Other concerns about international cooperation in S&T include the question of whether such activities limit competition among researchers, which may, in turn, inhibit innovation. Establishing and guaranteeing long-term commitments is difficult. The inability to gain international participation was one of the factors that killed the super-conducting super collider project in the United States, and the international space station is not going smoothly. In fact, large projects, which are often prime candidates for cooperation, are hard enough to manage without international complications.

4. Conclusion

Despite the problems and barriers involved in international cooperation in S&T, there is evidence that it is increasing. The fact is that S&T is too intrinsic a factor in economic development to avoid being globalized in a global economy. Because S&T plays such an important role in the "created comparative advantage" that now represents such an important part of international competitiveness, barriers to development of an easy set of relationships will continue to exist. However, it seems highly probable that various forms of international cooperation in S&T will increase in the next century.

PART 3

THE FINANCIAL CRISIS: IMPLICATIONS FOR ECONOMIC RESEARCH

WAS THE ASIAN CRISIS FORESEEABLE?

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1. Was the Asian Crisis Foreseeable?

On May 14 and 15, 1997, speculators launched a massive attack against the Thai baht, which required a joint intervention by Thailand and Singapore to defend the currency. Despite assurances through June that there would be no devaluation, on July 2 the Bank of Thailand announced a managed float of the baht, which effectively devalued the currency to a record low. By August, the Thai crisis had become an Asian crisis as the value of the Malaysian ringgit fell sharply and speculators attacked the Hong Kong dollar peg as the currency contagion spread. On October 14, Chinese Taipei announced a devaluation of the NT dollar, despite a strong current account surplus and a large stock of foreign exchange reserves. This signaled the severity of the crisis to financial markets, triggering a new round of speculative attacks and stock market crashes throughout the world. By November, the IMF had offered Indonesia a $23 billion support package, but the Hong Kong, China stock market continued to be hit by high domestic interest rates, falling property prices, and the emerging weakness in the Korean won. In 1998, the worsening outlook in Indonesia has led to civil unrest, and general Asian weakness has put pressure on other Pacific Rim currencies. Asset prices and exchange rates throughout much of East Asia are well below their levels this time last year (see Figure 1).

The standard explanation of the Asian currency crisis suggests that conditions of easy global liquidity helped finance excessive and imprudent investment in Asian economies, inflating asset markets. When the asset bubble started to burst, corporate and financial sector weakness emerged. These weaknesses and worsening external conditions led to a reversal of capital inflows, pressure on exchange rates, and finally, devaluations. The devaluations made it increasingly difficult to service debt borrowed at short maturities and in foreign-currencies, furthering the decline in investor confidence and creating contagion both through competitive trade pressures and through financial linkages throughout Asia.

This explanation emerged soon after the crisis broke. Since then, it has been somewhat refined and is now accepted by most economists. The alacrity with which this conventional wisdom on the cause of the crisis was achieved (using well-established and broadly understood economic logic) is quite remarkable, given that the crisis was completely off the radar screen only a few months before. This naturally leads to the question of why the crisis was not foreseen, when it was so easily explained only a few months later. Was in fact the Asian crisis foreseeable?

Prior to the crisis, there was reason to believe that some currencies were overvalued, global financial markets were providing excessive liquidity, and domestic lending activity warranted closer monitoring by international lenders (if not domestic financial

institutions or regulatory authorities). Nevertheless, the magnitude of the depreciations, collapse in asset prices, and international capital movements seems much greater than can be explained as a market correction. From the perspective of standard models of bank runs and speculative attacks on exchange rate pegs (discussed later), one is left with an abundance of questions about the chain of events above:

- What event(s) triggered the sudden rash of speculative attacks in Thailand?
- What accounted for the rapidity and virulence of the contagion between economies?
- Could the depletion of Thailand's reserves (and eventual fall of the baht) really be significant enough to depress the currency and/or output growth of nearly every economy of the Pacific Rim?
- If not, what was it in the summer of 1997 that did?
- Why did economies with stronger fundamentals (such as Indonesia) often suffer more than economies with weaker fundamentals (such as Thailand)?
- How could such a drastic change of environment take place without warning?

2. If the Asian crisis was foreseeable, why was it not foreseen?

Economic logic suggests that if the Asian crisis were foreseeable, then someone would have foreseen it, given the number of market participants and the financial benefits from correctly predicting such a crisis. However, to my knowledge nobody publicly prophesied the crisis, or at least the breadth and magnitude which it achieved. In fact, the crisis has been accompanied by a sea change in the conventional economic wisdom about the region. Before July 1997, the crisis economies were paradigms of capitalism, proof positive of the benefits of small governments, high investment rates, and economic and financial liberalization. Since then, these same economies have been scolded for "crony capitalism", too much government influence, excessive investment, and too little authority over economic and financial institutions. Even among those now claiming that we should have seen the crisis coming are some who, only months before the crisis appeared, were holding up Asia as a model for other economies' economic development. The obvious question is why such a drastic change in both economic performance and opinion occurred so unexpectedly.

This presumes, of course, that the evolution of opinion observed among economic pundits was shared by the market. Evidence from financial institutions lending to emerging markets offers the *prima facie* case: capital flowed liberally to these economies and then underwent a sharp reversal after the crisis began.[1] However, this is not enough to prove that the Asian crisis was not expected by the market, only that the exact timing of the crisis was not foreseen. In the years leading up to the crisis, it had been clear that the Thai economy was experiencing a "bubble" in its property markets, in which excessive investment was fueled by the expectation that the overvalued property prices would continue to be overvalued in the future as well.

[1] Private companies that in 1996 had lent $93 billion to the five "crisis economies" (Korea, Thailand, Indonesia, Malaysia, and the Philippines) reversed course in 1997, resulting in a net outflow of $12 billion (Capital Flows to Emerging Markets, Institute for International Finance, 1998).

To an investor looking for high returns quickly, investing in such an expansion is not necessarily irrational. Many claim the U.S. stock market is currently overvalued, and that the rapidly rising stock market indices reflect a speculative bubble and not the increasing value of the underlying fundamentals. Should this dissuade one from investing in the stock market now? Maybe. But by many measures, the stock market has been overvalued for years, and those people that got out of the stock market years ago lost out on the opportunity to realize substantial gains. Ultimately, behavior is driven in part by investor psychology: will they feel worse if they fail to invest and others get rich or if they do invest and the stock market crashes as they were told it would? And, if the expected correction occurs, will we be back here asking why those investors that stayed in the stock market did not foresee the crash, pumping in money right up until the end?

Risk is an inherent feature of financial markets, so investors generally seek hedging opportunities. Often this is done through derivative assets such as options. An option allows the purchaser to buy or sell a particular asset at a pre-specified exercise price. The most rigorous way to test whether the Asian currency crisis was actually "foreseen" by the market would be to study the value investors placed on the ability to avoid losses if those currencies were devalued. This was the approach used by David Bates to test whether the U.S. stock market crash of 1987 was expected by the market.[2] He finds evidence that it was, as out-of-the-money puts became unusually expensive in the year prior to the crash.[3] Given the lack of an obvious trigger to the 1987 crash, one hypothesis developed about the crash was that it was the collapse of an explosive bubble, fueled by self-fulfilling expectations. Money went in as investors followed the rising stock market, but expecting an eventual correction, people were quick to pull out their money when the first signs appeared that the bubble might begin to burst.

Lack of futures and derivative price data make a comparable rigorous test of market expectations difficult in the case of the Asian currency crisis. However, the Asian currency crisis bears some resemblance to the 1987 crash. For some time, it was clear even to the casual observer that a bubble existed in the Thai real estate market (and possibly elsewhere). Inflation of domestic asset prices put pressure on Thai competitiveness, and thus the exchange rate peg. But rising prices also led to capital gains that maintained the flow of capital from abroad, which eventually found its way into the real estate bubble. Thailand's current account deficit in 1996 was about 8 percent of GDP, well above historical "crisis levels", as indicated by previous currency

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[2] Bates, David S. "The Crash of '87: Was It Expected? The Evidence from Options Markets" The Journal of Finance, 46 (3), July 1991. For a general treatment of option pricing tests see Bates, David S. "Testing Option Pricing Models" in Maddala and Rao, eds., Statistical Methods in Finance. New York: Elsevier, 1996.

[3] An "out-of-the-money" put is an option to sell where the exercise price is less than the current futures price at the time of transaction. Since puts represent an option rather than a contract, a premium on out-of-the-money puts (relative to out-of-the-money calls) suggests that the market was expecting a large fall in stock prices, making the puts more likely to finish "in-the-money" than the calls.

crashes.[4] In the end, despite the high level of savings and investment and otherwise strong performance, Thailand's financing suffered from a mismatch of both liquidity and denomination. Short-term loans was used to finance investment in projects with long-term payoffs, while money borrowed in foreign currencies helped support investment in non-tradable assets like real estate (rather than in the export sector, which would generate foreign exchange necessary to repay the loans).

The increasing pressure from speculative attacks during the summer suggested that the market did begin to expect the eventual fall of the baht. However, a devaluation in Thailand, if it occurred, would affect the competitiveness of its ASEAN neighbors, who are both trading partners and competitors in third markets, and put pressure on their currencies as well. Many of these neighbors were slightly better positioned than Thailand prior to devaluation of the baht, but had similar patterns of rapid investment financed by capital inflows in the form of short-term foreign-denominated bank loans. By 1997 the stage was set for the "competitive devaluations" that occurred that fall.[5] Nor was this sort of contagion unknown. The same pattern of devaluation that occurred in Asia in 1997 occurred among countries in the European Exchange Rate Mechanism (ERM) crisis of 1992 (see Figure 2).

So why was the Asian crisis such as surprise? It is true that some market information was not present, and the emergence of the crisis itself in late summer may well have been an important piece of "news" to investors as well. However, investors already had a good deal of relevant information, including macroeconomic data, trading patterns, foreign debt levels and maturities, and government policies, as well as the lessons of centuries of currency crises. In the cases where key data were not made available, this itself still provided investors with information – namely, that they should be concerned about risk, and be properly hedged. The claim made earlier that "if the crisis was foreseeable it would have been foreseen" is less trite than it may sound. In theory, agents in efficient markets, forming expectations of the future based on all available information, should take advantage of any arbitrage opportunities they perceive resulting from market misalignments, such as a future change in the value of a currency or a stock price. In aggregate, by changing demand for the currency or stock in line with their expectations, the actions of these individual agents should act to correct the existing misalignment. A paradox exists when markets work perfectly: if the Asian crisis had been foreseen, adjustments would have been made earlier that would have prevented it from occurring.[6]

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[4] A current account deficit over 4 percent of GDP has generally been considered a rule-of-thumb indicator of vulnerability. The usefulness of this and other leading indicators are discussed later.

[5] The quotation marks are intended to signal the existence of some uncertainty regarding the actual forces underlying the series of devaluations. Although a story of competitive devaluations through trade channels (or at least the market's expectation of these) is certainly a leading explanation, it is not the only one. Other sources of "contagion" will be explored later.

[6] Any speculators that foresaw the Asian crisis could have made quite a bit of money from the wild swings in currency prices. As they moved to take advantage of the perceived arbitrage opportunities, key aspects of the economic landscape would have changed: capital flows to these economies would have decreased, liquidity would have dried up, and pressure on exchange rates would have come earlier and, arguably, more gradually. In short, many of the features which contributed to the creation of the Asian crisis would have been removed. Some evidence exists that the IMF did have some private

When all systematic pressures are thereby removed, any remaining shocks must be, by definition, unforeseen (economists often refer to these as *innovations*, emphasizing that their value in the next period is unknown). These unforeseen shocks often occur in the real world, but it is unsatisfactory to suggest that the Asian crisis was nothing more than an unforeseeable negative shock. The "news" that coincided with the start of the crisis (the July 2 decision to float the Thai baht) seems insufficient in itself to have produced the huge asset and currency devaluations that took place in Asia. This is even more true given that the market seemed to believe that this event would soon occur anyway. To explain the Asian crisis, our initial "perfect capital market" (or PCM) model must be modified in such a way that agents responding to unexpected news acted to generate rather than remove the pressure for large, discrete jumps in currency prices.

A related challenge for the PCM model is the growing conventional wisdom that financial liberalization and globalization, by increasing the ease and the size of capital flows (respectively), have increased investment risk by making the international financial system more susceptible to major shocks like that in Asia. However, this view runs counter to the theoretical notion that global financial markets should help reduce the impact of local shocks by offering hedging opportunities through international diversification. The risk to global investors associated with investment in a particular economy or region should not be based on the absolute level of uncertainty in that market *per se*, but on the covariance of local shocks with aggregate (global) outcomes (this is analogous to the concept of the "beta" in risk assessment of stock portfolios). However, casual observation of investment patterns suggests that the level of risk in emerging markets *is* a primary concern to global investors, more so than the covariance of returns between other markets. This is consistent with the fact that most investors are not, in fact, fully diversified, but it begs the question of why this is so.

Currency crises are not, however, strictly incompatible with the PCM model: Markets can work efficiently while governments attempt to pursue mutually incompatible policies. An example is the case where governments attempt to pursue an independent monetary policy (or inflationary fiscal policy) under an exchange rate peg. How these expansionary policies are financed is determined not by the government but by investor portfolio demand: any excess money printed to decrease interest rates or finance a deficit is exchanged by investors for foreign currency at the fixed rate. Implicitly, therefore, governments are using their finite stock of reserves to pursue an indefinite expansion. Agents with rational expectations of the future will be able to predict the point where, left unchecked, reserves will be insufficient to cover demand for foreign assets, the government will be forced to float their currency, and the exchange rate will begin to fall. Thus, investors will rush to buy up the remaining foreign currency reserves, to avoid being the last one left holding the local currency when the music stops and devaluation begins. In this basic model, far from being unforeseeable, a currency crisis is the predictable outcome of incompatible government policies.

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information, which made them worry and led them to urge policy reforms. Apparently this advice was ignored by governments. Experience suggests, however, that markets can have even more leverage in forcing politically painful economic policy choices than the IMF.

However, in contrast to the efficient market prediction that "market expectations are always wrong" (that is, any expected price changes disappear under advance arbitrage), economists have come up with so-called "second-generation" models in which currency crises can be self-fulfilling, such that "the market expectation is always right." The asset bubble is one example of such a phenomenon; another is the bank run. If investors fear a bank run, they will withdraw their deposits, creating a bank run. If they are not worried about a bank run, they will not withdraw their assets, and no bank run will occur. This same principal can underlie currency crises: if investors in a country come to expect a devaluation in that country's exchange rate, they will immediately sell the currency short, putting pressure on the currency to devalue. If they do not expect a devaluation, no pressure will be brought, and no devaluation need occur. This explanation offers the possibility that Asian currencies were devalued just because investors believed future devaluation in those economies was likely.

This offers a possible explanation for why the Asian crisis was not foreseen: namely that it arose from self-fulfilling expectations of devaluation rather than poor economic fundamentals.[7] This explanation also serves to introduce the concept of multiple equilibria: a single model can generate two very different possible outcomes, and a small perturbation in initial conditions or in beliefs about the future can shift from one equilibrium (e.g., no Asian crisis) to another (the Asian crisis) without any institutional or structural economic change.

Getting the Questions Right

To summarize briefly, I believe the question of whether the Asian crisis was actually foreseen by markets is an empirical one that should be sorted out by studying the market valuation of hedging mechanisms prior to the crisis. If the answer is that the crisis was expected (in the same sense as the U.S. stock market crash of 1987), then proponents of the "self-fulfilling prophecy explanation" are likely to feel vindicated. The Asian crisis may have occurred more because of these market expectations than because of a change in economic fundamentals. This would explain the lack of an obvious exogenous "trigger" for the crisis, such as the interest rate hikes in Germany and the United States that preceded the 1992 ERM crisis and 1994 peso crisis, respectively.[8] It would also explain why the depreciations and capital outflows that occurred seemed disproportionate to the weakness of the fundamentals. And it would help explain why speculative attacks occurred both in Thailand and in Hong Kong,

[7] Jeffrey Sachs is perhaps the best known proponent of this view. However, a purely "no fault" theory of the Asian crisis overlooks the fact that some underlying problem with economic fundamentals must exist to cause a large number of small investors to focus on a given economy or set of economies in their speculative attacks. In fact, the prediction of the second generation currency crisis model is that (at a certain level of central bank reserves) speculative attacks will *always* occur on a fixed exchange rate when the fundamentals are unsound and will *never* occur without some problem in the fundamentals. It is only when fundamentals are in a middle range, where expectations of a devaluation and expectations that the peg will be maintained are each consistent, that the possibility of a speculative attack becomes self-fulfilling. Thus, *something* was clearly amiss in Asia.

[8] Although I previously described the devaluation of the Thai baht as the trigger for the larger Asian crisis, this was most certainly an endogenous response of the crisis rather than an exogenous event. That is, the fall of the baht was really the first symptom rather than the cause of the crisis.

China despite the very different situation and quality of the fundamentals in these two economies.

If the answer is that the crisis was not expected, however, this leaves open the question of whether the Asian crisis *could* have been foreseen. If the crisis could have been foreseen, as sometimes suggested in a growing literature looking at "leading indicators" of such crises, then it is important to examine why we failed to do so. If it could *not* have been foreseen, then we should simply focus our attention on improving the speed and quality of the international response to such crises, and on preventative measures such as those being suggested in the discussion of a new international financial architecture.

Given the failure of the perfect financial market model to explain certain aspects of the crisis, the search for a good explanation would seem to require modifying one or more of the basic assumptions of the model. The next section of this paper will explore the process of economic modeling, and assess how changing certain modeling assumptions can affect the predictions of the model, to help ascertain where economic forecasters might have gotten it wrong.

3. How Economists Forecast: A Model of Economic Modeling

Weathermen and economists often invite comparison, as well as a certain amount of heckling. Latter-day oracles, they each employ convoluted statistical modeling exercises that, to the common observer, can have both the appearance and the success rate of reading chicken entrails. Both fields appear to be governed by well-specified laws (of temperature and pressure in one case, of supply and demand in the other) that should be easily captured in a simplified model of a few equations. In practice, however, things rarely go as predicted. Certainly neither science can hope for the exacting standards of fields like physics or chemistry, which can create, controlled experiments. However, prediction error still seems to exceed even a broad level of tolerance: weathermen cannot forecast tornadoes more than a few minutes before they appear, and economists seem to have the same trouble with currency crises.

Meteorologists found a nice excuse when they helped develop a new theory of "deterministic randomness," popularized as *chaos theory*. The trouble with prediction may result from the fact that variables interacting through time in a non-linear dynamical system often wind up with wildly different behavior when given small initial shocks. In such instances, the existence of small unknowns or measurement error undermines our ability to forecast with confidence more than a few periods ahead. Chaos theory, it is said, implies that the flapping of a butterfly's wings in Indonesia could cause in a tornado in New York. Could it also be that the flapping of gums on Wall Street can create a financial tornado in Indonesia?

The credibility of chaos theory is based largely on observations of apparently random behavior in the absence of any obvious (appropriately sized) stochastic source driving such behavior. While it is accepted by many, if not most, that non-linear dynamics play an important role in determining the weather, it remains unclear what promise chaos

theory holds for economics. Even accepting that non-linear dynamics probably do play a role in economic behavior and outcomes, there are practical difficulties in using this insight to learn more about the world. Testing for chaos is extremely difficult, even in a simple series like a single stock price. This inability to estimate the underlying non-linear equations, or to know whether theoretical models constructed with non-linear dynamics are correct, is problematic, given that non-linear models are, by nature, not robust to mis-specification.

Therefore, although the term "chaos" is an apt label for the fallout of the Asian crisis, and it is possible the movements in currency values fit some unknown set of non-linear equations quite well, the approach of this paper will be to see whether something approaching this "observed non-linearity" can be justified with a simple modification to conventional neoclassical economics, rather than throwing out these models as being "insufficiently non-linear."[9] In particular, I will address how a drastic change in the Asian economic environment could result from what was at most a small piece of "news" (the devaluation of the baht).[10] To neoclassical economists using static models, this is simply the notion of multiple equilibria discussed earlier in the context of self-fulfilling prophecies.

So one explanation for the Asian crisis is that it represents the "bad equilibrium" of an economic system with multiple equilibria, triggered by the small change in investor information that accompanied the July devaluation of the baht. If this is the case, economists need a method to predict when a system will jump to such a bad equilibrium, and how such jumps can be avoided. A second possible explanation for the "non-linear" appearance of the Asian crisis is that the structural interaction of economic forces create a multiplier effect in which small shocks were magnified. Again, I propose that informational problems" in particular, the presence of asymmetric information" offers an explanation.

Lastly, it is possible that the key to understanding why the Asia crisis was not foreseen lies in the very nature of the forecasting process. Figure 3 gives a general description of the forecasting process, in which information (economic data) is fed into a structural (theoretical or computable) model of the economy, which yields a predicted outcome. Changing the economic data input slightly will no doubt change the outcome somewhat

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[9] The latter being the approach, or at least implication, of the papers presented to this Symposium by Dan Ciuriak and by Mark McKergow, which present an interesting perspective contrasting that put forth in this paper. Each author also sidesteps the pitfall of having to identify chaotic behavior: Ciuriak's paper documents how patterns associated with non-linear dynamics fit elements of the Asian crisis that conventional economic theory fails to explain adequately, while McKergow asks, *if* non-linearity is in fact at the heart of the crisis, what are the implications for an appropriate policy response?

[10] Another implication of non-linearity is the existence of "emergent processes", which may ultimately be a more useful framework to think about the crisis. The apparent sensitivity of the crisis to initial conditions suggests a process of cumulative causation, whereby the series of events slowing growth and exports, large dollar-denominated debt obligations, defense of fixed exchange rates, bad loans in an unregulated financial sector and lack of key information all built upon each other, reinforcing the negative consequences of each. Like tumblers falling into place, the combination of these events unlocked the Asian crisis.

as well. However, economists use this information not only as an input into their models, but also in determining which models are appropriate. Figure 3 also presents a list of some information that would have been relevant for forecasting the Asia crisis, of which financial data is only a subset. The insight is that, because the emergence of new information may affect both the data input *and* the choice of model itself (or equivalently, set of model assumptions), this may create a discontinuity in the mapping of information to predicted output. In other words, "non-linearity" may exist in the modeling process, rather than the model itself. If investors feel that they and economic forecasters have all the relevant information, and markets are working correctly (including perfect hedging and equilibrium pricing) they will behave one way, but this behavior may change if new information suggests they should adopt a different outlook on how the market is likely to operate.

Modifying Assumptions of the PCM Model

Economists building models make many assumptions by necessity, making forecasting as much an art as a science. It would be difficult at best to study how each one affects the predicted outcome; however, three suggestions have been offered (explicitly or implicitly) by commentators on the crisis. These include the possibility that agents were not rational, that market competition was imperfect, and that information was incomplete. Each of these is addressed below, to ascertain whether that assumption was likely to have been an inappropriate one, the presence of which may explain why economists failed to predict the outcome of the crisis. It is asserted that the last of these, imperfect information, seems the most likely culprit.

Rationality

Regardless of the underlying cause of the Asian crisis, there is evidence that the fall in Asian currency values was in excess of that necessary to correct any overvaluations or other market misalignments. Some economists have suggested that much of the crisis was the result of financial panic.[11] "Panic" is a descriptive word often used in association with economic crises. To my knowledge, however, there is no formal economic definition of panic. The word itself is more a normative than positive description of behavior, and implies a degree of irrationality which would be unappealing to mainstream economists that rely on models of self-interested rational agents. Many of those blaming private-sector investors for the crisis no doubt secretly (or not so secretly) feel that they were acting irrationally.[12] Thus, the assumption that market participants act rationally may be the most obvious shortcoming of our perfect-market model.

In fact, it does not necessarily follow from the observable patterns that investor behavior was not rational. Models based on rational agents have been used to explain

[11] Radelet, Steven and Jeffrey Sachs, "The Onset of the East Asian Financial Crisis", Harvard Institute for International Development Working Paper, May 30, 1998.

[12] The term "irrational exuberance" has also been used recently by Alan Greenspan to describe continued bullish behavior in the U.S. stock market despite signs that it is overvalued.

exchange rate overshooting; in fact, rational expectations are central to the argument.[13] Moreover, agents can still be rational even if their *expectations* are not rational (in the strict econometric sense). This is the basis of the bounded rationality literature, which emphasizes that agents in the real world may have limitations imposed on their ability to optimally compute forecasts. This may be due to cognitive limitations or to actual rational economic calculations made as investors shop around for economic forecasts. Trying to decide which "forecast" to purchase, they judge by past performance. If a costless rule-of-thumb allows an investor to achieve almost as high a return as if he had purchased costly market intelligence and made a detailed econometric forecast, then it would be *irrational* to have what economists consider *rational* expectations.

The interesting insight from this literature, however, is that an equilibrium may be achieved where all investors make the same profits, but some do so by paying slightly more to be informed and make a slightly higher profit, while others have lower profits but no informational costs. Chronic instability may exist, however, since rules-of-thumb or other forecasts based on the past may lead market participants to take actions that do not lead the market to converge to an equilibrium.[14] Since the possibility exists for agents to switch forecasts, once the system gets far enough from equilibrium that conventional wisdom ceases to be an effective indicator of profits, agents suddenly find it profitable to become better informed. This seems a fairly apt characterization of the Asian crisis.[15]

On inspection, what actually seems to be implied by economists using the word "panic" is one or some combination of the following: the presence of excessive volatility and/or overshooting, herding behavior, or the existence of multiple equilibria ("panic", "no panic") based on self-fulfilling expectations. Neither the first nor last of these three implies irrationality. Herding also is rational behavior in institutional environments that compensate fund managers based on their performance relative to other investors rather than on some absolute standard, or if managers otherwise feel uncomfortable with strategies too different from the social convention. As will be shown below, herding behavior can also occur in the presence of imperfect information.

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[13] Dornbusch, Rudiger, "Expectations and Exchange Rate Dynamics", Journal of Political Economy, 84 (August 1976).

[14] This is a technical point. Rational expectations models generally involve a highly unstable dynamical system, in which there is one specific time path that economic variables must follow to achieve an equilibrium state in the future from any given initial state. All other paths are unstable, so that once off the "equilibrium path", the system diverges from its equilibrium. This requires that the variable(s), which can be instantly adjusted by the market (such as prices), be set at precisely the level(s) necessary at the current state to put the system on the stable path to equilibrium. If some agents do not enjoy such foresight they may not react appropriately to projected future conditions. Moreover, if these agents predict the future out of their past experience, updating their expectations more slowly than market transactions occur, or if there are lags between an agent's decision and its impact on the market, unstable cyclical behavior can result.

[15] This can lead to a rich set of complex dynamics in a market. See Brock, William A. and Cars H. Hommes, "Rational Routes to Randomness", *Econometrica*, 65, 5 (September 1997).

Competition

Ever since George Soros won the title of "The Man Who Broke the Bank of England" by speculating against the pound in 1992 and forcing it to leave the ERM, he and other large investors have been easy targets for those seeking an ulterior force behind the chaos. The logic is the same as that of self-fulfilling prophecies in more competitive markets, but does not require any weakness in fundamentals to act as a focal point for atomistic investors. All that is required is a few large investors who can put sufficient weight against an exchange rate peg by selling it short, forcing devaluation, and netting these "market manipulators" a nice return.

Although this is a problem in theory, market manipulators did not appear to be responsible for the Asian crisis. Although George Soros did take positions in these markets, by and large it appears he bet the wrong way. Recent investigation of the role of hedge-fund managers by the IMF also supports the claim that large institutional investors did not play a disproportionate role in the crisis. Rather, it appears that small agents – both foreign investors and domestic citizens – were just as responsible for the market forces brought to bear as large investors. I will assert that this assumption of the PCM model seems reasonable as well.

Information

When full information is made available to all in the market, investors can evaluate the fundamental value of assets. Thus, they can buy when the assets are undervalued and sell when they are overvalued, causing a natural adjustment of prices to fundamental values. Without perfect information, however, investors are unable to evaluate fundamentals exactly and may rely heavily on the information that they can extract from market "signals." For example, a fall in the price of an asset may signal that the market has some "news" not yet available to the individual investor that the asset is worth less than previously thought. Investors reacting to this information may rush to sell "early" before others do, even if the new price is below the fundamental value, which would otherwise encourage investors to buy.[16]

Nor is the market a perfect mechanism. In the time required to process and match orders to buy and sell, particularly during "rush" periods that suddenly create large trading volumes, drastic movements may occur in prices (this may be a particular problem in emerging markets with low levels of capitalization, a small number of large companies, and thin trading volumes). Investors may then incorrectly conclude that the market adjustment will be larger than each initially perceived, or that the large volatility implies increasing risk, thereby encouraging them to buy or sell more than warranted on the basis of the initial information.

The existence of private information – when investors collect their own market intelligence and guess what information others have – can also result in herding behavior. Imagine that a currency trader has two sources of information: some private

[16] In practice, investors use a number of such technical trading rules. The one described above has been coined "the trend is your friend."

signal of where the market is likely to go, and the observation of what other traders are doing. Suppose he (the investor) receives a weak signal that a currency value may decline but is not convinced a devaluation will occur on that basis alone; he is therefore willing to continue holding the currency. A different trader with a slightly stronger signal of devaluation may decide to sell the currency, however, which sends the first trader information about the signal the second trader received. If this additional information prompts the first trader to sell, other agents in the market may then perceive from this additional signal that the first two agents received information sufficiently pessimistic that they decided to sell. A third agent might have received an optimistic signal of the currency's value, but in the face of the overwhelming reaction of others in the market, discounts that information and sells against his own "better judgement" (which in this case can be a completely rational decision).

Just as this idea can be used to explain herding (the sequence of similar behavior among investors in a particular market), it can also explain contagion (the sequence of similar investor behavior among different markets). If investors have imperfect information but learn that one economy will devalue (Thailand) in part related to certain conditions (unwise investment because of crony capitalism) that also exist in another country (Indonesia), then they may start to lose confidence in Indonesia as well, since they do not have sufficient information about Indonesia's fundamentals to make a completely accurate judgement. Although it is hard to imagine that Indonesia's huge depreciation could result from a market signal from Thailand, even a slight currency depreciation in economies with a heavy load of unhedged short-term foreign debt can be very costly, undermining investor confidence and furthering the pressure on exchange rates, creating a vicious cycle of depreciation. This information-based theory of contagion corresponds with suggestions that have been made that the Asian crisis resulted from a "wake-up call" to reassess the creditworthiness of Asian borrowers sounded by the devaluation of the baht.[17] Previously, however, evidence has suggested that contagion is more likely to be spread to economies closely linked through trade channels than to economies similar in macroeconomic circumstances, supporting the "competitive devaluation" explanation of contagion.[18] In either case, a major reason the Asian crisis was not foreseen appears to be the significant degree of contagion that took place between economies where one might have expected a crisis to those where one would not have.

Two well known problems arising from situations of incomplete information have been widely studied in the economics literature and may provide some insight into the Asian crisis: moral hazard and adverse selection. Where the action taken by one side of a market exchange is unknown to the other party, the problem of *moral hazard* results. For example, the presence of insurance removes the incentive of the insured parties to be careful, if the behavior of individual policyholders cannot be monitored. This will increase the probability of an accident, and thus, increase the total costs to society.

[17] Goldstein, Morris, "The Asian Financial Crisis", a speech delivered at luncheon hosted by the Institute for International Economics, in Washington, DC on December 2, 1997.

[18] Eichengreen, Barry, Andrew K. Rose, and Charles Wyplosz: "Contagious Currency Crises", NBER Working Paper No. 5681, July 1996.

When it is not an agent's action *per se*, but their nature (or that of the good they are selling) that is unknown to the other party, then the problem of *adverse selection* results. At a given insurance premium, only those people to whom it is a good deal (i.e., those who feel they are likely to make a claim) will choose that policy. Knowing that they are attracting only the worst health risks, and none of the best, insurance may revise their premiums upward to maintain profitability. However, this only increases the adverse selection problem as the healthiest of those who had initially taken the policy now choose to go uninsured.

Recently, economists have offered explanations of the Asian crisis drawing on these insights and the apparent fact that Asian banks borrowing money from abroad had better information than the international investors loaning the money about the nature of the investment projects being financed. Paul Krugman stresses the role moral hazard played in the crisis: Lender ignorance and government guarantees of a bailout promoted excessive, overly risky investment by local banks causing an expansion and subsequent bursting of asset bubbles.[19] Furthermore, he insightfully suggests that if the market expected that a bailout will occur with the next crisis, but there would be no more such bailouts thereafter, prices would fall even more than normal during the collapse of the bubble. The problem of moral hazard at the international level – stemming from the IMF's continual bailout of economies in crisis – also has been the subject of much recent discussion.

Asymmetric information between domestic borrowers and international lenders may also have led to problems caused by adverse selection. Bruce Greenwald discusses how foreign investors may be forced to ration credit when they don't know the quality of the underlying investments, and how this can help explain some stylized facts of the Asian crisis.[20] Starting with the PCM model, with full diversification of risk from local production shocks, Greenwald shows that uncertainties in prices and exchange rates should not matter to capital market investors: devaluations associated with financial crises should not have significantly adverse impacts on national output, and local stock markets and asset prices should not play a role in the level of economic activity. Incorporating only the adverse selection problem, he shows that as local shocks cause certain firms to become increasingly risky (so that market lending rates increase), the "safe firms" drop out of the foreign capital pool leaving only the excessively risky. At some point, investors' expected returns may begin to fall even as the interest rates continue to increase (because of the high possibility of default).

Thus credit rationing will result, constraining their ability to borrow and forcing firms to finance internally (the adverse selection problem may also present these same firms with difficulty in equity finance). The net result is that problems exist in diversifying sufficiently to remove systematic risk. Firms' production decisions will incorporate a "wealth effect" that leads firms to be risk averse (since they cannot diversify completely, and must therefore hold a disproportionate share of their own wealth) so

[19] Krugman, Paul: "What Happened to Asia?" (January 1998).

[20] Greenwald, Bruce, "International Adjustments in the Face of Imperfect Financial Markets," presented at the Annual Bank Conference on Development Economics in Washington, D.C., April 20, 1998.

that they react to the volatility as well as the level of returns. In short, the presence of asymmetric information may explain why complete global diversification does not occur, why investors are sensitive to nominal price changes, and how an asset price collapse can trigger contraction of output and devaluation; major features of the financial landscape that the PCM model failed to explain adequately.

4. Why the Asian Crisis Was Not Foreseen

When tasked with drafting the 1996 *APEC Economic Outlook*, U.S. economists saw little sign of the impending turmoil in the Asian economies. The story of East Asia was the story of its miraculous growth, and to the extent that the soundness of the economies was questioned at all in the *Outlook*, it was simply to evaluate the source of the "miraculous" Asian growth rates. In other words, the *Outlook* simply mirrored the view commonly held by professional economists at the time, who were currently in the midst of a debate over Asia's high growth in output: whether it should be attributed to high investment in human and physical capital or to technological progress. The debate was sparked by Paul Krugman's publicizing of Alwyn Young's work on growth accounting for Singapore in a 1995 issue of *Foreign Affairs.* He argued that if high Asian growth simply reflected the rapid mobilization of factors of production rather than intangible "Asian values," then growth would most likely begin to slow eventually. Nevertheless, Krugman has stated that despite the suggestion in the article that Asia's miracle should not be expected to continue indefinitely, he did not foresee the crisis that occurred. His pessimism was related to the economic forces underlying the growth miracle and did not involve financial/monetary concerns.

Ironically, in a second *Foreign Affairs* article a year later, Krugman did discuss issues relating to the Asian crisis, such as asset price bubbles, unregulated financial markets, and "self-fulfilling political economy," in which economies that adopt policies that investors believe will lead to high growth will enjoy easier access to foreign capital, allowing higher investment and growth.[21] However, this discussion was made in the context of the 1995 Latin American crisis, with little connection between his theoretical statements and the growing applicability to East Asia. It is possible that, despite his own pessimism about the foundations of Asian growth, he felt that the Asian economies were so much more successful than other emerging markets that they could avoid the problems of these markets (despite Asian economies' own histories of speculative attacks and devaluations further back in history). There is some reason to believe that the failure to see the crisis emerging in Asia (or at least to discount the impact of microeconomic financial sector conditions on overall macroeconomic performance) because investors were implicitly relying on the efficient market hypothesis to correct misalignments on the margin. This raises the question: was there a fundamental confusion between *perfect* markets, which operate according to the efficient market paradigm, and *successful* markets, which need not?

[21] This suggests, of course, that the economic success of emerging markets is attributable at least in part to investor sentiment, and can be easily reversed if those sentiments change.

Why didn't we see the warning signs?

Like the agents in the bounded rationality models described above, real world economists have historically searched through a number of possible predictors of crises, choosing favorite variables and model specifications based on their past performance in predicting future economic movements. This holds for currency crises as well, in which a number of rules-of-thumb have been suggested as to when economies might be entering a zone of vulnerability.[22] Such rules include debt (net of foreign reserves) equal to more than 200 percent of exports, a ratio of interest payments to exports above 15 percent or total debt service to exports above 50 percent, and ratio of foreign exchange reserves to monthly imports above 3 or 4.[23]

Although these rules-of-thumb indicate vulnerability, they are neither necessary nor sufficient conditions for a crisis to occur. Economies can enter the "danger zone" implied by one or more of the above rules without triggering a crisis, and crises can occur without these signs of vulnerability. Although the debt crisis of 1982 appeared to vindicate these rules-of-thumb, many of these traditional rules-of-thumb would not have forecasted trouble in Mexico a year before the December 1994 peso crash. The fact that most of these indicators are normalized by exports also implies that Asian economies generally appear much better off than Latin American countries simply because they are more open.[24] Some went so far as to suggest prior to the 1997 crisis that Asian economies' high export base made them less vulnerable to currency and debt crises.

A year before the Asian crisis, Jeffrey Frankel and Andrew Rose published a rigorous econometric study of currency crises, which looked at various macroeconomic variables to see what might make good "leading indicators" of currency crises.[25] The statistically strongest of the variables they surveyed included output growth, the rate of change of credit, and the total debt burden. Foreign interest rates were also found to be statistically significant.[26] They also suggested that the composition of capital flows might be as important as the overall magnitude; they found the most significant compositional indicator was the ratio of foreign direct investment (FDI) to debt. This supports suggestions that have been made that FDI is a more appealing form of capital inflow than portfolio investment, which is generally considered to be more speculative in nature, and more likely (and capable of) sudden capital flight.

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[22] Recent work has also tried to establish predictors for the next two phases of the currency crisis paradigm described earlier: speculative attack and contagion.

[23] Frankel, Jeffrey and Andrew K. Rose: "Exchange Rate Crises in Emerging markets: An Empirical Treatment", International Economics Department, World Bank (October 5, 1995).

[24] These same rules could be scaled by GDP rather than exports. Generally, however, exports are considered the more appropriate measure.

[25] Frankel, Jeffrey and Andrew K. Rose: "Currency Crashes in Emerging Markets: An Empirical Treatment" Journal of International Economics 41, no. 3/4, 351-366, 1996.

[26] To quote: "the combination of high indebtedness with an increase in foreign interest rates seems to be a recipe for a currency crash" (ibid.). But it is not the only recipe, clearly.

It is interesting that these indicators would have done a better job in predicting the peso crisis than those rules of thumb developed prior to 1995, but still would have done a rather poor job of predicting the Asian crisis. Since the Asian crisis, however, this literature has continued to grow. A recent paper by the IMF finds that the variables with the best track record as indicators of crises include exports, deviations of the real exchange rate from trend, the ratio of broad money to gross international reserves, output, and equity prices. Interestingly, in terms of actual signal quality (i.e., taking account of false positives and false negatives), they find that the best performing indicators are the real exchange rate, banking crises, and exports. True to form, these measures would have fared slightly better at predicting the Asian crisis.

The silver lining of every crisis that we fail to predict is that we learn a little better what types of policies and climates can breed instability in capital markets. It may be a long and painful process but, with each crisis, the economists forecasting the probability of a crisis are given more variables that might offer some indication of a crisis, and lead to some marginal improvement in our ability to predict crises. As econometricians know, increasing the number of explanatory variables – no matter what they are – cannot decrease a model's ability to explain observable variation in currency prices, and may improve the forecast. However, in addition to creating clutter and confusion by increasing the number of statistics to which we should turn for "warning signs" (many of which may be contradictory), there is a problem in simply using every possibly relevant indicator in predicting a crisis in the form of false positives. Arguably, predicting a crisis when one does not occur is preferable to not predicting a crisis that does occur. However, given the increasing evidence that self-fulfilling expectations may play a role in these crises, there may be a real cost to such false positives, if they generate panic in a vulnerable currency market that might not otherwise have crashed.

Distinguishing Hindsight from Insight

In hindsight, the currency crisis that hit Asia was surprisingly similar in many respects to the one that hit Latin America in 1994-95, and even to that which caused the pound to leave the ERM in 1992. Each involved a sustained build up in vulnerability in one or more economies with fixed or managed exchange rate regimes that was a matter of general recognition, if not concern. Then some event triggered speculative attack on the currencies of an initial economy, resulting in a sudden large depreciation. Lastly, in a process of contagion, the currency devaluations spread to geographically neighboring regions.

Nevertheless, although the mechanism by which speculative attacks and currency crises occur, once they occur, is quite common among different historical instances, the events precipitating the crises were different. Each new crisis has helped us draw new lessons about how to prevent the same crisis in the future, but relying too heavily on those lessons may channel our thinking too narrowly. None of the usual indicators conventionally associated with currency crises (low growth, high budget deficits, high inflation, low savings rates, low investment rates) were present in Asia. Export growth had begun to slow somewhat, and growth projections were lower than in many previous years, but both remained much higher than in other regions. Debt was growing, as was the share in short-term maturities. For Asia as a whole, however, both indicators

remained below levels in Latin America, where capital inflows were steadily resuming in the wake of the peso crisis.

The fundamental problem with the Asian crisis was that its origins were of a fundamentally different nature than other currency crashes in recent memory. Unlike the 1982 debt crisis, 1992 ERM crisis, or 1995 peso crisis, which fundamentally rooted in the public sector and macroeconomic policy, the Asian crisis was really a private sector crisis. The biggest trend in capital flows to emerging markets in the 1990s was the growing role of the private sector. In 1990, private sector flows were less than two-thirds or official flows; by 1996 they were six times as large. The most obvious reason the Asian crisis was not foreseen is that all the macro indicators were sound. Fiscal and monetary policies were sound; while even the slowing growth rates of exports and output were still well above those in most other regions. Asia still seemed the best bet for investment among developing country regions. There were structural weaknesses, particularly in the financial sector, and the composition of debt suggested some vulnerability, but this debt represented private debt, and it is not immediately obvious that this should have been a warning sign of a currency crisis *ex ante*. Why did investors pull their capital out of economies, and not just the companies that were failing?

Historians documenting a crisis have advantages of perspective and information that were not necessarily available to others prior to or during the time the events took place. The lack of information on Asian crisis economies may even have played a role in the timing and the severity of the crisis. It seems as though the pieces of the puzzle were before us, but we had not yet put them together, and were thus unable to see the larger picture developing. There was evidence that Asian growth might be slowing. Projected export growth was lower than in previous years. The dollar was appreciating against the yen. We were familiar with the logic of financial crises that arise from the tension between liquid financial deposits and non-liquid investment projects. Slowing growth signals a decrease in the profitability of investments, and if investors sought to pull out their money it might force a devaluation. International investors were aware of the debt obligations and debt structure of these economies. There were also suspicions about the state of internal economic conditions. So why did nobody put these facts together? Perhaps investors were slightly mistaken about the state of Asian economic fundamentals, but most will agree that the market reaction and the Asian adjustment went far beyond that warranted by adjustment the true fundamentals.

So where was the failure?

In short, the events that triggered the Asian crisis were not those that had been associated with other recent crises.[27] The individual conditions blamed for the crisis may have been at least vaguely understood by individual experts concerned with those particular aspects of the Asian economies. However, apparently there was a lack of both an overall understanding of the scope and magnitude of underlying weakness in

[27] Going further back in history, however, the current crisis does seem to mirror events in 19th century U.S. history (see Paul Krugman's "Paradigms of Panic" in *Slate*, March 12, 1998).

the fundamentals, and appreciation for how these weaknesses might reinforce each other in a vicious cycle.

As stated previously, currency crises need not imply the existence of informational deficiencies. Runs on currencies in economies with overvalued exchange rates and insufficient government reserves or political will to defend those rates are completely "rational" phenomena that can be anticipated by speculators and governments alike. Because of this, however, governments may have a motive for hiding information, such as foreign reserve levels, from the international community, if they worry that a negative shock that carries reserves below the "threshold" invites a speculative attack. Evidence from the current crisis seems to suggest, however, that although hiding information may delay a crisis, it may also make the crisis worse when it hits.[28]

5. Conclusions

Someone seeking to assign "blame" for the crisis could probably blame just about everybody.[29] Governments should have had tighter regulation of domestic lending activity and should have been more open and transparent in their financial and national accounts. The IMF had information that led them to have doubts about the Asian economies earlier than financial markets, and should have been willing to act sooner and more decisively on that information. The moral hazard problems associated with the IMF's role as a lender of last resort requires strict oversight of national policies, just as the moral hazard problems associated with the unwise lending practices of Asian financial intermediaries required stricter monitoring by their governments. International investors could have been more responsible as well, in assessing risk, in their initial allocation of capital, in monitoring their investments, and in the knee-jerk retraction of that capital when the investment environment changed. To the extent that international investors fulfilled their expected role as independent individuals pursuing their own best interest, however, it is the institutional environment of global investment – not the investors themselves – that are most to blame for the crisis.

How can we better forecast currency crisises? More Information.

Globalization may entail higher risk as well as higher returns. Sound macroeconomic management and increased transparency should be emphasized in emerging markets if they are to reap the gains of globalization at minimum cost. Without transparency, agents in the market need to rely much more heavily on past information in future predictions than they otherwise would. This is troublesome for two reasons. First, before the crisis hit in mid-1997, emerging market experience suggested that Asia certainly was not a region where one would have expected major economic problems.

[28] Furthermore, having learned their lesson the hard way, investors may now penalize economies they feel are hiding relevant economic information by demanding some risk premium on their return. This raises the possibility that economies seeking foreign capital may suffer from the "lemons problem" (adverse selection) unless they increase transparency and adopt internationally respected accounting standards.

[29] The ironic exception is George Soros, who was among the first to be blamed.

If complete information was costly to obtain, investors probably felt that it was worth allocating their resources more towards evaluating risk in Latin American markets than in Asia. As the bounded rationality literature reviewed earlier suggests, this pattern of "rational ignorance" (reliance on cheap rules-of-thumb rather than costly market intelligence when the market is close to equilibrium) can produce an unstable dynamic in which economic variables diverge from "equilibrium values" until a point like the Asian crisis is reached, when agents decide that obtaining better information is the more sensible option.

Currency crises are not a new phenomenon in the history of the world. It has been suggested that the Asian crisis is very similar to the 1873 Panic in the United States. The advantage of being a developing economy today is that it is possible to review the experience of economies that have undergone similar problems and remedy them. Although it has taken the United States a century and a half to learn the importance of and adopt good accounting practices, transparency, and a solid institutional environment and regulatory framework, Asian economies may be able to save themselves this pain by strengthening their institutions and adopting the best practices of more developed economies.

Asia is clearly at that fork in the road. The crisis has been so severe and wide-ranging that it has shaken loose the conventional wisdom and opened the door for real, and rapid, change. Although the crisis has led to a worldwide dialogue on strengthening the international financial system to avoid similar crises in the future and improve response should they occur, ultimately the Asian economies hit by this crisis must take it upon themselves to act while they have the opportunity and political support to strengthen their financial institutional environments, improve transparency and accounting, and institute global "best practices" borrowed from other economies.

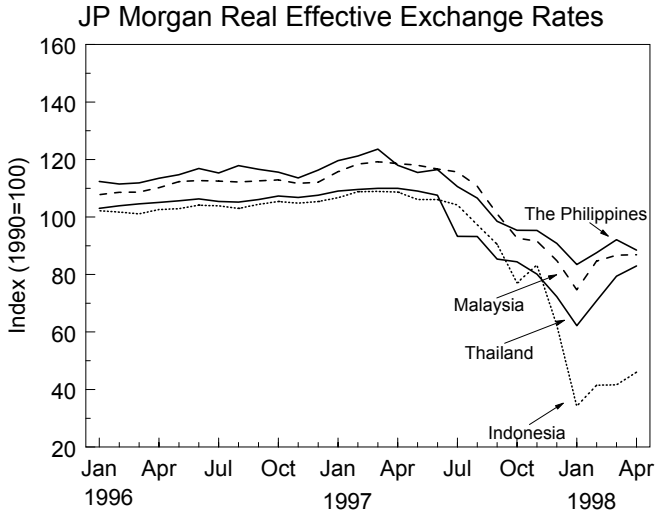
What role for APEC?

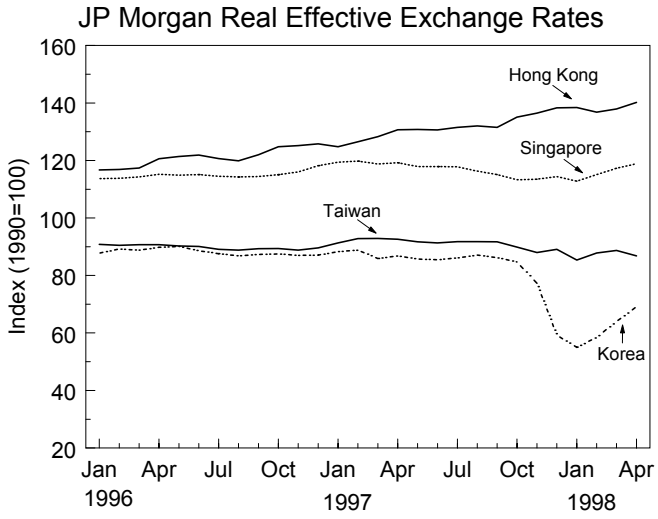
As a forum for economic cooperation and informational exchange in the Asia-Pacific region, APEC is positioned to play a role both in stabilization and recovery from the current crisis, and in preventing future crises. The actual institutional infrastructure of APEC is small, of course, and developing a role for APEC in improving our ability to foresee future crises must be cognizant of the available resources. Larger international organizations, particularly financial institutions like the IMF, clearly have the comparative advantage in monitoring and intervening in times of crisis.

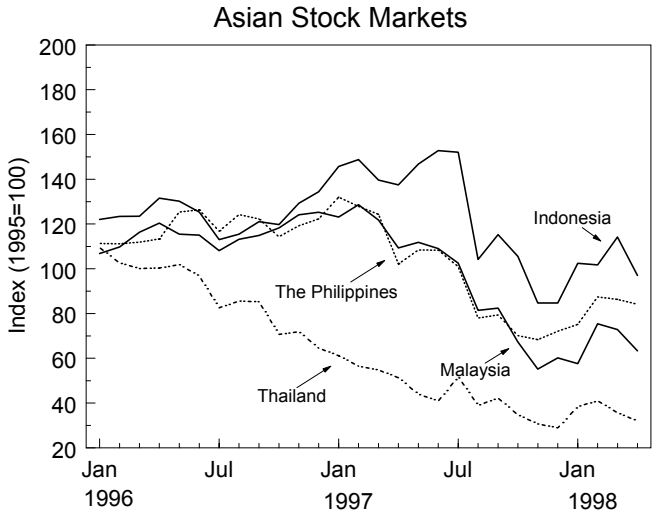
APEC's comparative advantage lies in other areas. First is its regional focus. One reason that the current crisis was not foreseen was that few expected to find a crisis in Asia. The current crisis will no doubt change this, but the point remains that investors seeking information specifically on APEC member economies should be able to turn to APEC as an organization for ready access to all sorts of financial information. Moreover, as an open forum based on consensus and designed to foster economic cooperation, rather than a closed institution like the IMF, APEC may afford a natural forum for multilateral discussions on the economic reality of the playing field and potential solutions unfettered by bilateral politics or pressures

Lastly, in its role in promoting greater trade and economic liberalization, APEC can help support the rapid adjustment process that must occur for the crisis economies to regain their previous economic vitality. With domestic demand crippled by falling asset prices, export led growth appears to be the only conduit for these economies to reestablish aggregate demand. However, this is likely to engender protectionist tendencies, both in crisis economies that feel they have been stung by globalization and in economies like the United States that are facing the prospect of a rapidly widening trade deficit as international adjustment takes place. APEC may be able to play a role in facilitating this process while supporting further liberalization, rather than a retraction from the progress made so far, thereby speeding global recovery from the current crisis.

Figure 1
Real Effective Exchange Rate and Stock Market Movements in Asia, 1996-1998






Asian Stock Markets
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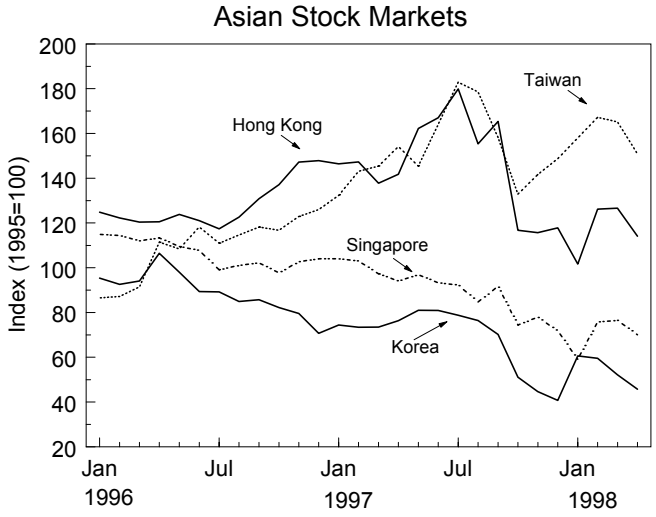
Asian Stock Markets
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Figure 2
Patterns of Contagion

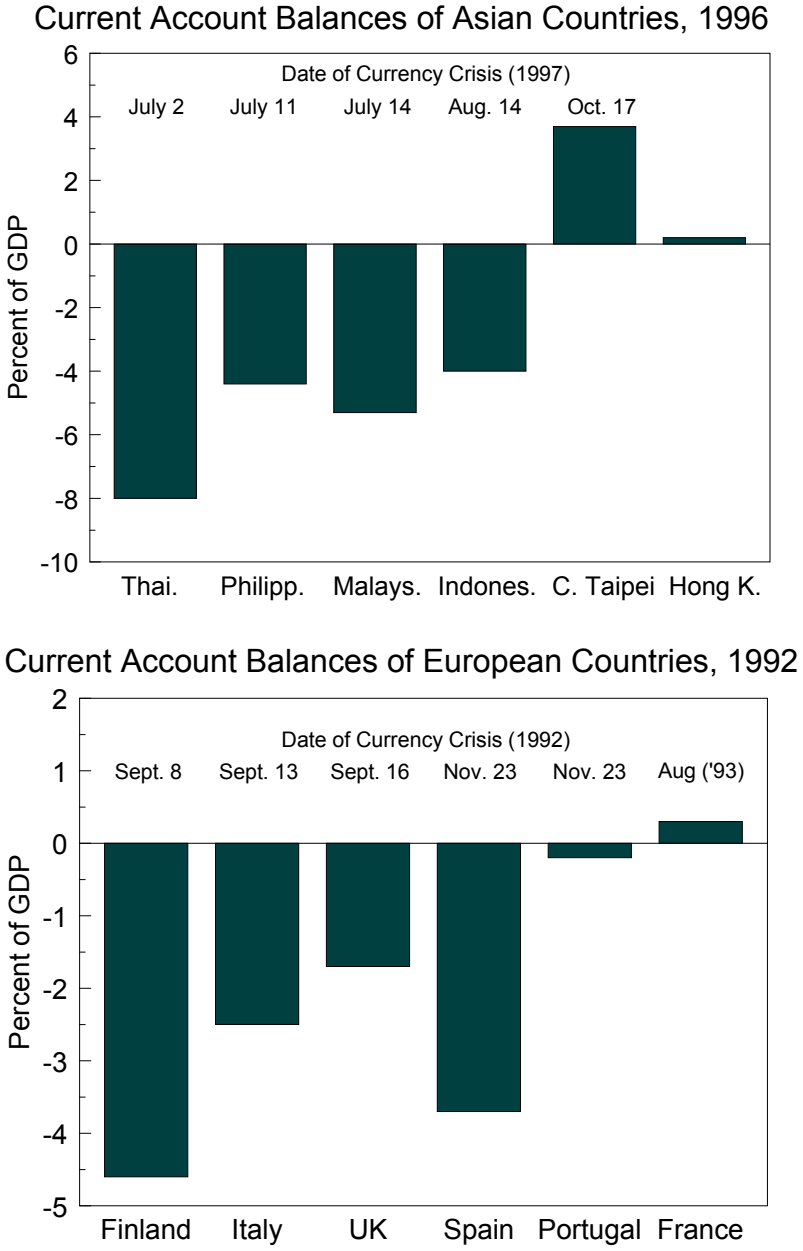

Figure 3
The Economic Modeling Process

Informational Considerations:

1) Economic Data
   -Reserves
   -Exchange rate/competitiveness
   -Exports
   -Growth
   -Debt: level and composition
   -Domestic prices (including asset prices)
   -Investment: quantity and quality
2) Agent behavior/goals
   -Maximizing profits or market share?
   -Risk aversion
   -Is investor compensation based on relative or absolute performance?
   -Do agents have private information?
3) Institutional Environment
   -Moral hazard/do private costs = social costs?
   -Perfect information?
   -Full international diversification?

THE ASIAN CRISIS:
THE CHALLENGE TO CONVENTIONAL WISDOM

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1. Introduction

In the physical sciences, the litmus test for theory is prediction. However persuasive a theory might be in its articulation, if it fails to predict then it is suspect, if not worthless. Accordingly, it is an understatement to say that the Asian crisis poses a serious challenge to the currently accepted body of economic theory, which in its mathematical articulation at least has emulated these sciences.[1] Not only was the crisis not foreseen, but the gap between what conventional wisdom had to say about Asian economic prospects on the dawn of the crisis and what actually transpired in the ensuing quarters is enormous.

The Asian crisis has led to some intellectual profit taking by Asian-growth skeptics, and the question has of course been raised: was Asia's economic boom in fact a miracle or just a passing mirage? However, an extended growth period such as was witnessed in Asia is very hard to dismiss, particularly since the growth was built on high savings and capital formation, a strong commitment to education and human capital development, and market-oriented policies – factors that have a central place in accepted growth accounting literature and that figure prominently in the micro- and macroeconomic policy of many (if

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[1] As will be discussed in this paper, while the failure to predict is a critical flaw in a theoretical framework modelled on that of the physical sciences where prediction is possible, in complex systems, as Stuart Kauffman puts it, "failure to predict does not mean failure to understand or to explain". See Stuart Kauffman, At Home in the Universe: The Search for the Laws of Self-Organization and Complexity, Oxford University Press, New York, 1994). Writing two decades earlier, Friedrich August von Hayek had the following to say on the wisdom of economics modeling itself on the physical sciences: "It seems to me that this failure of economists to guide policy more successfully, is closely connected with their propensity to imitate as closely as possible the procedures of the brilliantly successful physical sciences – an attempt which in our field may lead to outright errors. It is an approach which has come to be described as the "scientisitic" attitude – an attitude which, as I defined it some thirty years ago, "is decidedly unscientific in the true sense of the word, since it involves a mechanical and uncritical application of habits of thought to fields different from those in which they have been formed". Friedrich August von Hayek, The Pretence of Knowledge, Nobel Memorial Lecture, December 1l, 1974, reprinted in The American Economic Review, Vol. 79, No. 6, December 1989. While it may have been imprudent for economics to hold out the hope of prediction, it is certainly stuck with this now and it is legitimate to make this a test of the conventional model.

not most) governments around the world today.[2] More tangibly, the boom was also built on ubiquitous high-quality products that flooded markets in the east and the west – in other words, the East Asian economies were not producing junk. More recently, the propagation of the crisis beyond Asia has caused a shift in the focus of analysis from factors intrinsic to the economies of East Asia that made them susceptible to a crisis of confidence to the behaviour of international financial markets.

Accordingly, there has not been a rush to claim victory – even Paul Krugman, who triggered the heated debate about the Asian Miracle by comparing aspects of East Asian growth to Russia's command-economy economic expansion (i.e., the parallel role played by mobilization of latent factors of production in both growth surges), has publicly admitted that his skepticism about the Asian economies was about their medium- and longer-term performance, and that he had not anticipated an abrupt collapse.[3] The result, to cite Krugman, is "As all too often the case, we find ourselves playing theoretical catch-up – trying, after the fact, to develop a framework for thinking about events that have already happened".

The Asian crisis was not, of course, the first significant failure in economic forecasting that brought economic theory into question. Cyclical turning points have always escaped economic models and the amplitude of cyclical fluctuations generated by standard macroeconomic models has always been embarrassingly modest compared to actual experience. These failures are considered relatively minor because no-one seriously expects economists to have crystal balls. However, there have been several more fundamental failures over the past several decades that have left policymakers groping and shaken economic thinking to varying extents: the unanticipated stagflation and mysterious productivity growth slowdown of the 1970s, the unexpected persistence of high unemployment in the 1980s expansion, and the unexpected disinflation (verging on deflation) in the latter part of the 1990s come particularly to mind.

Nonetheless, it is fair to say that, as long as the main economic drama was playing itself out in the developed economies of the west, mainstream economic theory was able to surround these pockets of resistance and grind them down by developing plausible wrinkles to the standard models – the Phillips Curve, the NAIRU, and rational expectations to name but the main new concepts that have entered the economic lexicon in the process.[4]

Moreover, events outside of the developed west, rightly or wrongly, only served to reinforce the credibility of the conventional body of theory. These events included: the collapse of the alternative Soviet model with the collapse of the Soviet Union itself; the

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[2] These arguments are summarized in Joseph Stiglitz, "Restoring the Asian Miracle", Asian Wall Street Journal, February 2, 1998.

[3] Paul Krugman, What Happened to Asia, (January 1998). The article is sourced from Krugman's website at MIT.

[4] Entered yes, but not without controversy: see J. K. Galbraith, "Time to Ditch the NAIRU" in Journal of Economic Perspectives, Vol. II, No. 1 (Winter 1997) pp. 93-108. Galbraith pointedly notes "the persistent failure of inflation to accelerate in recent years despite transgressing past NAIRUs" and argues that policy is being misled by this innovation.

collapse of various alternative development models with the implosion in Africa and the prolonged stagnation in most of Latin America and South Asia for much of the postwar period; the spread of rapid growth throughout East Asia and in certain other economies such as Chile that adopted what in broad brush at least were market-and trade-oriented policies; and perhaps most importantly, the success of the North American economy whose functioning, rightly or wrongly, is associated with the tenets of the conventional economic theory.

While the labeling (by the World Bank) of the Asian growth spurt as the "Asian Miracle" launched a somewhat rancorous debate about exactly how miraculous the Miracle was, much of the debate was carried on comfortably within the context of standard growth accounting frameworks and the aspects that were not especially tractable in these terms (e.g., the role of "Asian values") were not taken especially seriously – at least, outside of Asia itself.

Where will the round of critical review that the crisis has already launched take economic theory and applied research? Some of the likely lines of inquiry have already been broached or hinted at. By and large the focus has been on the behaviour of financial markets since that is the proximate source from which the "Asian flu" emerged, and in particular on the factors that led to the build-up of short-term, unhedged foreign currency debt which, in the final analysis, left the region vulnerable to a crisis of confidence. However, the international institutional framework has also come under scrutiny and retrospectives on Asian development models are also being undertaken. Here is a preliminary list of lines of attack on the issues raised by the crisis:

1. The examination of systemic moral hazard in financial sector intermediation as a structural cause for a generalized financial sector crisis (i.e., the role of implicit government guarantees to financial institutions which might lead to essentially rational decisions to gamble intermediated funds; and related questions of "burden sharing" with respect to the consequences of failure).

2. The role of information asymmetries in generating mis-allocations of capital, which subsequently lead to abrupt adjustments (i.e., addressing the role of inadequate financial reporting, inadequate accounting methods[5] and lack of transparency in misleading investors).

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[5] In contrast to the often-made assertion that the problems in Asia were due to inadequacies in data disclosure, see the following view from Jeannie Cameron, formerly of Arthur Andersen: "Asia's financial crisis has put the efficacy of traditional accounting practices in the spotlight. The major international firms have performed their accounting roles in Asia by and large with all the required care… So the unavoidable question is: Has traditional accounting failed? The answer to many in Asia seems to be "yes". The article goes on to note that

"The Asian crisis is sending a clear message to the accounting profession -- that traditional accounting methods are outdated and it needs to do more to help clients detect and eliminate business risk. Traditional auditing methods focus on substantiating what is in a client's year-end records and the preparation of financial statements. This amounts to a retrospective point-in-time review to protect against intentional or unintentional mis-statements. But activities that have a major impact on business – such as share or derivatives trading, mergers, acquisitions or lending strategies – would not necessarily be reflect in a company's statements until after they have occurred and the consequences are already known. So what to do? The so-called Big Six accounting firms operating in Asia – Arthur Andersen,

3. The role of corporate governance in the efficient allocation of investment (addressing the role of so-called "crony capitalism", as well as the roles of unsophisticated lenders and unsophisticated borrowers in leading to unprofitable investment behaviour[6]).

4. Market imperfections in international capital markets that warrant some form of regulation or other intervention (e.g., addressing the behaviour of hedge funds and other trading strategies[7], the "herd" behaviour of investors, and the structural factors that create incentives for large short-term capital flows to occur in the first place[8]).

5. The optimal sequencing of liberalization of product versus capital markets, addressing questions such as why economies such as China and Singapore were for the most part spared while neighbours succumbed to the crisis, and what is the state of development of domestic financial markets (i.e., in terms of depth, range

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Deloitte Touche, Ernst & Young, KPMG and the soon to be merged Coopers & Lybrand and Price Waterhouse – all know that traditional auditing methods have been growing less relevant to the needs of their customers. They also know that a shift is needed to "continuous business auditing'' methods that focus more on the entire business and the risks it faces. And, to varying degrees, they are all implementing this shift within their operations. It would, however, be fair to say that had these methods been in place earlier, their accountants would have been better equipped to detect recent business risk in Asia". See Jeannie Cameron, "The Useful Death of Traditional Accounting", Asia Wall Street Journal, April 22, 1998.

What is particularly interesting about this article is that it disabuses one of the notion that the Asian crisis was simply an "Asian" crisis, a product of a specific business culture, of less-than-sophisticated new entrants in the economic major leagues. Many parties to this crisis were, like the above-mentioned accounting firms, the biggest players in the biggest of leagues -- and still the crisis happened and still it happened by surprise. A similar point is made with respect to the role of Asian financial supervisors: "One might argue that responsibility lies not just with bank supervisors in the borrowing countries but also with their counterparts in lending countries, particularly if the international community feels that there is sufficient systemic risk to the global economy to warrant interventions." Joseph Stiglitz, "Restoring the Asian Miracle", Asian Wall Street Journal, February 2, 1998.

[6] As Joseph Stiglitz puts it, "The borrowers who misallocated their investments share responsibility for the problems with the lenders, many of them international commercial banks, who provided them with the money in the first place." Joseph Stiglitz, "Restoring the Asian Miracle", op.cit.

[7] The IMF has already conducted a study by a team headed by Barry Eichengreen which found that there was approximately US$ 20 trillion in profit-seeking capital at play in the world's developed economies; although hedge funds constitute only a small fraction of this total, other types of funds and multinational firms also take "macro bets". See Barry Eichengreen, Donald Mathieson and others, "Hedge Funds and Financial Market Dynamics" Occasional Paper 166, (IMF, Washington, 1998). This has also been reported in "IMF Reports on Hedge Funds' Role in Asia", Asia Wall Street Journal, April 15, 1998; and in the IMF, World Economic Outlook (May 1998), Box 1: The role of Hedge Funds in Financial Markets.

[8] In this regard, Joseph Stiglitz argues that "First we need to eliminate the tax, regulatory and policy distortions that may have stimulated such [short-term capital] flows. Examples of distortions are evident in the case of Thailand where the Bangkok International Banking Facilities in effect encouraged short-term external borrowing. Subtle examples exist almost everywhere." See, Joseph Stiglitz, "Boats, planes and capital flows", Financial Times (March 25, 1998).

of instruments, and capacity to match term of maturity of assets and liabilities) that is a pre-condition for prudent liberalization.

6. Optimal exchange rate regimes under relatively free trade and relatively open capital markets (including the requisite conditions for successful application of, *inter alia*, pegs to individual currencies, pegs to baskets, fluctuation bands, managed floats, and currency boards).

7. The channels of transmission of crisis (including directly through trade links, through exchange rate relativities, and through market perceptions of "similarities" across economies).

8. Appropriate instruments and policy approaches for international financial institutions in addressing national crises that originate in private behaviour rather than public sector fiscal failures (i.e., responding to the widespread suspicion that fiscal and monetary restraint may not have been equally appropriate in the Asian crisis as it was in past crises which originated in public sector imbalances[9]).

9. Consideration of possible modifications to, and/or enhancements of, the international institutional framework (suggestions have ranged from an Asian Fund[10], to a regional surveillance mechanism,[11] to increased financial resources in the IMF[12]).

10. Rethinking the model of development: how stable is the Asian "fast track" to developed economy status?[13] Is parallel "democratization" of the political economy required?

There is a sufficient number of avenues of attack that the crisis has come to be explained, in retrospect, as the confluence of a number of factors, none of which individually would have been sufficient to explain the crisis, but which added up to a deadly cocktail. The outlines of the consensus view as to the causes and the appropriate responses was already

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[9] See for example Yilmaz Akyuz, "The East Asian Financial Crisis: Back to the Future?" (UNCTAD); this paper reviews the debate as to the appropriateness of the policy response and summarizes the various arguments.

[10] As suggested by Japan in September 1997 but subsequently withdrawn.

[11] As proposed by APEC Finance Ministers at their meeting in Kannaskis, Canada, May 23-24, 1998.

[12] One way or another, the Asian crisis has taken the IMF into new territory. Stanley Fischer, the IMF's second in command has been quoted as saying: "What's different about the last three programs is that banking- and financial-sector restructuring is absolutely at the heart of the program. That's new". See Richard Stevenson and Jeff Gerth: "IMF shifts strategies to douse financial fires", New York Times Service, Washington, December 9, 1997

[13] See "A Time for less Hectic Growth", Business Times (Singapore), August 20, 1997. The "fast-track" road to development referred to is the route taken by Southeast Asian economies, relying heavily on FDI, most notably Japanese FDI, and subsequently portfolio capital inflows, rather than domestically generated savings. The linkage between speed of growth and the ensuing turbulence is an interesting one which is explored in a preliminary fashion below.

visible in how the issues were framed in the early months of the crisis and this version of events has become increasingly a set piece over the course of 1998.[14] The question then arises: is this enough?

There are two clear-cut reasons for going further.

First, addressing the various individual elements that have already been identified as part of the puzzle will not address why they came together, nor why they came together in 1997 versus any other time, nor the specific configuration of various key variables at which the cocktail exploded. For example, while in retrospect it seems clear that East Asian companies took on too much debt, what is required is to know how much debt is too much, and how this might be affected by the quality of financial supervision, the extent of current account imbalances and the state of various other integral and contextual factors. Even more importantly, and this simply cannot be stressed enough, the ability to point to flaws – however severe – in individual economies does not explain why the crisis spread across the region, nor why in 1997 the outflow of capital from the regional capital markets destabilized exchange rates and the real side of the economy whereas, in 1994, the backwash of capital out of emerging markets which occurred in that year left exchange rates and real growth unscathed even as stock markets plummeted (at least in Asia – in Mexico of course it led to a real side collapse).

In the end, it was the doubt about the quality of lending in Southeast Asia that escalated and spread the crisis.[15] The question is, was this a "visceral, engulfing fear" that triggered "massive disengagements of investors and declines in Asian currencies" and that had "no tie to reality", as suggested by Federal Reserve Board Chairman Alan Greenspan?[16] Or was it informed judgements of market analysts and investors who looked for and found signs of property exposure, looming excess capacity and potential payments defaults – and took the essentially rational decision to get out before the bubbles burst[17]. *Ex post* it is virtually impossible to distinguish between these scenarios since, once the crisis of

[14] The *1998 APEC Economic Outlook* summarizes the analysis of the crisis by the IMF, the World Bank, the ADB and the OECD. It is quite striking how similar the views expressed already have become on an issue that was such a surprise to all in the first instance. See APEC Economic Committee, 1998 APEC Economic Outlook, (APEC Secretariat, Singapore, 1998).

[15] Note: while this appears to be clear from the behaviour of international investors, it must also be noted that part of the capital flight stemmed from domestic investors faced with no safe domestic currency options and/or seeking to cover forward foreign currency obligations.

[16] Cited in Tom Plate, "Who's Acting Wisely, Who's Not", Los Angeles Times, March 3, 1998.

[17] See for example Morris Goldstein, "The Asian Financial Crisis", International Economics Policy Briefs, 98-1, March 1998 (Institute for International Economics, Washington DC). Goldstein puts forward a "wake-up call" hypothesis: i.e., that Thailand's crisis led international investors to reassess creditworthiness of Asian borrowers and when they did that reassessment, they found that a quite a few of these economies had weaknesses similar to those in Thailand (that is, weak financial sectors with poor prudential supervision, large external imbalances, appreciating real exchange rates, declining quality of investment, etc.). Goldstein notes in his article that over US$ 420 billion in net private capital flows had gone to Asian developing countries in the 1990s. It is not immediately clear which scenario is more disturbing: Greenspan's reported view that investors were divorced from reality or Goldstein's that those charged with managing funds equivalent to a medium-sized economy are perhaps rational -- when not asleep at the wheel.

confidence strikes, a mis-match of term or currency which might be quite benign in a stable situation becomes deadly and the end result looks the same – widespread failures. To get at this issue, one must in a sense answer the counter-factual question of whether a crisis would have eventually emerged in Malaysia, the Philippines or Indonesia had there not been a trigger in Thailand? And this in turn would appear to involve an investigation of system dynamics.

Secondly, addressing these individual elements will not explain the sharp discontinuity in the overall macro environment that will almost certainly obtain as the region emerges from the crisis: the "stylized facts" of East Asian economies will be different, with a different future speed of growth as will the mix of sources of growth (i.e., labour vs. capital vs. technology; domestically financed versus through foreign investment), and a different flavour to the microeconomic structures of individual economies that will flourish. There is a good likelihood that the world that emerges from this crisis will be different from that which entered the crisis and in ways that could not be predicted pre-crisis.[18]

Accordingly, it is arguable that the crisis that began in East Asia and has now spread well beyond that region warrants a more fundamental review of the basic model. Where does one start and how might one proceed on this?

2. Examining the Asian Crisis through the Prism of Non-Linear Dynamics

One of the striking features of the crisis has been the extraordinarily limited extent to which the traditional micro and macroeconomic models have been used to describe the developments. In fact, in the commentaries and descriptions, metaphors for the crisis have been drawn from anywhere but economics. These include the weather ("storms"), nuclear physics ("meltdown"), biology ("flu", "contagion", "virulence"), mass psychology ("panic" and "herd behaviour") amongst others. It can be noted that none of the sources of these metaphors falls into the class of linear mechanical equilibrium systems.[19] Is it not

[18] An interesting development that provides a clue to how and why this will take place is the "benchmarking" that is occurring as regards the perceived factors behind the crisis. For example, a report on the Chinese parent firms of Hong Kong, China "Red Chip" firms, compared their debt-to-equity ratios and exposure to short-term debt to the respective patterns seen in Thailand, Korea and Indonesia prior to the crisis. See Erik Guyot "Red Chip Parents Carry Huge Debt Loads", Asian Wall Street Journal, April 21, 1998. Through such benchmarking, *ad hoc* rules of thumb are established about what are risky configurations of data, which in turn drive market behaviour. Out of this behaviour emerge new "stylized facts". What is particularly of interest in the context of this paper is that this "benchmarking" appears to be taking place outside the context of any explicit economic theoretical context. The fact that economic theory appears to be conspicuously absent from the formulation of a revised worldview is notable. The market actually seems to work on the basis of pattern recognition than on theory-driven analysis.

[19] Even in a more formal sense, the traditional economic theory is conspicuous by its absence as part of the framework of explanation. This is perhaps not surprising since virtually all the explanations offered fall under the category of "institutional failure" and institutions are not intrinsic to neoclassical theory. This is not the first time that a momentous event in modern economic history has seen neoclassical theory essentially on the sidelines. Consider the following passage from Sherwin Rosen on the limited role of neoclassical theory in explaining the collapse of centrally planned systems which almost

logical therefore to follow our metaphors and look for explanation and insight to systems that naturally produce the type of behaviour that has been seen in the course of the crisis?

For some time now, a revolution has been brewing in the natural and social sciences, variously labeled "non-linear dynamics" or "complexity theory". Aspects of complexity are referred to as "chaos theory" and many of the same ideas crop up in the application of "multi-valent logic", or "fuzzy logic" as it has been dubbed. What is driving the revolution is a combination of (a) the inadequacy of linear systems to deal with many important practical issues in areas such as climate change and weather patterns, biological and ecological systems, optimal control systems, and artificial intelligence research; and (b) the enormous increase in computing power (including the advent of parallel processing super computers) which is enabling researchers to explore the behaviour of non-linear systems by dealing directly with the enormous quantities of data which such systems generate.

Linear models were of course adopted by natural and social scientists for very good reasons – most importantly, tractability. As Parker and Stacey put it, "Traditionally, both natural and social scientists have explained the behaviour of systems in linear terms. They knew, of course, that the true relationships were non-linear, but non-linear relationships are notoriously difficult to handle and it was generally held to be a useful and acceptable simplification to employ linear approximations."[20] They go on to argue that "[I]t is acceptable and useful to employ a linear approximation of a non-linear system only if the following conditions hold. Synergy[21] [amongst components of the system] has to be relatively unimportant and some method has to be devised of taking into account both this minimal synergy and the range of effects which a single cause might have."[22] In other words, if the error terms are indeed distributed as assumed and small 'errors' or 'noise' (i.e., random or non-modelled factors) do not escalate to "take over, to alter completely the

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universally has been viewed as a victory for market-oriented economics: "The failure of planning and central control and market reforms occurring all over the world today is one of the most significant economic events of our age. Isn't it odd that so few neoclassical economists could use their theory to take much of a stand on such matters? But the logical basis of neoclassical theory is not well equipped for that task. The collapse of central planning in the past decade has come as a surprise to most of us." Rosen also reminds of the essential similarity between neoclassical economics and central planning in that, given sufficient information, the central planner could successfully mimic the competitive market solution by acting as the Walrasian auctioneer and choosing the correct prices to yield a neoclassical equilibrium. See Sherwin Rosen, Journal of Economic Perspectives, Vol. II, No. 4 (Fall 1997) pp. 139-152.

[20] David Parker and Ralph Stacey, Chaos, Management and Economics, Institute for Economic Affairs (1994)

[21] By the term "synergy" they mean the property of a non-linear system whereby the overall behaviour of the system cannot be accounted for additively as the sum of the behaviour of the component parts of the system. Systems exhibiting a significant amount of synergy in this sense require a "holistic" or "systemic" analytical approach to understand the patterns of behaviour that are generated.

[22] This latter requirement reflects the fact that, in non-linear systems, a given cause can have many different effects or outcomes whereas linear systems have only one solution. The method used in linear approximations is to add stochastic error terms onto equations to take account of the approximations inherent in the linear specifications as well as random factors (i.e., non-modelled factors or omitted relationships).

behaviour of the system", then the non-linearity of the underlying relationships can be safely ignored.

Economics has not been front and centre in the application of non-linear methods but neither has the issue been entirely ignored. Indeed, many of the central ideas and some of the language of complexity theory are clearly visible in the ideas of the Austrian school of economics and particularly in the writing of Friedrich von Hayek who wrote about economics as dealing with "phenomena of organized complexity".[23] There has been formidably sophisticated analyses of the implications of relaxing, on a partial basis, the linear assumptions that underpin the mainstream neoclassical model and, moreover, since the mid-1980s, a not inconsiderable number of papers have directly explored the application of non-linear theory to economics.[24] However, applications of this work to the discussion of the Asian crisis has been limited.

Indeed, as a very broad generalization, economics remains cast in a mechanistic, linear mould oriented towards establishing the existence and characteristics of equilibria in worlds that are populated by rational, optimizing individuals and firms possessing perfect knowledge (or at worst "imperfect information"), that are inherently stable unless "shocked" by some external factor, and whose macro behaviour is derived as the sum of its parts.[25]

The Asian Crisis appears to stretch the credibility of the assumptions essential to a "linear" treatment of the issues. The defining characteristics of the Asian Crisis were its sudden, unanticipated emergence,[26] the absence of a significant external shock (or any external shock for that matter)[27], the wide difference between the size of the apparent causes and

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[23] By organized complexity, von Hayek meant structures that depend not only on the properties of the individual elements of which they are composed, and the relative frequency with which they occur, but also on the manner in which the individual elements are connected with each other. Absent this full information about the individual elements, prediction of specific events is not possible and analysts must content themselves with predictions of general patterns. See Friedrich von Hayek, "The Pretence of Knowledge", *op cit*. There has recently been a renewal of interest in the Austrian School that has paralleled the emergence of non-linear dynamics. See The Journal of Economic Perspectives, Vol. II, No. 4, (Fall 1997). One of the interesting points made concerns the similarities between the Austrian School of economic thought, which stresses the self-organizing nature of markets, and the emphasis on emergent self-organizing behaviour in complexity theory.

[24] Much of this is game theoretical and agent-based analysis. See the Santa Fe Institute's The Economy as an Evolving Complex System II, W. Brian Arthur, Steven N. Durlauf and David A. Lane editors (Addison Wesley, Reading Mass. 1997). Parker and Stacey, op. cit., also has a good bibliography of the literature through 1993.

[25] A criticism of mainstream economics that focuses basically on this point can be found in, for example, in Paul Ormerod, The Death of Economics, Faber and Faber (1994).

[26] It is a matter of some irony that the big event of 1997 was supposed to have been the sovereignty transition in Hong Kong on July 1, marking in some sense a milestone in Asia's re-emergence as a global economic presence. However, it was the following day, July 2, that has turned out to be the main event. The fireworks over the skies of Hong Kong were barely over when the Asian crisis began. What sort of system moves so precipitously from an apogee to its nadir?

[27] The fact that there was no shock is not only significant to note but is also significant because it has not been a focal point of discussion!

the eventual intensity of the impacts, and the depth of transformation of the economic landscape of Asia that it has wrought. These characteristics are typical of systems that incorporate non-linear dynamic non-equilibrium behaviour; they are not typical of linear mechanical equilibrium systems.

In this regard, it is ironic that a statement made about the Asian Crisis at the ADBI-ASEAN Economic Forum on Current Asian Financial Developments so closely echoes the argument made on behalf of the relevance on non-linear dynamics. The report on the discussions at that forum goes as follows: "In short, financial liberalization and integration accentuated booms, but there was a symmetrical effect contributing to busts. In the view of one participant, this led to a crisis that was not predictable, but explainable" (emphasis added)[28]. Compare this to Parker and Stacey: "The arrival of a mode of thought which challenges the whole way the world is viewed is timely, if only because the way it is now seen is so patently unable to explain events, except in the *ex post* sense."

3. The Asian Crisis: Non-Linear Dynamic Aspects

One way to open up the discussion of the insights into the causes and course of the Asian Crisis that might be yielded by non-linear dynamics, or complexity theory, is to compare statements about the Asian Crisis to statements about non-linear systems and then to draw some preliminary conclusions and hopefully identify some avenues for future work.

1. Unpredictability

Non-Linear Models: The long-term future is not simply difficult to see, it is inherently unknowable because of the nature of the system itself and not because of changes going on outside it and having impacts on it. Such random factors add even more complexity. Consequently, decision-making processes that require reliable forecasts -- even those based upon making assumptions about long-term future states -- are called into question. Those applying such processes in conditions of bounded instability are engaging in fantasy.[29]

The Asian Crisis: It is an incontrovertible fact that the economic forecasting and analytical community, including within the private and public sectors and within the international organizations, did not come remotely close to anticipating a crisis, let alone anything of the order of magnitude that has emerged. A failure to predict is not, however, the same as an inability to predict in principle and it is the latter point that is at issue here. For example, a failure might be due to lack of key information about exogenous variables or, simply, due to human error, in the sense that the model was telling us the crisis was at hand but the information was ignored or misinterpreted. The third alternative is that the model could not predict the crisis because it fails to capture linkages or because the

[28] The ADBI-ASEAN Economic Forum on Current Asian Developments, "Executive Summary", (http://adbi.org/120298es.htm)

[29] David Parker and Ralph Stacey, op cit. p. 40

underlying assumptions about the behaviour of the error terms are unfounded. In the latter case, the crisis would be unpredictable in the context of the model.

A first point to take up in this discussion is the absence of a shock to pitch the region into a crisis. The crisis in a sense crept up on everybody, its true dimensions hidden at every stage. Various events and trends in the years immediately the onset of the crisis have been adduced as factors contributing to it but none of these constitute a "shock".

For example, some analysts have cited China's unification of exchange rates in 1994 as having effectively undermined the competitiveness of Southeast Asia. This argument often ignores both the fact that the effective devaluation was much smaller than the 50 percent change in the quoted external rate, and the fact that the subsequent burst of inflation in China of over 40 percent over the succeeding two years would have eroded most if not all of any possible competitive advantage which that event would have gained for Chinese industries. An alternative and perhaps more plausible argument is that the redirection of FDI flows from Southeast Asia to China signaled that large current account deficits in Southeast Asia would not in the future be sustainable because of lack of supporting FDI inflows; however, this is not the argument usually advanced regarding the role of China in this event).

Similarly, the rise of the US dollar against the yen from mid-1995 is often cited as a factor contributing to the erosion of competitiveness of Southeast Asia. This is a doubtful argument on many counts. In this regard, the height of the Japanese *endaka*, or strong yen period, was generally considered to be the aberration or shock, not the subsequent return to the 110-120 range. Indeed, it will be recalled that the rise of the Yen to the range of 85 to the US dollar in mid-1995 was a source of extreme difficulty for Southeast Asia because of the effective increase in debt service on yen-denominated borrowing. Moreover, when the crisis unfurled, the yen devaluation had only returned it to the 110-120 range where it had been most of the 1990s.

Further, the role of Japanese FDI in Southeast Asian growth must be taken into account: indeed, much of the FDI that had flowed into Southeast Asia and that had fueled the boom represented an out-sourcing strategy of Japanese multinationals to ease the impact on their costs of the post-Plaza Accord rise of the yen against the dollar. In this context, the implications of a fall in the Yen for competitiveness of Southeast Asia are not clear at all. The strong yen did give Korea a brief competitive advantage in 1995 which appears to account for the very strong 9.5 percent growth in the latter economy that year; however, it would be hard to interpret the removal of this temporary boost to Korea's fortunes as representing a fundamental undermining of its longer-term competitiveness.[30]

A third background fact introduced into the discussion is the semiconductor slump of 1996. This certainly depressed exports in 1996 and contributed to an overall growth

[30] A summary of the arguments on the yuan/yen devaluations as key factors can be found, for example, in C. Fred Bergsten: "Why the Asian Monetary Crisis?" EDI Forum (Economic Development Institute, World Bank, Volume two, Number four, Spring 1998). Bergsten places the effective yuan devaluation at 40%; others suggest lower figures.

slowdown, particularly in Singapore, Korea and Chinese Taipei. This sector was, however, rebounding in the first half of 1997, which partly accounted in fact for the upward revision in forecast growth for the region at that time. The following is a typical assessment from mid-1997:

> "Recent indicators suggest that the deterioration in trade sector performance [for Asia-Pacific] that occurred in 1996 may have gone into reverse. Export growth has begun to revive in Singapore, Korea and Thailand, while Malaysia's current account is on the mend with the help of weaker domestic demand. Increased export growth in Korea has afforded a strong boost to industrial production, which was up 10.7 per cent over the previous year in April. A rebound in demand for semiconductors and computer-related equipment is a welcome signal that the worst effects of the 1996 chip price collapse have passed." [31]

The article goes on to note the currency turmoil in Southeast Asia that resulted from Thailand's floating of the baht and then forecasts increased growth for the region. The point here is not to single out any forecaster in particular, merely to underline the point that all of these facts were well known to the market – this was not new information – and these events would not fit the bill of "shocks" that destabilized the region.

Indeed, it is instructive to recall the tone and substance of the mainstream economic press more generally in the days and weeks immediately preceding the onset of the crisis. In the case of Thailand, The Economist article of May 24th, 1997, entitled "The Fall of Thailand?" provides a cogent summation of the issues facing that economy, and the question mark was not an accident -- the tone of the article was on the whole optimistic. The Economist noted that "forecasts have been shaved down to 5% from 9% in 1995.... the fact that growth rates of 5% are viewed as 'poor' only shows how high regional standards have become.....". Now it is true that private assessments of the outlook may indeed have been even more negative than +5% but it is unlikely that any forecaster would have wanted to venture a forecast of zero growth in public in May 1997, let alone the -3% which the IMF currently expects for 1998.[32]

It is also highly instructive to re-read Euromoney's May 1997 article on Korea. "The Collapse of Korea Inc." As with the Economist's article on Thailand, all the factors that are now talked about in "hindsight" are there fully flagged and without minced words before the crisis dawned. Moreover, even taking these factors into account, the conventional wisdom before the crisis was that Korea would rebound from the growth slowdown of 1996. All in all, the Euromoney article came out on the moderately positive side and consistent with the then-current view of continued stable growth.

The most telling point actually is that, not only were these factors well known before the onset of the crisis, but the view in the spring of 1997 was that risks were receding rather

[31] Conference Board of Canada, World Outlook (Summer 1997).

[32] IMF, World Economic Outlook, May 1998.

than about to flare.[33] Consider, for example, the perspective on Asian and global growth prospects as set out in the IMF's May, 1997 World Economic Outlook:

> "Economic and financial conditions are generally propitious for the global expansion to continue in 1997 and the medium term at rates at least those matching those seen in the past three years. There are few signs of the tensions and imbalances that usually foreshadow significant downturns in the business cycle; global inflation remains subdued, and commitments to reasonable price stability are perhaps stronger than at any other time in the post-war era; fiscal imbalances are being reduced with increasing determination in many countries, which should help contain real long-term interest rates and foster higher investment; and exchange rates among the major currencies appear to be generally consistent with broader policy objectives."[34]

A sunnier outlook could scarcely be imagined. The IMF did qualify these "grounds for optimism" by noting risks to this central scenario. These risks were in order:

- high unemployment in the European Union which could undermine fiscal targets associated with monetary union and lead to turbulence in financial markets;
- the strength of equity prices in the USA and "many other countries" which could lead to a stock market correction that could impact on confidence;
- higher interest rates and adverse developments affecting systemically important capital-importing countries could expose countries relying on capital imports to risk; and
- fragile banking systems were of concern in a broad spectrum of countries.

While the fourth-named risk has exploded in some of the "broad spectrum of countries", this risk was, in the Spring of 1997, very much in the background and, at least for Asian developing economies, discounted as reflected in the fact that the growth outlook in 1997 for these economies was revised upwards by 0.7% from the October 1996 forecast. Moreover, of particular interest given the *ex post* analysis that has appeared, the IMF noted that "In contrast to the run-up in asset prices in the late 1980s, especially in Japan but also in the United States and several other countries, a generalised overvaluation of asset prices, leveraged by increased indebtedness, does not appear to be present in most countries with strong stock markets."[35]

It is important to note that the IMF was not a lonely outlier in its perspectives. The private sector was also bullish on Asia. The Asia Wall Street Journal's Asian Economic Survey 1996-97 (October 22, 1996) noted that the private sector consensus (the average of 120 forecasters) was that growth would accelerate slightly to 7.8% in 1997 from 7.6% in 1996.

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[33] The section follows Ciuriak, "Reflections on APEC's Progress in 1997 and the Challenges Ahead", Occasional Papers, Columbia University (February 1998).

[34] IMF, World Economic Outlook (May 1997), p.1.

[35] *ibid.* p. 2. Which countries had "strong stock markets" is a matter open to interpretation. The sense conveyed by the passage reflects the perception that conditions were for the most part benign at the time the crisis hit.

What is particularly interesting about this survey is that all the issues that have since been blamed for the crisis were duly noted in its economy-by-economy analysis. Again and again we are reminded that these were not new issues that caught the market by surprise; the market was familiar with them and they were reflected in forecasts – *insofar as was possible at the time*. In fact, the main concerns articulated about the outlook were with respect to the medium term and to the ability of Asia to progressively switch to growth based on increasing efficiency and away from growth based on mobilising factor inputs.

It is also important to note that the tone of private sector commentary on East Asian economic prospects for the most part improved over the course of the early months in 1997. The growth slowdown of 1996 bottomed out in the fourth quarter of 1996 and the first quarter of 1997 and industrial production and export growth were beginning to rebound as the second quarter figures started to come in. As the Conference Board article cited earlier noted, East Asia appeared to have truly effected a "soft landing" and to be on a path to a re-acceleration of growth when the crisis hit.

The reality is that the factors underlying the crisis were known and they were not being ignored to – to the contrary they were being stared at – and nonetheless the crisis itself was not foreseen. One can argue human error but, given the number of forecasters and market watchers involved, the crisis really does appear to be something that was beyond reasonable expectations to predict.

This points us towards the third alternative, that the crisis was not predictable because the model which we use to understand the international macroeconomy fails us. In this regard, it is worthwhile to note that: (a) in standard empirical models the dynamics of stock markets and short-term capital flows do not drive the real side of the economy (a point echoed in the witticism that "the stock market has predicted five of the last two recessions"); (b) exchange rate movements have defied structural models and are best predicted by random walks; and (c) "confidence" (the crisis in which precipitated events) does not appear as an argument, exogenous or otherwise, in the standard macro model. Assuming that the formation of rational expectations and the pricing of information into asset values reflects the negative results of empirical research as well as the positive, then it might be stated in a rather firm manner that the crisis was unpredictable.

2. *A small error escalates and takes over to alter completely the behaviour of the system*

Non-linear systems: "It is now understood that [in] non-linear feedback systems ... some tiny error to a number of decimal places, some imperceptible "noise" in the system, can escalate into major qualitative changes in the behaviour of the system."[36]

The Asian Crisis: The Asian crisis is generally traced back to problems in Thailand's financial sector. These problems first surfaced to a noticeable extent when Moody's downgraded the credit rating of several Thai banks in mid-1996. Subsequently, the problems of Finance One, a relatively prominent finance company in Thailand but with little previous profile internationally, and Somprasong Land Company, one of Thailand's

[36] Parker and Stacey, op. cit., p. 13

largest developers, dominated business news out of Thailand through the first months of 1997.

The problems in the Thai financial sector were not imperceptible but, on a global scale or even a regional scale, they certainly were very small. Thailand's GDP was about 1% of APEC-wide GDP and thus substantially less than 1 percent of global GDP. Moreover, the total amount of non-performing financial assets would certainly have been only a fraction of Thailand's GDP[37]. Not only was the original source of the instability small on a regional and global scale but it was also not a direct argument in any macroeconomic model; in other words, the problems were in effect buried in the error terms of macroeconomic models of Thailand.

The shoe would seem to fit: a small element of "noise" in an error term in the system escalates to take over and generate large qualitative changes in the regional and global economies.

3. A single cause leads to a wide range of effects.

Non-Linear Systems: "The range of effects to which a single cause can lead may well be huge. In fact, the links between cause and effect disappear in the complexity of interactions."[38]

Asian Crisis: As the crisis unfolded it resulted in runs on various currencies, including those of relatively "similar" economies such as Indonesia, Malaysia and the Philippines, quite dissimilar economies in the region such as Hong Kong and Singapore, and still less-similar and more distant economies such as Chinese Taipei and Korea. It resulted in a radical restructuring of trading patterns and a resort to barter in some cases. It has triggered a reverse flow of migrant workers in many economies. It has abruptly put on hold numerous major infrastructure projects that were generally considered vital to alleviate bottlenecks to future growth. It triggered deep economic restructuring in Korea, an economy that had successfully managed four decades of strong growth. Arguably, the outflow of funds from Asia helped boost the USA stock exchanges and thus contributed to the record breaking bull market on Wall Street. The crisis has also, according to some, favourably altered the context for the launching of the Euro. And it has led to the creation of a new international institutional mechanism for regional surveillance in the Asian Development Bank.

The range of effects is certainly very broad and the links between the effects and the original cause are definitely buried in the tangle of the complex intermediate developments.

[37] Even if the figures were as high as some guesstimates, which put the figures at between 1/4 and 1/3 of GDP before the crisis broke, and applying a deep discount of, say, 50% on the value of the assets, the size of the problem would have been a figure on the order of magnitude of 0.1% of regional GDP.

[38] Parker and Stacey, op. cit., p. 13

4. Positive and Negative Feedback Loops

Non-Linear Systems: "Non-linear feedback systems are driven by positive and negative feedback... Negative feedback feed[s] modifications back into the system so as to secure the convergence of actual and intended [outcomes]...Any planned system is based on the notion of negative feedback. Keynesian demand management is essentially of this kind. Positive feedback...instead of feeding back the discrepancy between an outcome and an intention in a manner that closes a gap between the two, ... *progressively widens* the gap. Positive feedback appears to be widespread in economic and business life. It can take the form of self-reinforcing growth, bandwagon effects, chain reactions, self-fulfilling prophecies and virtuous and vicious circles".[39]

The Asian Crisis: The crisis clearly featured examples of negative feedback: for example, government policies such as increases in interest rates that were meant to stabilize capital flows.

There were also many examples of positive feedback:

- the exodus of portfolio capital out of individual economies evidenced a positive feedback loop as withdrawals of funds lowered prices on asset markets which in turn triggered further outflows, further lowering prices;
- the drying up of liquidity in the banking system led to failures of industrial corporations which in turn led to a worsening of the loan portfolios of the banking systems -- a classic vicious circle;
- the propagation of the crisis from Thailand to its neighbors in rapid succession had the appearance of a chain reaction; consider for example the impact of the NT dollar devaluation in triggering an immediate attack on the Hong Kong dollar;
- the concept of a "self-fulfilling prophecy" has been invoked in explaining why forecasts such as those by the IMF were so rosy in the spring of 1997 – i.e., it is argued that pessimistic prognoses would have triggered the crisis even earlier[40] – so the behaviour of actors within the system appears to be understood as evidencing positive feedback loops.

5. Bounded Instability

Non-Linear Systems: "For any non-linear feedback system there can be points within it to which the system is drawn.... The path is aperiodic and never reaches a stable equilibrium. Equally, it does not follow a regular cycle like a pendulum. At the same time it has bounded movement and is not completely unstable. The motions are contained within the region of the attractor... Far from equilibrium, behaviour is both stable and unstable... Fairly constant cycles of behaviour can occur, interrupted from time to time and

[39] Various statements drawn from Parker and Stacey, op. cit., p 25-26

[40] Note: this argument, which is quite valid in explaining the circumspect language of official pronouncements on macroeconomic issues, but as noted earlier does not explain why the IMF's forecast for East Asia was upgraded in May 1997 by 7/10ths of a percentage point from the October 1996 forecast.

without warning by phases of chaotic turbulence...The aperiodic motion is not due to a change in the underlying relationship or structure of the system. Nor is it due to stochastic or random disturbances. *It is pre-determined within the system*."[41]

The Asian Crisis: The movement of the East Asian economies did not explode into total instability (although in the case of individual economies such as Indonesia the instability was sustained longer and went much deeper than in other economies), but rather showed tendencies to stay within bounds.

Moreover, the early months of 1998 evidenced continued but relatively muted unstable behaviour of both exchange and stock markets although in new neighborhoods, which had no particular "equilibrium" features. Rallies and slumps on currency and stock markets emerged without warning, sometimes linked to rumour and sometimes to news but not to any identifiable external shocks or internal structural changes, and dissipated as rapidly. In between, there were periods of relative calm with markets evidencing relatively stable "sideways" movement. All in all, market movements appeared to be aperiodic and chaotic and the course of the crisis is well captured by the descriptions of typical non-linear systems.

6. Sensitive Dependence

Non-Linear Systems: Sensitive dependence is an important feature of the disorderly behaviour of deterministic dynamic systems in science. In particular, it is responsible for their unpredictability, for the system can be sensitive to even minute changes in the value of its conditions or parameters. Very small variations in parameter values lead to huge variations in behaviour of the system. The system can go from periodic to chaotic and back again as a result of very minor parameter values. This is what lies behind the "butterfly effect", first observed by Edward Lorenz, who was attempting to predict weather patterns.

The Asian Crisis: Initial conditions in East Asia vary considerably, whichever variable one chooses: geographic form, population sizes and degree of homogeneity, per capita incomes, stage of development, government system, industrial organization, length of the preceding boom, exchange rate system, stock market capitalization relative to the size of the economy, relationship of actual and purchasing power parity exchange rates, and so forth. Accordingly, there is much scope to identify differences that might account for the differences in eventual outcomes which, as it turns out, have covered quite a spectrum, although not in any reasonably predictable way.

In the early stages of the Asian Crisis, Indonesia, which in the end was the worst affected, was usually judged to be well-positioned to avoid significant impacts and, indeed, the decline of the rupiah started comparatively late. In this regard, the Bank of Indonesia was generally given high marks for having managed a steady downward float against the US

[41] Parker and Stacey, op. cit., p. 36. Note: an attractor is the set of points to which the system is drawn in the complex manner described. An equilibrium point or a limit cycle are "normal" attractors. The points in the non-linear dynamic system are called "strange attractors" because of the complex movements that they generate.

dollar rather than maintaining a fixed exchange rate, and for prudently widening intervention bands progressively in the years prior to the crisis to avoid giving markets an easy target to shoot at. In the end, the depth of depreciation of the various currencies varied widely and Indonesia went down the furthest.

The Asian Crisis has resulted in social disturbances and deep recessions in some economies but only relatively modest growth slowdowns in others. Interestingly and ironically, the social disturbances have peaked in Indonesia, where again policies had been perhaps the most commended for their effectiveness in spreading the benefits of growth across the population in the decades leading up to the crisis.[42]

In the aftermath of the crisis, attention is turning to identifying differences among the economies which might explain the differences in impacts; for example, attention has focussed on the degree of capital account liberalization, the extent of SME development and so forth. It is noteworthy, that these aspects of economies are not explicitly captured as arguments in macroeconomic models. Rather they are buried in parameter values and error terms.

7. Self-Organization

Non-Linear Systems: When non-linear systems are pushed far from equilibrium into chaos, they are capable of producing spontaneous, more complex forms of behaviour through a process of self-organization... At the boundary between stability and instability, the system produces an endless stream of new and creative forms.... Order may emerge from chaos without formal design, although there is no guarantee that it will.[43]

The Asian Crisis: The quintessential feature of the market is of course its self-organizing nature. Accordingly, virtually any statement about market responses to the crisis should suffice for this purpose. That being said, there appears to be little in the way of a private sector market response to the crisis X the reactions have come predominantly, it would appear, from governments and the international financial institutions.[44] However, there have been some anecdotes about "coping" behaviour of individuals, firms and governments in the region and there may well be much more of this which so far is below the threshold of observation of the mainstream economic media[45].

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[42] See Tamar Manuelyan Atinc and Michael Walton, East Asia's Social Model after the Crisis, The World Bank (1998). Between 1975 and 1995, Indonesia effected an 82% decline in poverty, with Indonesia's "head-count index" falling from 64% in 1975 to 11% in 1995.

[43] David Parker and Ralph Stacey, op cit, p. 36

[44] An interesting observation which may be quite relevant in this connection was made by Sherwin Rosen in his article comparing Austrian and neo-classical economics: "The more distressing fact is that the enormous growth and influence of the state in the 20th century, surely the most important little-understood economic fact of our era, cannot be explained by either Austrian or neoclassical economics. The economics of the state, Austrian or otherwise, fills the pages of a very small (though growing) book." See Sherwin Rosen, op. cit., p 148

[45] One example reported in the Asia Wall Street Journal (April 22, 1998) involved a Thai footwear exporter Wongpaitoon Group PCL borrowing $100 million from Daiwa Securities America on the basis of securitisation of its future export earnings. This followed a similarly structured $100 million deal with

8. Dissipative Systems

Non-Linear Systems: "Non-linear systems can import energy or information from the environment which is then dissipated through the system, in a sense causing it to fall apart. But the system still has a structure in the form of irregular patterns capable of renewal through self-organization. Dissipative systems have the following properties:

- They use positive feedback to amplify fluctuations in their environment so as to disrupt existing patterns of behaviour....
- There is structure as well as variety. The structure takes the form of correlations or communication between individual components of the system....
- They make choices at critical points. A system may have qualitatively different behaviour due to a small change in the control parameters. The system suddenly flips from one type of behaviour to another....
- They evolve sometimes in unexpected and sudden ways, becoming increasingly comple*x. ..The system's history is important* and new order emerges without prior intention. Emergence means that outcomes are a surprise." [46]

The Asian Crisis: The role of information and analysis in transmitting the "Asian flu" seems to correspond to the statements about "importing information and then dissipating it through the system". The process through which individual opinions about the future course of the crisis started to form an emerging consensus, as negative views fed on negative also clearly embodied the effects of positive feedback. Once a view established itself (e.g., the market would not stabilize until such and such move was taken...), it effectively changed behaviour in the self-fulfilling prophecy sense. Different economies experienced pressures at different times (recall: "they make choices at critical points"), and then stabilized at different times. Both the onset of pressures and the stabilization were usually quite sudden, capturing the sense of the system flip-flopping from one state to another. Accordingly, many of the statements made about dissipative structures ring true for the Asian Crisis.

9. Double Loop Learning

Non-Linear Systems: "Double-loop learning is a positive feedback process of attending to the contradictions and conflicts between what is actually happening and the expectations to which an outdated mental model leads...Double-loop learning therefore has a destructive aspect. It is a process of making old perceptions redundant. But it also has a creative aspect in that it leads to a new mental model or paradigm[47]...It is essentially destabilizing because it challenges the *status quo*."[48]

Indonesia-based Asia Pulp & Paper in December 1997. Securitisation of future flows has been widely used in Latin American countries but was new to Asia.

[46] David Parker and Ralph Stacey , op. cit., pp. 38-39

[47] The term "paradigm shift" has been used often enough to have become a cliché. It is interesting to note, therefore, that this concept has no theoretical counterpart within the neoclassical model.

[48] Parker and Stacey, op. cit., p. 27

The Asian Crisis: One of the intriguing developments in the Asian crisis was the chain of reasoning and analysis that spread the crisis from economy to economy.[49]

The trigger for the Asian Crisis was the crisis of confidence in Thailand that appeared initially to be a *sui-generis* issue rooted in the flaws in Thailand's banking regulation and supervision. It was actually a lot more complicated than that. Among the "atmospheric" elements contributing to the Thai crisis were:

- the protracted debate that had been engaged in the months preceding the crisis regarding a possible change in the exchange rate regime to one in accordance with World Bank recommendations;
- the export growth slowdown in 1996 and the lackluster export recovery in the early months of 1997;
- the aforementioned default on interest payments by two prominent Thai companies, Finance One and Somprasong Land Company, which was quickly seen as the tip of an iceberg of non-performing debt;
- the persistence of a deep current account deficit, coupled with
- the protracted and messy negotiations for a Bangkok rapid transit system that impacted on confidence in the viability of Bangkok, where much of Thailand's economy is based.

The discussion about possible changes in the exchange rate regime seemed to have information value for the exchange markets as the daily swirl of market reports associated trading activity with reports concerning the intentions of the Central Bank. The discussion certainly served to focus market attention on the baht and the market was said to be "testing" the baht. "Testing" is learning behaviour and an important aspect of learning is associating factors.

When the baht in the end proved to be vulnerable, attention turned to other "most similar" economies in the region, namely Indonesia, Malaysia and the Philippines. These latter economies tried vigorously to differentiate themselves from Thailand. However, the pressure was unrelenting and the peso devalued as well, along with in short order the ringgit and rupiah.

What is interesting, and indeed quite fascinating, is that the explanation for pressures on these economies stemmed from the very fact that they were indeed "similar" in some ways to Thailand X i.e., they were all fast-growing economies located in the same region and all with current account deficits. It is important to note at this point the weight of opinion in this regard over the several years preceding the crisis. During this period, large current account deficits were being run in the region yet were tolerated by the market, in part on the grounds that the deficits reflected *private* rather than *public* borrowing. The view expressed was that rapidly growing economies whose investment requirements and opportunities exceed domestic savings capacity can -- and indeed should -- absorb excess capital from elsewhere in the world. Since the borrowing was by the private sector, it was

[49] The discussion below draws heavily on and builds on the discussion of this issue in Ciuriak "Reflections on APEC's Progress in 1997 and the Challenges Ahead", *op. cit*.

assumed that the money was being put to productive use rather than being "squandered" by governments.

Arguably, what transpired here was precisely a paradigm shift. The eventual vulnerability of the baht led the market to question the basic pattern of growth that had been followed in Southeast Asia and learning behaviour shifted from within the old frame of reference to seeking out a new frame of reference. This would appear to be a clear example of a shift from "single-loop" learning to "double-loop" learning.

When the pressures shifted to the Singapore, NT and Hong Kong dollars, the explanation had to shift again as these economies have current account surpluses, sound fiscal structures and massive foreign currency reserves. Moreover, all three were in the midst of upswings from the slowing growth trend in 1996. Ad hoc explanations were offered: It was suggested that Singapore wanted to see its currency weaken given the deeper slide in its ASEAN neighbours, while in the case of Chinese Taipei and Hong Kong, it was explained that the pressures reflected a market "test" of the exchange rate pegs to the US dollar. The market would appear at this point to have been iterating its way around the second loop – a new paradigm was not yet established and the market was probing and testing to see what the new order would be. The language of "testing" is evocative of learning, as is the rapid shift of explanations.

The further spread of the crisis to Korea brought the argumentation full circle as once again domestic financial sector difficulties became the focus, with a strong theme of the need for fundamental structural reforms to Korea's idiosyncratic *chaebol* system. Moreover, these themes continued in Japan where the financial sector woes were again brought to the boiling point with the collapse of Yamaichi Securities and the apparent drift of the economy towards a possible recession put the spotlight on structural issues as well.

When the market's testing of Korea exposed a critical exposure to short-term credit, one might figuratively say that the market had gone full circle around the second loop and now made some fundamental reassessments of previous beliefs. This appeared to be what was happening as 1997 drew to a close. As 1998 dawned, forecasts were revised sharply down and Asian markets plunged.

The shifting tone and focus of the discussion and the sharp reevaluations of prospects of economies seem inconsistent and erratic if seen as occurring within a fixed frame of reference. However, if seen as a learning process, the issue of consistency drops away and what was erratic becomes exploratory. All in all, the course of the Asian crisis seems quite well described by the process of "double-loop" learning, which resulted in a paradigm shift.

10. Discontinuities and catastrophe theory

Non-Linear Systems: Catastrophe theory describes the geometry of systems that are characterized by discontinuities.[50] As Casti puts it, "In colloquial terms, we might think of

[50] Catastrophe theory was developed by French mathematician Rene Thom in his 1972 book "Structural Stability and Morphogenesis." A simple and well-understood example from engineering is that of a beam of

the catastrophe points as the straws that break [the system's] back. As it turns out, these catastrophe points arise at just those input levels where there is more than one possible fixed point to which the system can be attracted. And the jump discontinuity is a reflection of the system's 'deciding' to move from the region of one attractor to that of another. Catastrophe theory shows us that there are only a small number of inequivalent ways in which these jumps can take place, and it provides a standard picture for each of the different geometries that the surface of attractors can display."[51]

The Asian Crisis: The Asian Crisis is generally understood to be a crisis of confidence. The role that confidence played in the crisis seems to correspond rather well to the elastic beam in the example given above. The long boom had generated a considerable amount of confidence that the Asian economies would continue to grow at a rapid pace for the foreseeable future. This confidence supported a particular pattern of optimistic investor behaviour. The sequence of negative events is analogous to the pressure on the elastic beam: initially, confidence like the beam holds firm and does not buckle. At some point, however, a sufficient pressure of negative events results in confidence crumbling and behaviour changes and investors flee. The high optimism is replaced by a deep pessimism, without an intervening period of neutral outlooks.[52]

Moreover, as pressures are relieved, the failure of economies to "snap back " is reminiscent of the over-shooting behaviour of markets. It is interesting to remark in this context that a number of economies which, by all accounts, came under pressure primarily because of current account deficits, have swung into large current account surpluses but remain at depressed levels of economic activity.

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length L that is used as a strut or support and that is subject to pressure (denoted by, say, P). Initially, the beam is unbuckled. As the pressure on the beam is smoothly increased, it reaches a point where the beam suddenly buckles in one direction or another, say upwards (this point is where $P = p^2l/L$, where l denotes the elasticity of the beam). If a force F is then applied to the midpoint of the buckled beam, the displacement or bow will be smoothly reduced until suddenly the beam buckles in the opposite direction or downwards. If the force F is then smoothly decreased, the beam remains buckled downwards past the point at which it jumped into that state. As F is still further reduced, a point is finally reached where the beam suddenly snaps back into the upward buckled state. These discontinuities are described geometrically by a 3-dimensional folded surface whose fold lines projected onto a 2-dimensional surface map out a cusp point. The point at which the beam buckles initially is the tip of the cusp.

[51] It turns out that there are seven well-defined mathematical "catastrophes" with exotic names like: fold, cusp, swallowtail, butterfly, hyperbolic umbilic, elliptic umbilic and parabolic umbilic. These names have been inspired by the characteristic shapes of the spatial interpretation of the respective geometries of various non-linear systems. The application of catastrophe theory is rigorous only where the underlying dynamic process has an explicit mathematical formulation. Attempts to apply it in instances where the underlying math is not known have proven highly controversial. See Casti (1993) pp. 43-84 for an accessible introduction.

[52] In the real world where risks are hard to quantify and investors rely on subjective evaluations ("gut instinct" etc.), this would correspond to "in" or "out" behaviour -- for example, a small depositor who becomes concerned about the solvency of a bank will probably decide to simply switch banks or withdraw all his or her funds rather than to gradually reduce the proportion of deposits in that bank; similarly, a portfolio investor may move from a particular economy weighting of, say, 1% or 2%, to zero as risk is perceived to increase past an acceptable level. This, coupled with positive feedback loops and herd behaviour, can explain a sharp shift in investment behaviour. It would not however explain the language that describes market behaviour -- the exuberant optimism of bull markets and the dismal lows of crashes and bear markets.

11. Speed and turbulence

Non-Linear Systems: A common association drawn in descriptions of the crisis is that between speed of growth and the onset of turbulence. There are physical models where speed leads to turbulence. For example, the flow of water through a pipe at some speeds will be "laminar" or smooth; past a certain speed, it becomes turbulent. The design of airplane wings involves determining a shape such that the flow of air over the wing will be laminar, with turbulence only breakout out behind the wing. The phase change from laminar to turbulent flow is an example of a complex phenomenon.

The Asian Crisis: A number of analyses of the Asian crisis have argued that the speed of growth during the decade leading up to the crisis in some sense contributed to it. For example, some have argued that the rapid growth masked the build-up of "structural flaws" and/or resulted in the flow of investment funds into the region outpacing the capacity for wise investment.[53] Another conclusion being drawn is that the liberalization of capital accounts moved faster than the development of domestic supervisory capacity – a linkage between speed of change in components of a system, that has led to substantial work on the issue of appropriate sequencing of liberalization. However, as the discussion of the crisis shifts from Asia to the global system, one is struck by the common description of the 1990s as a period of rapid change, led by globalization and the information revolution. One might pose the question of whether it is a question of sequencing in particular economies or a more general phenomenon of speed of change resulting in a breakout of turbulence, perhaps reflecting a phase change from economic growth exhibiting "laminar" qualities, which we would interpret in an economic setting as representing "stable" growth, to a turbulent phase such as we have witnessed since mid-1997.

There are, of course, no speed limits on a neoclassical economic highway – the theory says nothing about sustainability of any particular absolute rates of growth. Non-sustainability of particular tempos of growth can only be determined by the onset of problems such as acceleration of inflation that in retrospect inform the policymaker that the speed of expansion was excessive. Indeed, the physical model adopted by economics – the mechanical equilibrium system – yields no parallels.

12. Non-equilibrium systems

Non-Linear Systems: In contrast to an equilibrium system, which reverts to a state of rest following a disturbance, a non-equilibrium dynamic system must be driven by a source of

[53] The analysis of the crisis by the IMF and the World Bank rests to an important extent on this argument. The World Bank points to the acceleration of growth in private capital inflows to the East Asian region in the 1990s to nearly 30 percent per annum (from US$ 42 billion in 1990 to US$ 256 billion in 1997), with the most mobile forms of flows, commercial bank debt and portfolio investments, setting the pace. This growth was propelled by an aggressive search for ever higher returns to capital by financial institutions trapped in slow growing but highly competitive home markets. This analysis has led for a search for culprits – overly optimistic foreign investors, imprudent borrowers, lax regulators, governments encouraging moral hazard by providing implicit guarantees to friends of political figures and so forth. The search for culprits however distracts from addressing the question of whether the turbulence is inherent in the system.

energy. Simple examples include a rolling wheel, which falls if not driven by some mechanical means, or a hot air balloon, which collapses if the source of heat is removed. More complex examples include the weather systems in the atmosphere, which are driven by the heat of the sun.

The Asian Crisis: In the preceding point, the question was addressed of whether it was speed of change or growth that led to turbulence as is often assumed. One might also consider the opposite question of whether it was the inability of the system to maintain stability as it slowed down that led to its difficulties. One can observe that Asia was doing fine as long as growth was rapid – indeed, the traditional signs of excessively rapid growth such as inflation were not to be seen. It was during the phase of slowdown that the problems emerged. It might accordingly be the case that the design of Asian economies did not permit them to slow down – for example, economies characterized by high savings/investment ratio might become unstable below a certain pace of growth. Similarly, economic systems characterized by too small a government sector might lack the stabilizing presence of a large source of economic spending energy.[54]

An alternative way to view events is to note the dependence of the Asian economies on a source of outside energy – in this case the inflow of foreign capital. When this inflow reversed, economic activity collapsed. This is readily understandable in the framework of non-equilibrium dissipative systems but quite foreign to a mechanical equilibrium system. Here again one is led to the conclusion that the nature of the traditional economic model stands in the way of understanding of what happened in Asia.

4. Some Tentative Conclusions

Some of the conclusions to be drawn from the recognition that the global economy has important elements of non-linear dynamic systems are as follows.

1. The importance of flexibility and institutions

To the extent that economic and social systems have important aspects of non-linear dynamic models, with positive and negative feedback, spontaneous organization and dissipative structures, the central message is that long-run planning or forecasting is pointless. Since outcomes emerge from spontaneous organization, the emphasis of policy should be on "structures and processes that promote maximum flexibility".[55] This

[54] The "bicycle theory" is often used to support the need for sustained liberalization of trade in order to prevent backsliding; in this model, a standstill is not possible, which is an implicit acknowledgment of its non-equilibrium nature. This is essentially the same metaphor as is derived here.

[55] Casti, op cit., pp. 40. The importance of economic analysis in institutional design is well made in the following comment from David Colander: "[Complexity] tells us that the institutions are needed to provide a stability, and it does little good to analyze systems without explicitly modeling their detailed institutions. It brings back the need for researchers to have a feel for the market, and how to design institutions to keep the system in what Axel Leijonhufvud calls the corridor. Once the system falls outside the corridor, most standard rules break down, and a new model is needed. So researchers need more than one model....[W]here [economists'] policy input is strongest is on institutional design--being on the crest of the new wave and providing judgment on how alternative institutional designs can make

certainly corresponds well with the general consensus within the economic policy community on the need for flexible markets, institutions and so forth. [56]

2. The doubtful role of improved financial disclosure

The emphasis on improving information and transparency as a palliative response may have unknowable consequences. To the extent that economies behave as dissipative systems, additional information would be imported into the system and dissipated through it, changing structures. It is assumed that this would be for the better (i.e., better information to supervisors would enable them to nip problems in the bud; better information to investors would channel investments into safer and more profitable investments, and so forth). However, there are no guarantees of that in dynamic dissipative systems.

To some extent, this seems to reflect the actual experience of financial supervisors in dealing with problem financial institutions. All information about financial institutions is partial. This includes the information available to the executives of the financial institution themselves, the individual account managers within the financial institution, the financial supervisory office, inside and outside auditors, and the markets (meaning both sophisticated analysts and credit rating agencies and unsophisticated depositors and small investors). Moreover, the interpretation of this information is partly subjective and partly a function of views about the future of economic growth, inflation, interest rates, asset prices and exchange rates, all of which are speculative. Moreover, markets anticipate information (i.e., act on rumour as attested to by the market adage "buy on rumour, sell on news") and adjust for the inadequacy of information (e.g., the market speculates on the "real" percentage of non-performing loans on the books of banking systems in economies with inadequate financial information, with typical press reports go something like the following: "In Country *A* non-performing loans were reported at 2% of total; however, market analysts suggest that, under USA norms, the figure is more likely to be 6%").

Furthermore, authorities need to take into account market reactions to news since information about a financial institution can change its circumstances dramatically -- for example, a bad financial report can lower its stock price with consequent impacts on its ability and willingness to raise capital; and also can force it pay higher rates to attract funds. All of which can tip it from solvent but somewhat risky to insolvency. This very fact is one important reason why publicly known risk-adjusted deposit insurance premiums have yet to be widely introduced -- not only is it difficult to actually measure the riskiness of a particular institution but the publication of the information changes the risk. If the report triggers a run on the institution, it can in fact kill it and spark runs on

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major differences in the path chosen, and hence in the ultimate outcome." Correspondence from David Colander, Department of Economics, Middlebury College, Middlebury, Vermont.

[56] At the same time, this leads to a somewhat more troubling conclusion: "While free markets are clearly creative, self-organizing systems, ..there is nothing about the nature or operation of self-organizing systems which either maximizes or optimizes outcomes. The forces of selection (competition) weed out all systems that are not flexible. There can be no *guarantee,* therefore, that competition and free markets will 'optimize' anything other than flexibility itself." Casti, op cit.,, pp. 40.

"similar" institutions (and since similarity is in the eye of the investor, this means it will in fact vary from case to case, as the history of financial crises has in fact showed).[57]

While this should not preclude moving forward in improving financial disclosure and supervision, it does suggest that caution is needed at every step, since improved information is, in non-linear dynamic systems with positive feedback loops, a two-edged sword.

3. The importance of strong negative feedback

If crises are driven by positive feedback loops, it would appear reasonable to presume that the stronger and earlier the negative feedback, the less the impact on the system. This seems to coincide with the view of those who observe that, given the psychology of markets, early and pre-emptive massive "overkill" is required to stem a crisis.

4. Sensitivity to Initial Conditions

Non-linear dynamic behaviour requires a careful attention to initial conditions which linear models do not. This complicates enormously the challenge for institutions involved in responding to crises since what works in one economy cannot be presumed to work in the same or even remotely similar way in others.

5. A crisis of the model

If one accepts the proposition that a conventional wisdom has emerged in economics – i.e., that there is now a generally accepted "core" macroeconomic model grounded in neoclassical economic theory – then the Asian crisis clearly poses a challenge to it. This challenge comes from two distinct directions: first from its failure to predict; and secondly, from the fact that it has so little to say, even in retrospect, about the apparent causes of the crisis or the nature of the solutions. In point of fact, the macroeconomic event of the decade is generally seen and discussed as reflecting idiosyncrasies of a business culture, as a crisis of confidence, as a failure of institutional controls or as some combination of the above – factors that do not even appear as arguments in generally accepted "core" macroeconomic theory.

[57] Hans Genberg, Director of the International Centre for Monetary and Banking Studies in Geneva was quoted as follows on the impact of greater disclosure: "The risk is that an indicator, once supported by surveillance institutions like the IMF, will be elevated to a semi-official status and be taken too seriously. This would create the danger that a signal might become a self-fulfilling prophecy as financial markets react to it as it were the unavoidable truth". Reuters, Geneva, April 30, 1998.

THE EAST ASIAN ECONOMIC AND FINANCIAL CRISIS: LESSONS FROM COMPLEXITY THEORY

Dr Mark McKergow*

1. Introduction

What do a freeway traffic jam, stock market fluctuations, a tractor accident and the layout of characters on a typewriter keyboard have in common? Answer: they are all examples of, or results from, "complex systems".

Complexity theory has been one of the most interesting scientific developments of the 1990s. Taking insights and inputs from mathematics, biology, computing, economics and evolution amongst others, scientists have begun to grapple with the structures and development of complex systems. Applications are being sought in the fields of economics (Ormerod, 1994) and management (McKergow, 1996). In this note, I will describe briefly the characteristics of a complex system in the sense that scientists understand them, and use four particular aspects of complexity to hold up a light to the ongoing economic and financial crisis in a number of East Asian economies. This light will not reveal answers, but can help us to arrive at some good questions. These "Lessons from complexity theory" may be summarized as:

1. Searching for "The Cause" of the crisis is futile. Think instead about the way ahead.

2. Don't ask whose fault it was. Ask instead about the influences to be brought to bear on the future.

3. Don't ask, "What's going to happen?" Ask, "How would we recognise a useful way ahead?"

4. Don't seek a grand plan for recovery. Seek small steps combined with positive feedback to grow the recovery.

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2. Complexity Theory

There are a number of meanings to the word "complexity", and it will be as well to be clear about how we are using it here. We do not mean simply "complicatedness". A system or artifact can be complicated or intricate without have any "complexity" attributes. Peter Senge, in his book The Fifth Discipline, makes the point well in drawing the distinction between "detail complexity" (for instance, highly intricate machines or management systems) and "dynamic complexity" (where inter-relationships between elements in a system are based on feedback loops, and are many and varied).

In this context, the complexity we refer to is similar to Senge's dynamic complexity. There are some attributes that are associated with complex systems. Such systems are self-referential (i.e., their elements interact in a systemic fashion) and contain elements of both positive and negative feedback. They are non-linear, so that a small change can lead to much larger effects in other parts of the system and at other times. Systems that display these traits have some interesting properties:

- They are non-deterministic. Wholly accurate predictions of future states cannot be made, *however well the current and past states are known*.

- They show emergent properties – patterns which result from the overall action of all the elements of the system, are not obvious even if the system interactions are precisely known, and may be rich and unexpected.

Perhaps surprisingly, complex systems can be made up of many relatively simple parts. An example might be ants in a nest, molecules of air, birds in a flock, people in an organization, or elements in a computer program. It has been shown, however, that even if *all* the details of the individual parts are known (as has been demonstrated using certain types of computer program), the overall system can still be Complex and non-deterministic, and can produce effects which are real and observable, but cannot be determined by examining a single element out of context.

There is not space to review complexity science further here. Further reading for the interested layperson can be found in Waldrop (1994) and Casti (1994).

The economic and financial crisis that has hit East Asia certainly fulfills the criteria above as the result of a "complex system". So what can the study of complexity do to help us to understand the situation and guide us about future developments? I do not propose to tackle the economics of the situation directly. Rather, I will take four angles for which complexity gives us some pointers:

- "Causes" of the crisis
- Who is in control of the situation?
- Possibility space
- Increasing returns and positive feedback

3. Causes of the East Asian economic crisis

In researching this piece, I have been struck by the number of factors that have been identified by various writers as contributing in one way or another to the crisis. These include, *inter alia*:

- The floating of the Thai baht against the US dollar
- Shifts in the Hong Kong, China stock market
- Investment choices and decision-making in Southeast Asia
- The differences between Asian and Western values
- The prevalence of family and clan-focussed business structuring in the region
- Foreign currency speculators
- Autocratic government
- Market protectionism
- Frictions surrounding Myanmar s entry into ASEAN
- Indonesian borrowing from Japan and South Korea
- State-directed economic development in Malaysia, Korea, Singapore and Chinese Taipei
- Moves away from state-directed economic development
- The halting nature of Japan's recovery from recession in the early 1990s
- Strength of the US economy and currency, coupled with large volume of dollar-denominated loans made to Southeast Asian economies

There is also disagreement as to the extent to which the difficulties faced by the economies involved are the same. Is this one crisis, or several? Will the resolution to the crisis be the same for all concerned?

The list goes on.....but how sensible is it to construct such a list? Complexity theory has shown us how sets of dynamic interlinks and feedbacks combine to produce an unpredictable and developing outcome. But to what extent can the crisis be laid at the door of any one of these? It can't.

In the UK, there is a popular radio serial called "The Archers", about a rural community in the English Midlands. John Archer, a bright 24 year-old, has just been killed in an accident where his tractor overturned and crushed him. His distraught parents are currently trying, in a mood that will be familiar to many of us, to work out "Why?" If only the tractor's wheel alignment hadn't been faulty.....If only his father hadn't shouted at him that fateful morning.... If only he hadn't been turned down by his girlfriend the day before.....If only he hadn't been working too hard….. If only his mother had gone to look for him earlier.....This list could go on as well.

Which is the "actual" cause of the accident? In complexity terms – none of them *and* all of them. In such cases, cause and effect become intertwined, in ways that may be hard to unravel. And, even if we could unravel them, the outcome would still not be predictable. In complex systems, like their close relations from chaos theory, outcomes are highly sensitive to even infinitesimally small changes in the system parameters. So, it makes no sense to ask, other than for fun in the bar afterwards, "What was the cause

of the accident?" We must beware the over-application of formal logic – if applied to the wrong question, it can lead us into tight and unwelcome corners (Kosko, 1994).

Turning to the Asian crisis, the above suggests that, rather than seeking to identify the cause, better questions to ask might be:

- *What actually happened?*
- *What contributed to the situation?*
- *What combination of events preceded the crisis?*

This may shed light on the ways in which events combined to produce the crisis, and would provide historians with some data to perhaps identify similar patterns in the future. This might help to prevent a future crisis. But it may not help resolve this one. In my work with the UK nuclear energy industry, we have been known to say that the circumstances leading up to an incident may help prevent the next one - but it sure doesn't help clean up this one!

Who is in control of the situation?

This question is sometimes phrased in terms of "Whose fault is it?" For similar reasons to those outlined above, the complexity answer is – nobody *and* everybody.

In a complex system, we observe how rich and varied patterns of behaviour can arise from the interactions of many "agents", each with a relatively simple behaviour. Yet the net effect may be contrary to the wishes of the agents. An example is the phenomenon of "phantom traffic jams" on freeways. When the road is busy, a small action (for example, one car braking sharply to avoid another) can result in other drivers having to brake briefly. These drivers then go on their way – but back down the motorway more and more drivers are braking, by greater and greater degrees, to avoid those in front, until the freeway is at a standstill. Each driver approaching the scene sees a jam, which progresses slowly for a distance and then frees up. From a higher vantage point, for example a police helicopter, we can see a standing wave of traffic passing up the freeway, as cars join the back, work their way to the front, and then go on.

Who is in control of such a phenomenon? No one. It is the result of the interactions. Everyone has an influence - maybe small, but an influence, and can potentially act to change the situation. There is a principle in cybernetics – a forefather of complexity theory – called Ashby's Law. It states that the part of the system with the most influence is the part that has the highest number of potential states – i.e., the most flexibility. The degree of influence of the players is, of course, not necessarily the same. And some players may deploy their influence by NOT acting, when it is known they have the potential to act. So complexity guides us away from question of control and blame, towards questions like:

- *Who are the players?*
- *What influence do they have?*
- *What influence <u>could</u> they have, if they chose to?*

One of the interesting properties of cybernetically-interlinked complex systems is that, in principle, any of the players with some kind of influence may have a critical effect on the whole. This potential impact is most definitely not in proportion to the size of the initial influence. Just as in the infamous "butterfly effect", small beginnings can lead to significant ends.

Possibility Space

One of the ideas from the mathematical side of complexity theory is that we can imagine a "space" - a many-dimensioned array - where ALL the possible future states of the system are arranged, rather like a library of possibilities. One way to imagine this is as a library of books. In his short story "The Labyrinth", Jose Luis Borges postulates the existence of a library containing *all* the books which could ever be written in Roman script. This would be a truly gargantuan place. The vast majority of the books, of course, would be completely meaningless in any language. In one volume, 300 pages of the letters "pdfe" would be repeated. It contains the book that described YOUR life! It also contains the book that describes your life up to this point, and then turns into a complete fiction. This library is enormous.

One of the findings of complexity theory is that, huge though such spaces must be, it can be profitable to search through them, using criteria to quickly sort out useful possibilities from the useless. In order to do this, some kind of boundary is defined, to set out the possibility space, so that the search algorithms can go to work. A similar process might be applied to our consideration of East Asia. Rather than simply trying to define the most likely outcomes, we might ask:

- *What is the range of possible outcomes?*
- *What are the bounding cases - the most unlikely scenarios we can think of?*
- *What characteristics could we use to begin to identify useful routes through these possibilities?*
- *How would we know the difference between a strong recovery and an unsustainable lurch forward?*

By concentrating on establishing what would be a "useful" scenario (and also what would not!), we can then start to look around and find elements which are already in place in the world. We can then start to put into place other, missing, elements, and refine the way forward. Otherwise we may end up like the man who rebuilt his house so that the sun wouldn't get in his eyes while he worked - rather than simply adjust his work desk!

Increasing returns and positive feedback

One indicator of complexity is the presence of positive, as well as negative, feedback. Negative feedback serves to return a system to its equilibrium state, and is well understood - indeed classical economics is founded on it. Positive feedback is well understood in scientific terms, as the self-generated escalation of a systemic variable. Controversial economist Brian Arthur (1990, 1995) has examined the role of positive feedback effects in economics. He concludes that such effects are indeed present, and

can lead to situations such as "lock-in", where the benefits of standardization around a particular technology can lead to its persistence even after "better" alternatives are developed. (The best known example is the ubiquitous QWERTY keyboard, designed to slow down the operators of 19th century machines, and now an apparent fixture.)

Complexity leads us to conclude that large changes can be produced by a small initial event combined with positive feedback. This is contrary to the "conventional" thinking that large changes require commensurately large actions -- for example, to kick-start the economy, the Government of Japan has recently announced a massive fiscal stimulus package amounting to 3% of GDP; this is already being criticized by economists and observers. What is the best way to grow an oak tree - to plant a single acorn, around which guards are stationed, with electric fences, spotlights, round-the-clock forestry experts in attendance, waiting to see whether it comes up.....or to plant many acorns, expecting only a few to grow, and then to nurture the ones that actually grow, knowing that one is enough.

Complexity therefore leads us away from designing grand plans for recovery, and instead gets us to ask:

- *What positive feedback mechanisms are available to help advance the situation?*
- *What small actions can be taken to prime these mechanisms?*
- *How many actions, each costing small amounts of money, can we devise?*
- *What has not yet been tried?*

4. Conclusion

We have explored some basic aspects of complexity theory. We have seen how the science world's exploration of complex systems can offer some guidance. This comes in terms of pointing out that some questions are unanswerable, some are unhelpful, and others may provide useful pointers. Complexity theory is a rich source of inspiration, and there are may other angles which the reader may know of, or find, which could be helpful. I chose these four. In considering the way forward, we can summarize the "Lessons from Complexity" by comparing the ways to seek progress in an ordered world, and in a complex one.

"Ordered" world	"Complex" world
The cause and effect of actions can be determined precisely.	Cause and effect are intertwined, and cannot be determined in advance - don t pretend they can.
	Cause and effect are intertwined, and cannot be determined in advance - don't pretend they can.
Certain parties have control	All parties have influence.
There is only one way out - first we must find it.	There are many possible ways out - we should focus on finding their starting points.
Large effects require enormous co-ordinated efforts.	Large effects can come from small starts and positive feedback.
The future can be planned.	The future "emerges" from the combined actions of the players.

This note has not attempted to provide answers. These must come from those who know the territory better then I. Whatever answers we may find, and however the situation develops, one thing is certain. Despite the assumptions in classical science and economics about reversibility, the world is in fact undergoing a continuous and irreversible process. There is no way back. To want to return to a past situation is as unrealistic as wanting to be 5 years old again, wanting to unscramble your breakfast eggs, or wanting the atom bomb never to be invented. We may want these things - and yet we cannot have them. We must go on, to marvel at our own five-year-olds, to have boiled eggs tomorrow, to devise treaties for disarmament. The future, whatever it holds, however wonderful or dreadful it may be, always starts..... now.

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