TECHNOLOGY AND INNOVATION IN DEVELOPING EAST ASIA: AN INTERPRETIVE SURVEY*

Hal Hill
Australian National University/Columbia University
<hal.hill@anu.edu.au>
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(1) INTRODUCTION

Technology and innovation lie at the heart of the process of economic development. They are important obviously because they are central to the process of raising productivity and therefore living standards. One only has to reflect for a moment on the daily life of most East Asians now compared to three or four decades earlier to understand the importance of this proposition.

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Especially in the poorer states of the region, in the early 1960s, motorized transport was not commonly used by the mass of the people, who travelled around cities and towns by bicycle or on foot. Few people had travelled beyond their locality of birth; only the tiniest fraction had ever travelled by air. A small percentage of households, mostly confined to the larger cities, had electricity. The reach of newspapers and modern forms of communication was restricted in the main to metropolitan areas. Most people ate unprocessed food; foreign consumer goods were a rarity. Indeed, there was little contact with foreign capital, technology, and markets. Most people left school before completing their primary education. If they fell ill, it was unlikely that they would have access to modern pharmaceuticals and hospital services. In the poorer countries again, as much as one-eighth of the population did not live to see their first birthday and up to one-quarter did not celebrate their fifteenth birthday. Production technologies were predominantly simple, mostly involving manual labour. In the food sector, the green revolution had yet to sweep through Asia, and chronic malnutrition was widespread. Manufacturing was still a very small share of the economy, and export-oriented industrialization had barely begun.

Practically every aspect of life for the citizens of even the most remote locations of East Asia has been transformed since then: the way they live, and for how long; what and how they eat; what they learn, and for how long; the nature of their work, family, and social interactions; and their mobility, both occupational and spatial. Technology has been at the heart of this major transformation.

This paper examines the processes of technological change and innovation in selected East Asian developing countries. It aims to survey and synthesize a very large literature on a diverse set of countries and institutional contexts. The topic is necessarily broad and complex, and impinges on practically all major facets of economic analysis. The study of technological change and innovation – of how, why and for what purpose – sheds light on broader processes of development. Perhaps more than any major area of public policy, technology and innovation require an understanding of the interaction between long-term economic development, the internationalization of an economy, government intervention, and the microeconomics of firm-level innovation. These constitute the major themes to be studied in this paper.

There are also practical reasons to study the topic. In the more advanced East Asian economies, more than 1% of GDP is being spent on research and development. In Korea the figure is almost 3%. In Singapore it is almost 2%, and the share of a fast-expanding economy has almost doubled in just a decade. Most of these funds are government-supplied, directly or indirectly, and a substantial proportion entails direct government implementation. Poorer countries in the region have aspirations to support funding on such a scale within a decade or so. In toto the effective reach of technology and innovation programs is greater still. Thus, programs of this scale warrant attention.

The issue of technology and innovation may usefully be examined under several broad headings.

- First, what are ’technology’, ’R&D’ and ’technology policy’? How do we define them, and are there suitable empirical proxies for these analytical and conceptual constructs?
- Second, and related to the first issue, is there a case for government intervention in technology markets, and if so, what are the analytical underpinnings of market failure and what sort of intervention might be suggested by this approach? What light does East Asian and other countries’ experiences shed on these questions?
- Third, what has been the approach to technology policy of East Asian governments, both in the realm of philosophical foundations and practical implementation strategies? What institutions, in both the public and private sectors, have been established to sustain these countries’ technological effort?
- Fourth are quantitative indicators of technological development in comparative international perspective.
- Fifth, there are the international dimensions: the mechanisms and magnitudes of technology flows, the special role of multinational corporations (MNCs) in these flows, and the growing globalization (and faster diffusion) of technology flows.
- A sixth issue focuses on the microeconomics of technology development and innovation. This is an important but neglected area of research; many of the really interesting issues are industry or even firm-level in nature, and secondary data often tell us rather little about these micro processes.
- Finally, there is the question of these countries’ broader policy environment, to place technology policies in a political economy context and to evaluate interventions in education, international trade and investment, as well as those with an explicit technology mission.

There is no universally accepted definition of technology and innovation. The most common approaches define technology as 'a collection of physical processes that transform inputs into outputs and knowledge and skills that structure the activities involved in carrying out these transformations' (Kim, 1997, p. 4). More formally, one may regard the production isoquant as embodying the technological options available at a given point of time, based on the existing stock of scientific know-how. Technology progress may then be regarded as a 'better way of doing things' or of 'producing more from less', by employing new technologies and generating new products and processes.

At every point, one encounters blurred definitional boundaries, between ‘technology’, ‘innovation’ and ‘science’ policies. Dodgson (2000, pp. 230-231), for example, defines science policy to be primarily investments in universities and laboratories, whereas technology policy focuses on the development of generic technologies, such as IT and biotechnology. Innovation policy, in this schema, involves new products, processes and services. Kim and Nelson (2000) point out that the distinction between formal innovation and ‘creative imitation’ is often a fine one.

There is a tendency to equate technology and innovation with path-breaking scientific discovery and research at the frontiers of knowledge. In reality, much R&D involves not the 'R' of fundamental research, in the sense of inventing products and processes, but rather the 'D' of acquiring, adapting and modifying frontier technology. Some years ago, it

was estimated that, even in the US, just 8% of R&D expenditure was devoted to 'basic research', far less than was directed toward 'applied research' (25%) or 'development' activities (67%) (Rosenberg, 1994, p. 13). In a developing country context, the proportion devoted to basic or applied research would certainly be lower still. In the 'R&D&D' formulation, 'development' and 'diffusion' are the major activities, and the ones to which public policy needs to be directed.

A key strand in virtually every major study of technology is that the process of acquiring and mastering technical know-how is evolutionary, gradual and long term. Governments can expedite this process in ways discussed below, but there are no simple short cuts. This may seem so obvious as to hardly require emphasis. But since these tenets are at odds with much official thinking and popular discussion in East Asia, and with many ambitious high-tech projects, they deserve restatement. The literature on Japan, for example, emphasizes that it took that country over a century, from the beginning of the Meiji Restoration in 1868 until the mid 1980s, to reach the frontiers of global technology across many fronts (Hayami, 1997).

Moreover, all detailed studies of technological change emphasize that it is a slow, laborious and uncertain process (Lall, 2000). Mistakes frequently occur. Even seemingly simple cases of 'reverse engineering' are in reality complex and time-consuming. Economist's notions of infant industries may involve more protracted periods of endeavour than is commonly supposed. There are instances of spectacular reward. But more commonly there are failures, or at least long delays between inputs and outputs. These two features – uncertainty and long gestation periods – immediately underline the links between innovation and a country's political and institutional structures. That is, potential innovators need a nurturing environment, in which, at the very least, property rights, financial institutions, and the political system are supportive.

In turn, the range of policies that impinge on technology and innovation, broadly defined, go well beyond the narrow confines of official policies in these areas. Indeed, a government's officially enunciated 'technology policy' may well be a relatively unimportant part of a country's broader technological effort. What is one to make, for example, of a country with a major technological effort in an economy essentially closed off from the rest of the world (eg, the former USSR, or pre-reform India and China)? Or of a country which starves the public education system of resources, while investing in grandiose mega technology projects, as in Indonesia during Soeharto's last decade? For these reasons, we need to cast the net widely in thinking about technology and innovation policy, and official pronouncements on the subject may not be all that useful.

Most major East Asian economies grew rapidly before the 1997-98 crisis, but shared little else in common. This applies especially to technology and innovation policy. As Pack (2000) and others have emphasized, countries at very different stages of development face very different challenges. For lower income countries like Indonesia, the principal task of government should be to provide an enabling commercial environment and to supply crucial, growth-enhancing public goods. Thus, macroeconomic stability, public education and health, protection of property rights, openness to the world economy, a

functioning financial sector, and efficient physical infrastructure are all essential ingredients of rapid economic development. Countries will want to have some public scientific and research institutions in certain sectors (especially agriculture), but these are hardly a central feature of government's responsibilities. Getting the phones to work efficiently is arguably more important than elaborate technology projects.

Formal programs aimed at encouraging innovation and technological development become more important as growth proceeds, real wages begin to increase, and the bases of the country's comparative advantage shift out of simple, labour-intensive activities, and into those which are more skill-intensive. This distinction between countries and their levels of development is critical. There is thus a clear analytical dividing line within East Asia between the NIEs and the 'ASEAN 4' countries, for example (with Malaysia perhaps having a foot in either camp).

Nor is there one unique technological and innovation trajectory. Based on history, openness, and investments in education and institutions, countries have opted for differing strategies. At the risk of over-simplification, for example, the countries of Northeast Asia – especially Japan and Korea – have opted for large public investments in education and R&D but less internationally-oriented economies. In Southeast Asia, the economies have historically been more open, albeit with obvious exceptions, while public investments in education and technology have traditionally been more modest.

Our organization is as follows. Section 2 provides an introduction to the analytical and policy framework, including some discussion of the case in principle for government intervention. Section 3 surveys some widely used indicators, and applies them briefly to our sample of countries. Section 4 then gives a series of country profiles, identifying some of the key features and policy challenges. In section 5 we address a range of pertinent policy and analytical issues, providing also some country illustrations. These topics include international technology flows; foreign direct investment (FDI) and technology; industry policy and 'mega projects'; enclaves and electronics; SMEs and innovation; innovation in agriculture; public research institutes and education; and some key data and research questions. Section 6 sums up.

Two caveats should also be noted. First, I am focusing principally on the four Asian NIEs (Hong Kong, (South) Korea, Singapore, and Taiwan), and the 'ASEAN Four' (Indonesia, Malaysia, Philippines, and Thailand). I exclude China simply for lack of knowledge and because it is being covered extensively elsewhere in this project. Since I am more familiar with the Southeast Asian economies, these countries receive greater attention.

Second, I largely eschew discussion of the recent crisis, as it is not particularly germane to the issues of technology and innovation. There are of course connections. Since 1997, East Asian governments have been preoccupied with the crisis and its aftermath, and thus longer-term development issues such as those canvassed in this paper have been largely placed on the back burner. And, focusing on the opposite direction of causality,

technology policies may have been marginal contributors to the crisis.[1] But in both cases the links are rather tenuous, and therefore justify concentrating on the longer term perspectives.

(2) ELEMENTS OF AN ANALYTICAL AND POLICY FRAMEWORK

What factors shape the process of technological change and innovation, and how might governments intervene effectively? The literature on this subject (eg, Nelson, (ed) 1993; Kim and Nelson (eds), 2000) draw attention to the key elements, while also emphasizing that they differ in their relative importance both over time and across countries. Among these elements are the following:

Openness: More than 90% of the world's R&D is undertaken in OECD economies, and thus openness to the world is critical for borrowers and late-comers, such as those in East Asia. There are, of course, myriad transmission mechanisms involved. Technology is embodied in the trade of goods, as various studies of imitation and reverse engineering have demonstrated. FDI is a major, though still controversial, channel of technology flows, as is trade in non-factor services. Labour migration and associated flows of human capital have become increasingly important world-wide, and particularly so in East Asia (see Athukorala and Manning (1999) for a detailed study).

Human capital: This is a critical factor at all levels of development, in creating the ability to absorb, assimilate and diffuse imported technology, and to innovate on the basis of these imports. At early stages of development, mass literacy and universal primary education deserve priority, while upgrading strategies at middle incomes require more attention to higher education, to quality, and to the composition of educational output among disciplines.

Infrastructure and institutions: A diverse set of factors under this umbrella matter more than is sometimes recognized. An efficient business operation able to connect to the global economy requires high quality telecommunications and physical infrastructure. There needs to be a commercial climate which is conducive to long-term planning horizons and investments decisions, since as noted innovation is an inherently risky activity. Property rights and an adequately functioning legal system are also important. Financial institutions, domestic and foreign, need to be present. Macroeconomic stability, underpinned by good quality central banks and finance ministries, is very important. Few

[1] One can think of two different instances here, involving too much or too little attention to the technology issues. In the Korean case, there was arguably too much intervention under the broad umbrella of technology and innovation. To the extent that it involved directives to the finance sector and highly geared borrowings by the chaebols, it thereby rendered the industrial sector vulnerable to the crisis (see for example, Smith, 1998). Conversely, in Thailand, there was probably too little investment in technology and education from the mid 1980s onwards. Thus, with real wages rising rapidly in the 1990s, the country began to encounter major competitiveness problems, only partly eased by its open labour market (see Warr, 2000).

of these factors enter much of the literature on technology and innovation, but they are arguably more important than formal ‘technology policy’ initiatives, especially at low levels of per capita income.

Commercial environment: Competition is crucial to innovation, as a spur to raise productivity. Monopolies invariably prefer a ‘quiet life’, and should therefore be a cause for concern, unless they are ‘Schumpeterian’ in nature, or operate in an open international environment.[2] Whether industrial structure more generally (eg, the level of foreign or state ownership, the size distribution of firms) matters is a more complex question with no clear answers.

R&D institutions: These constitute the formal component of most governments’ technology and innovation policy. The fact that they are listed along with four other key areas of public policy emphasizes the importance of adopting a broad approach to the issue. Important questions here concern the scale of these institutions, their funding, and their interaction with enterprises and the education system. For late-comer countries, of course, their role will focus almost entirely on the modification and diffusion of essentially ‘off-the-shelf’ technologies.

All five elements are important ingredients in the overall schema. Success in two or three may be insufficient, especially if other facets of the policy framework operate in a counter-productive fashion. For example, countries may invest substantially in R&D institutions, but these investments may be nullified by poor macroeconomic management or barriers to international commerce. To focus just on technology policy, narrowly defined, would therefore miss this broader dimension.

What is the rationale for government intervention to develop a country's technological capability? The principal one has to do with the latter's 'public good' characteristics (see, for example, Lall, 2000; Pack and Westphal, 1986). Left to the market, there is likely to be under-investment in activities for which private agents are unable to appropriate adequately the returns from their investments. Such investments tend to enter the public domain quickly, a process facilitated in part by classic 'free-rider' problems. The returns are diluted, especially in developing countries, by a weak legal system that is unable to protect intellectual property rights. High interfirm worker mobility, especially for those whose skills are in short supply, exacerbates the problem, since firms are reluctant to invest in R&D programs if there is a high probability that key staff embodying these investments will quit before returns can be appropriated.

These problems are all the more serious in an economic and political environment characterized by great uncertainty. In the best of environments, investments in R&D are highly uncertain and generally slow yielding. Where private agents heavily discount future earnings, whether owing to high real interest rates, lack of credible macroeconomic

[2] At least for the industrial sector, almost all of which produces tradable goods, the most effective instrument of competition policy is an open trade regime. Especially where bureaucracies are weak, competition commissions and the like often simply add another layer of bureaucracy (and corruption) which firms have to endure.

management or political uncertainty, the incentives to invest will be weaker still. Thus, while reported rates of return on industrial R&D in the few studies to investigate the subject in developing countries (some of which are summarized in Evenson and Westphal, 1995) are high, these factors probably explain the limited scale of investment. The inability of firms to appropriate fully the returns on these investments results in social rates exceeding the private rates, and hence provides a justification for government intervention.

Other forms of market failure provide a further rationale for government intervention (see, for example, Stiglitz, 1996). Where markets are underdeveloped – incomplete or missing – price signals do not function adequately. This may arise because of poor information flows, limited entrepreneurial capacity, inadequate property rights or physical infrastructure bottlenecks. Institutions (such as producer cooperatives or industry associations) that foster the cooperative behaviour sometimes needed to achieve improved outcomes may not exist. Coordination functions, especially in dealing with international markets, may be poorly developed. The cooperative and coordination functions do not necessarily need to be supplied by government, but public policy can hasten their efficient evolution.

The new growth theories, with their emphasis on the determinants of long-term growth rates, have revived interest in technological change and technology policy. 'The suspicion that [growth differentials among countries] may have something to do with technology has been around for a long time', as Fagerberg (1994, p. 1,147) observes. The new theories have shifted attention away from the approach of the earlier neoclassical modelling. However, they have yet to develop powerful policy relevance. But empirical refinement is pushing in this direction, examining, for example, the growth-stimulating effects of investments in R&D and schooling, and attempting to measure the R&D spillovers from international trade and investment.

The literature in this field offers some, though limited, guidance on intervention strategies (see for example Lipsey, 1997): industry support should be in the form of subsidies rather than tariffs; externalities should be targeted as directly as possible; and governments ought to be involved most extensively in the 'pre-competitive research' phase. However, in spite of all the work in this field, there are still major areas of ignorance, especially in terms of explicit policy-oriented advice. If tertiary and vocational education is to be subsidized, what should the rate of the subsidy be, and should it vary across courses? Why does innovation occur more rapidly in some industries than others? How long, typically, is the 'infant industry' phase in various industries? How exactly can bureaucrats be induced to behave in a market-friendly, competitive manner?

The environment in which government intervention occurs may also influence the magnitude of the potential benefits. Here the distinction between 'forward-looking' and 'backward-looking' protection – that is, between protection that attempts to anticipate (and promote) new winners versus protection that simply props up declining industries – is relevant. In much of high-growth East Asia, import protection has more commonly been of the former variety, with the prospect – not always realized – of eventual liberalization. As

Lipsey (1997, pp. 105-106) observed (pre-crisis, it should be noted), although economists are in general skeptical of the efficacy of selective industrial policies, such a strategy may have more chance of success in East Asia, where '... governments are mainly concerned with encouraging growth rather than brokering conflicting special and regional interests as in the USA and Canada. Also, the export orientation gives the policies a cut-off point that substitutes for the bottom line in the private sector and prevents failed initiatives from persisting indefinitely ...'.

(3) QUANTITATIVE INDICATORS

We present here an illustrative set of indicators of factors which, consistent with the analytical framework adumbrated above, provide an approximate indication of technological and innovation capabilities for the countries in our survey. The data are provided for the four Asian NIEs, the ASEAN Four and, for comparative perspectives, three additional (and diverse) Western Pacific economies, Australia, China and Japan.

There is no widely used summary measure of technological competence analogous to, for example, GDP as a single measure of a country's level of economic activity. All technology indicators have serious conceptual and empirical limitations, which explains why a basket of such measures is typically employed in making comparisons over time and across countries, and also why many of the really important insights have originated from case study material. The usual approaches include both 'input' and 'output' measures. The former focus on resources devoted to the development of technological capacity, such as expenditure on R&D and investment in human capital. The latter concentrate on outcomes of this capacity, and include such indicators as patents and the proportion of output or exports originating from 'technology-intensive' activities.

Many of these indicators are empirically slippery, however. For every variable presented here, two or more alternatives could feasibly be employed. Many others could be added, to capture elements which are germane to the process of technological change and innovation. Different countries measure some of these variables differently. Some are obviously highly subjective.[3] It would be possible to write the paper focusing entirely on these measurement issues. But the purpose here is simply to provide a rough sketch, a snapshot, for each country. Extensive refinement of the measures would arguably not fundamentally change the basic picture.

Tables 1 to 4 present indicators grouped under four major headings: R&D, openness, human capital, and institutions and infrastructure. We consider each in turn.

With respect to R&D indicators, as would be expected the data show the Asian NIEs to be well ahead of the ASEAN Four. Their formal R&D effort is generally at median OECD levels or more, with Korea among the highest in the world, and comparable to Japan. Taiwan (and now Singapore) invests proportionately more in R&D than Australia, and

[3] There is much discussion of these indicators and their meaning in the literature. The work of Sanjaya Lall (eg, Lall, 1998, 2000) is particularly important in this respect.

several other middle-income OECD economies. By contrast, the ASEAN Four countries invest very little in R&D, although Malaysia is now beginning to.

China invests an unusually large percentage for a country with its per capita income; this combined with its size results in pockets of advanced industrial competence. The major outlier in this table is Hong Kong, which is perhaps the world's prime example of a rich technology-borrower economy, in which strategic location and the provision of extremely high-quality governance and service activities are its main competitive advantages.

Patent activity is more vigorous in the NIEs than the ASEAN Four, and these economies rate more highly according to a broad estimate of technology capabilities. Within the NIEs, according to this latter index, Korea's superiority disappears (and it falls below even Malaysia), raising the question of whether it is investing its R&D effort productively. We return to this issue in the next section. The composition of exports also presents an ambiguous picture, and one to which we likewise return later in this section.

One needs to disaggregate these data further to obtain a more complete picture: how much R&D is government-funded, and implemented; whether MNC subsidiaries are involved in the local R&D effort, and if so how; and what are the linkages between the formal R&D effort and educational institutions on the one hand and enterprises on the other. But as a first cut, these numbers do provide a useful indication of technological effort and capabilities.

According to the various indicators of openness, the distinction between the NIEs and the ASEAN Four becomes blurred. Singapore most of all, together with Malaysia and Hong Kong, stand out as the economies most open to trade and investment. This partly reflects their size – small economies by definition trade more than do larger ones – but it also indicates open FDI regimes, and in the case of the city states very low formal trade barriers. The latter are revealed in the practically non-existent tariff levels, and low import barriers in general.

Among the other economies, trade barriers are generally low, certainly in comparative developing country context. Barriers are somewhat higher in the ASEAN Four group (and appreciably so in China), though the difference between them and the other two NIEs is not great. Historically, of course, the patterns varied much more, with Korea, Indonesia and the Philippines displaying high levels of protection. The data are at best approximate, of course. One crucial distinction, not captured in these data, is the trade regime as it pertains to the export sector, and that for the rest of the economy. Almost all economies in the sample have placed exporters on something close to a free trade footing.

The major difference occurs with respect to foreign investment regimes. The ASEAN Four mostly and the city-states always have been more open to FDI than Korea and Japan, and this is reflected in the cumulative FDI data. (In this respect, China since the 1980s is arguably closer to the ASEAN countries.) These data have to be treated with caution: they reflect past investment decisions and regimes (Korea is now much more open to FDI); some countries are large FDI recipients in part because of the structure of their

economies (eg, Indonesia with its large 'FDI-intensive' natural resource sector); and low levels of FDI may indicate both restrictive regimes or unattractive investment climates (eg, the major factor in the low figure for the Philippines). But the general proposition does remain valid. That is, in general, the ASEAN countries and the city-states have mostly been more open to FDI than Korea (and Japan), with important implications for technological capabilities.

There are of course many other mechanisms for the international diffusion of technology, for some of which reasonably accurate quantitative indicators are available. The movement of skilled labour is perhaps the most important. Non-FDI licensing arrangements are another major source. Imports of capital equipment are widely used (Evenson and Westphal, 1995), particularly in countries like Korea with a well-established capacity for reverse engineering. The broader dimensions of international technology alliances are also documented in various data bases, although quantification is limited (see Duysters and Hagedoorn, 2000).

Human capital indicators present a mixed picture. Most East Asian economies score well on basic education achievements, certainly in comparative developing country context. The Asian NIEs are already at OECD levels, with Korea the standout. Malaysia and the Philippines also compare well among the ASEAN Four. Very high levels of secondary enrolments are evident among the NIEs, and the Philippines (Booth, 1999). At tertiary levels, the NIEs also generally stand out, although the picture is clouded somewhat by very large numbers of international students. In Malaysia and Singapore, for example, about one-third of the tertiary enrolments are abroad, and thus the national figures reported here greatly understate the true educational effort. (In Australia, for the opposite reason, the educational effort is over-stated.) These quantitative indicators reveal little about quality, of course. International quality comparisons are notoriously difficult, but the rankings (in international maths and science examinations) do confirm general impressions that quality is much higher among the NIEs. Within the NIEs, Korea and Hong Kong appear to be under-performing in this respect, while the impressive quantitative indicators for the Philippines mask generally very low academic standards.

The employment of scientific resources in R&D reflects both the supply of such labour and opportunities for employment in this field. Here the NIEs appear to be well ahead, though below the more advanced OECD economies in the region. Within the ASEAN Four and China, the resources available are much smaller, although in terms of absolute scale China (and to a lesser extent Indonesia) do have large numbers employed.

Finally, a range of institutional and infrastructure indicators are presented in Table 4. This is a very large topic, and the few variables presented here can provide only a very partial picture. In general, the NIEs perform quite well, and are ahead of the ASEAN Four, although Malaysia in some respects belongs more to the former than the latter. Thus, for example, the three former British colonies, the city-states and Malaysia, score the best on property rights and legal institutions (though in Malaysia their quality has been undermined in the last two decades). Indonesia and China rank poorly, though by no

means the worst in the sample. The physical infrastructure of the NIEs and Malaysia is generally very good, with Singapore topping the ranking exercise.

One indicator of financial depth (stock market capitalization) shows the city-states and Malaysia to be the most advanced. This is of course a very partial indicator, since one needs to know more about other financial institutions, particularly the banking sector, and the venture capital industry funding available for innovations. Moreover, as the recent crisis revealed, stock market capitalization can also be an indicator of financial vulnerability (as it was in Malaysia).

With regard to IT capacity, the city-states again emerge as the strongest, well ahead of Korea, which in turn is much advanced on the ASEAN Four.

To repeat, these indicators are partial and crude, but together they do provide something of a picture about economies' strengths and weaknesses in technology and innovation. We return to these indicators in the following section, which provides a series of country profiles.

Before concluding the discussion of quantitative indicators, it will be useful to mention some widely used data which, in our view, are at best of little value and at worst can be quite misleading. Two indicators in particular are singled out: export composition and total factor productivity growth (TFPG).

Starting in particular with the pioneering work of Lary (1968) there has been a long tradition of decomposing developing country exports according to some form of factor intensity classification, as a basis for measuring changing (revealed) comparative advantage. However, with the rapidly expanding 'slicing' of international production activities, these indicators have become practically irrelevant. This is particularly so in East Asia, where the electronics industry now dominates the merchandise exports of several economies, accounting for over 60% of the total in several cases. Perhaps more than any other major industry, electronics encompasses the full gamut of factor intensities, ranging from the highly R&D intensive (ie, the development and production of advanced components) to the technologically simple, very labour-intensive packaging and assembly operations in the export processing zones of low-wage economies. Unless a very detailed disaggregation of statistics is available at below the 5-digit SITC level (which is difficult to obtain on a comparable international basis, and frequently not available for developing economies), lumping together such a diverse set of factor intensities in one industry will generate quite misleading indicators.

This is in fact apparent in Table 1 above. The country which exhibits the highest proportion of 'hi-tech exports' is the Philippines, which has one of the weakest technological capacities in East Asia. The figure merely reflects the very high share of (low value added) electronics goods, originating almost entirely from export processing zones, in the country's exports. Its hi-tech share is a multiple of that of the three OECD countries in the sample (Japan, Korea and Australia), all of which possess a much stronger technology base. The very high share for the other countries in the region with a

major concentration on electronics – Singapore and Malaysia – also have to be treated with caution. As electronics becomes ever more important in country's exports (at least measured in gross terms, and as a proportion of merchandise exports), the indicator has now for all intents and purposes become a measure of the reliance on electronics exports. Clearly other indicators have to be employed to measure the technology content of a country's exports.[4]

A second concern relates to the use of TFPG as an indicator of technological progress. The computation of TFP of course has its uses, as a measure of aggregate productivity growth. Its limitations are also well known. It moves closely with the business cycle, reflecting the way it is computed. As a residual concept, it is also in part a 'measure of ignorance'. As the component inputs, and particularly their quality, are measured more accurately, the residual, and hence recorded TFPG, becomes smaller.

The Krugman-inspired 'perspiration versus inspiration' debate about TFP has revealed very little about trends in technological capabilities in East Asia. In general, TFPG and economic growth have been positively correlated across the region (see Chen (1997) for a comprehensive literature survey). But the TFP numbers mask the microeconomics of technical progress, for example the mastery of products and processes which in many cases did not exist in these countries a decade or more ago.[5]

Nelson and Kim (2000) introduce a useful distinction between what they term the 'accumulation' theories of growth (essentially growth accounting) and the 'assimilationist' theories, which draw attention to mastering new technologies, to risk-taking entrepreneurship, learning and innovation. They further assert that these 'assimilationist theorists' regard as '… very misleading the proposition that the remarkable expansion of capabilities in these [East Asian] economies came about more or less automatically as a result of these nations' high rates of investment in physical and human capital.' (p. 3).

For example, the proposition that there was little technological progress or innovation at the enterprise level in Singapore during the 1960s and 1970s because measured TFPG was close to zero (or even slightly negative according to some estimates)[6] contradicts all available evidence pointing to the rapid introduction of (MNC-dominated) export-oriented industrialization, into an economy which had hitherto been predominantly an entrepot port and the provider of high value services to the Southeast Asian region. It may well have been that measured TFPG was very low – Singapore is the world's highest saver – but this connotes little about enterprise-level technological progress. Thus TFP analysis has its uses, but it is not particularly relevant to understanding why and how technological capabilities develop and innovation occurs.

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[4] It is surprising how frequently and loosely this misleading indicator is still used. The more knowledgeable analysts of export composition data (eg, Lall, 2000a) are of course careful to point out their limitations.

[5] See Nelson and Pack (1999) for a detailed discussion of this issue.

[6] For what the numbers are worth, the estimates suggest that TFPG was significantly positive during the 1980s, coinciding with the shift towards higher value activities. See Rao and Lee (1996).

(4) COUNTRY PROFILES: EAST ASIAN EXPERIENCE AND ISSUES

We present in this section several country profiles, complementing the statistical indicators of the previous section, and as a prelude to the discussion of a range of topical issues in the following section. Particular emphasis is accorded to Indonesia, Korea, Malaysia, Singapore and Taiwan, a sample which in large measure captures the diversity of East Asian development levels and policy experiences. They are also among the better documented cases in the region. Much of what is said about Indonesia is also relevant to the Philippines and Thailand, although there are also significant differences among these three.

Korea

Korea attracts attention for several reasons: its extraordinary pre-crisis development achievements; its serious economic crisis in 1997-98 (the worst among the Asian NIEs); its controversial and highly interventionist industrial policy regime; and its major commitment to R&D and education at comparatively modest per capita income levels. Its record is also by far the best documented in developing East Asia.[7] Its recent membership of the OECD now provides the basis for comprehensive comparisons among rich economies.

Thanks to the major work of Kim (1997), we have a good understanding of Korea's technology development strategies and achievements, especially from the 1960s to the late 1980s. In narrow technological terms, its accomplishments were remarkable: expenditure on R&D as a percentage of GDP rose from 0.3% in 1971 to 2.8% at the time of the crisis. Most other input and output technology indicators also display a steep upward trajectory.

Kim emphasizes several key ingredients in the Korean experience. These include export orientation, as a means of ensuring that assisted firms have to quickly meet some sort of market test; a strong commitment to education; and reasonably sound macroeconomic management.

A central element was the strategy of promoting the chaebol. Much of the national R&D effort was concentrated within these (eg, Samsung, Hyundai, LG), rather than government-funded institutes, and their links to universities and SMEs have been weak. Even before the crisis it was obvious that these chaebol were both an 'asset and burden', in Kim's words (p. 196). While effective in pooling resources and marshalling inputs, there were large costs in terms of political corruption and neglect of SMEs. The restrictive FDI regime denied Korean firms access to international know-how. Such a strategy would be even more costly in countries which have not invested so heavily in scientific education. In

[7] See for example Dahlman and Andersson (2000), Kim (1997, 2000), Lee (2000), and references cited therein, together with much comparative material (especially Mathews and Cho, 2000), some of which is referred to below.

any case, it is not obvious that, in the current international commercial policy environment, such a restrictive regime would even be possible in the late-comer industrializers.

More generally, as Kim emphasizes, Korea's political and historical development was unique. The harsh Japanese colonial rule, the Korean civil war and the ever-present threat from the North bequeathed a regime with an unparalleled development commitment, an intrusive, authoritarian political system and a government bureaucracy that actively cajoled firms and individuals to meet highly ambitious targets. It is doubtful whether these elements are replicable.

Moreover, the crisis highlighted significant weaknesses in the Korean system, some of which are highlighted by Dahlman and Andersson (2000). It appears that Korea is not obtaining the full benefits from its very large investments in R&D and education because of weaknesses in the incentives regime and its institutions. These include inadequate conditions for the generation and exploitation of knowledge and information (eg, the protection of intellectual property rights). There is also insufficient competition, flexibility and diversity (eg, among the chaebol, and in the finance and education sectors). Moreover, there is a misallocation of investments, including duplication in public R&D investments, and probable over-investment in public education of limited quality. Finally, a consistent theme in the literature on Korea is the need to become more international, in the education system, in its R&D institutions, and in global commercial networks.

The Korean model suggests that successive governments were remarkably successful in lifting the country from very low levels of income to middle-income status, but that the government's role now needs to be redefined. That is, the policy framework was highly effective at 'catch-up', but less useful as the country approaches the technological frontiers. Much of the R&D was undertaken with the major chaebol, but linkages between them and universities, public R&D institutes and SMEs remain weak. Moreover, Korea paid a high price through its self-imposed exclusion from major segments of international markets, through its restrictive policies towards FDI.

The weaknesses of its highly interventionist strategy are indicated by the fact that it was the only Asian NIE to be seriously affected by the Asian economic crisis. As Kim (2000, p.336) observes, in the past decade the government shifted 'from an effective orchestrator to a rigid regulator'. Markets need to be able to function more effectively, and the economy needs to be less government-led and chaebol-dominated. To this end, Dahlman and Andersson (2000) include a long list of recommendations. These include:

- a more modern legal system;
- more competition in product markets;
- better supervision and transparency in financial markets;
- more flexible labour markets;
- removal of the still significant informal barriers to FDI;
- greater autonomy for educational institutions;
- liberalization and improved regulation of telecoms; and
- stronger linkages between educational institutions and research agencies.

Malaysia

Malaysia is a particularly interesting case study of technology and innovation issues. It has been a dynamic economy (apart from the recent crisis period) and possesses relatively strong institutions. It is very open to both international trade and foreign investment (apart from, recently, the special case of short-term capital). It has been a vigorous and by and large successful exponent of export processing zones. This, combined with good infrastructure, political stability, a liberal investment regime, and proximity to Singapore, has resulted in a huge electronics industry. Its human capital base is good, but not outstanding. Its business environment is open, with the one major complication that the government's ethnic restructuring objectives do impose some restrictions on firms' commercial freedom. In consequence, it has also consistently lost high-level non-bumiputera human capital. The country had notable early strengths in agricultural extension services (particularly for cash crops), which for many years underpinned its status as the world's largest producer of natural rubber.

More recently, the government has embarked on a number of ambitious projects.[8] This current 20 year plan seeks to lift the country to OECD status, particularly in knowledge-based activities, including computer infrastructure, 'infostructure', education and training, and R&D and technology. Just prior to the Asian financial crisis, the government announced its plans to develop a 'Multimedia Super Corridor' (MSC), which included the aspiration to develop a 'Silicon Valley of Southeast Asia'. The government is taking the initiative in this project, through the provision of subsidized telecommunications infrastructure, fiscal incentives, university-based incubators, and related government investments. The timing of the MSC's establishment – just prior to the crisis – was unfortunate. It remains in its infancy, and it is premature to offer any evaluation (other than the general remarks on the Malaysian approaches below).

Two recent edited collections, by Jomo and Felker (eds, 1999), and Jomo, Felker and Rasiah (eds, 1999) provide a comprehensive analysis of the country's technological capabilities and innovation system. It will be useful to provide some snippets from these volumes. Mohd Nazari Ismail provides a very interesting and balanced account of the dominant electronics industry, with much useful material on instances of 'technological deepening' (innovation) in the industry. Michael Hobday examines the process of innovation in the same industry, highlighting in particular its gradual and incremental nature, an issue to which we return below. Goh Pek Chen focuses on the semi-conductor industry, drawing attention to both its strengths, and the human capital and other obstacles to the upgrading process. Jaya Gopal's chapter on the palm oil refining industry is of particular interest, for it seems to suggest that the government's (largely uncosted) promotion of the industry may have paid off, in that by the 1980s it was able to compete internationally without subsidies. Rajah Rasiah provides a useful summary account of the country's national innovation system.

[8] For a description, see The Third Outline Perspective Plan, 2001-2020 (Economic Planning Unit, Kuala Lumpur, 2000), chapter 5, 'Developing Malaysia into a Knowledge-Based Economy'.

The picture which emerges from this analysis[9] is one of several segments with rather distinct features and performance. One is electronics, which has been extremely successful in terms of growth and exports, but now must make the transition upstream, integrate more with the rest of the economy (presumably by removing the artificial barriers between the zones and the rest of the economy), and develop its human resource base. Another segment is the automotive industry, whose record is the subject of considerable controversy. Here it seems that Malaysia has paid a very high price by attempting 'back-to-front' industrialization. That is, by going for a prolonged period of protection for the assembly industry, rather than following the more successful route of, for example, Taiwan and Thailand, which lowered protection a decade ago and have done particularly well in the components industry. Finally, there are agro-processing industries, where Malaysia has been able to develop on the basis of its traditional production strengths and a high-quality, publicly-funded (or at least mandated) R&D base.

In many respects, Malaysian approaches have mirrored those of Singapore, albeit with a lag. That is, it has sought to build on its very good physical infrastructure and openness to foreign trade and FDI. Initially, FDI in electronics and other labour-intensive industries was seen as a means of providing employment for a labour-surplus economy; the country has long been home to some electronics majors, including Motorola and Intel. After the recession of the mid 1980s, the government has pursued a strategy of 'technological leverage' vis-a-vis MNCs, by developing linkages through supply networks, joint venture training projects, and inter-firm worker mobility. While remarkably successful, particularly in the case of Penang (which in many respects is a 'mini-Singapore'), its public policy capacities have never matched those of the city state, clouded by a less secure legal environment, corruption, and the politics of affirmative action. Thus, there is a general consensus that Malaysia could have done more by way of 'leveraging' the MNC presence to its own advantage (see for example Westphal, 2001).

There is considerable regional diversity in the Malaysian industrial sector, to which Rasiah (2001) draws attention in a recent case study of SME subcontractors in the machine tool industry in two regions, Penang and Kelang Valley. Penang, which was the home to the earliest export-oriented investments, has developed a successful SME subcontracting base, whereas the Kelang Valley has not. He attributes the differences as due to industrial histories, and more effective government-business coordination. For example, the Penang government has provided support for the (mainly Chinese owned) SMEs, in the form of public training and market information. (The Penang Development Corporation, for example, is regarded as an effective government agency, but it only has control over state matters.) Malaysia has a federal political structure, and thus no doubt exhibits greater spatial diversity in administrative competence than other East Asian countries. But it is important to be alert to these variations, rather than simply drawing broad nation-wide generalizations.

Singapore

[9] See also Lall (1995) for an earlier analysis.

Singapore has notable strengths in the area of technology and innovation policy. It is an extremely open economy (except for some services, mostly now being opened up too); its bureaucracy is one of the best in the world; its physical infrastructure is likewise absolutely world class; and its education system is good. And, as it contemplates upgrading, it has larger fiscal reserves, relative to the size of the economy, than any country in the world.

Its technology and innovation policy has evolved rapidly, as it has shifted quickly from using to creating technologies.[10] The country embarked on its first serious R&D effort in late 1980s. Until then, it had lagged the OECD countries, and Taiwan and Korea. An 'applied R&D expansion' phase lasted for the decade commencing 1989, which saw the beginnings of innovation and local capacity, and increased government funding. A big push for higher education, high-tech industry and basic R&D got underway in the late 1990s.

R&D expenditure has increased rapidly, about seven-fold 1987-99, and in 1999 was 1.84% of GDP. Most of it is in the private sector, but features much state inducement. During the 1990s, funding for public research institutes and universities has increased quickly. There has also been some administrative reorganization, with the National Science and Technology Board focusing on basic R&D, and the Economic Development Board directed to applied and commercial areas. With its high salaries and open labour market, Singapore institutions are able to recruit on the international labour market. In 1999, for example, 17% of science and technology personnel were foreigners; many more were migrants who had become permanent residents and citizens.

Singapore's ownership structure is unique, with its large foreign and government-owned segments, and technology policy has had to take this into account. Multinational corporations have always been a dominant feature of the modern Singapore economy, generating about three-quarters of manufacturing value added. The government has actively sought to induce Singapore-based MNCs to upgrade and innovate, to use the country as a regional headquarters, to undertake product and process innovation, and to build and fund joint venture technology institutes to diffuse the MNCs' technology.

In certain designated industries, it has aggressively attracted foreign companies. This applies to electronics in general (see Mathews and Cho, 2000). A particular case of success is the hard disk drive industry, in which Singapore spearheaded its relocation to Southeast Asia (see McKendrick et al (2000) for a detailed case study). The initial attraction for the industry was the region's cheap labour and good infrastructure, in addition to which Singapore was motivated by a desire to overcome the economy's historically high rates of unemployment. Public policy played an active role not only in attracting the industry, but also in nurturing and developing it beyond its initial unskilled labour intensive phase, when it otherwise might have migrated to another low-wage location. A combination of push and pull factors were at work in this story. Agglomeration and momentum factors were both important, as was Singapore's growing 'country

[10] See Wong (2001, 2001a) for a useful analytical history, on which we draw. The NSTB (1997) provides a succinct official perspective, while NSTB (2000) and earlier publications in this series provide a statistical summary.

reputation' in attracting other MNCs. The Singapore government as host played a key role in developing complementary support facilities, in having the officials who understood the needs of the industry, and were able to take quick decisions. Singapore's high quality institutions made a difference. As McKendrick et al (2000, p. 231) ask: 'Why doesn't the Thai Board of Investment act like the Singapore Economic Development Board?'[11]

Openness was a critical factor in Singapore's case, as was infrastructure. Schemes were supported for the training of employees and the development of supplier industries. The government employed fiscal incentives to induce MNCs to use the country as a regional headquarters. Grants from the NSTB were offered to MNCs to undertake R&D. A Skills Development Fund levied on firms provided funds for training. Perhaps more than any government in the world, officials were attentive to the needs of foreign companies. No country in the world can match Singapore in the time taken between investment approval and the commencement of production operations. It therefore serves as a model of how to leverage the multinational presence, a point to which we return shortly.

There is some controversy about the size of 'Government Linked Corporations' (GLCs), particularly as these corporations are increasingly active investors abroad (and encountering resistance on the grounds of their ownership). They are undoubtedly large, equivalent to at least one-quarter of GDP, and probably a good deal more. The government has employed some of the larger GLCs as agents of innovation, especially the Changi Airport and the Port of Singapore Authority. (Both regularly receive commendation as among the most efficient service providers in the world.) Defence receives a high priority in the budget, and this too has important R&D implications. Some of the Defence-related GLCs have already been floated on the stock exchange.

It is not yet clear what has been the effect of this major R&D effort. Singaporeans are very fast adopters of new information and communications technologies, and patent activity is rising. Start-up activity and commercialized spin-offs from R&D institutes are also occurring.

Among the challenges, Wong (2001, 2001a) identifies developing links between enterprises and both the universities and the public research institutes; links among the latter two are already good. Venture capital funds are emerging, but rather limited. International R&D and educational links need to be developed. There is the question of what R&D to fund given that Singapore's size dictates specialization. The government laments the lack of domestic entrepreneurship, while vigorously recruiting the best and the brightest from tertiary institutions. With a large and well-paying MNC presence, it is perhaps not surprising that local privately owned firms are the country's weak link.

[11] The Singapore Economic Development Board is one of the most important government institutions in East Asia in the realm of technology and innovation policy. For a positive, quasi-official assessment of its first 25 years, see Low et al (1993). The one perhaps contentious aspect of their record is the liberal use of fiscal incentives, which in other institutional settings would almost certainly be susceptible to abuse. Helen Hughes in the Low volume also adopts a skeptical view of these incentives.

Taiwan

Taiwan stands out for its open economy, SME resilience, very high saving rates and international reserves, high educational achievement, good physical infrastructure and some effective support for innovation. What Chu (2000) terms a 'competent, authoritarian government' promoted rapid export-oriented industrialization from the late 1950s, after a brief period of import protection and significant state ownership. Most of the major labour-intensive export industries of the 1960s-80s received at most modest levels of protection, and in some cases were taxed. Examples included garments, footwear, travel goods, toys, and bicycles (in which Taiwan became the world's largest exporter by mid 1980s). A crucial feature was that firms were quickly subjected to the market test, either through domestic competition or export performance. Taiwan was consistently less interventionist than Korea, and embarked on few massive heavy industry projects. Taiwanese firms consistently score highly in terms of their flexibility, their ability to quickly penetrate, and switch between, international marketing channels, and their ability to rapidly absorb and diffuse technology introduced by FDI or government research institutes.

Lin (1998) argues that an early and major investment in education at all levels was important, including especially strong science and technology. Increasing numbers of students went abroad from the 1960s, principally to the US. Many stayed abroad for decades, returning not only with formal education but also commercial experience. This is a feature in all the Asian NIEs, but is arguably most important of all in Taiwan.[12]

In many respects, Taiwan differed significantly from Korea (Westphal, 2001). It lacked the large conglomerates within which major R&D initiatives could be funded. Historically, government-supported R&D was not large. And, although its FDI regime was not nearly as restrictive as that of Korea, neither has it been as open as the city states and Malaysia. Instead, the keys to its success appear to be its extraordinary SME-based resilience and flexibility, combined with a government-supported R&D effort from the early 1980s, and a capacity among SMEs to absorb and diffuse new technologies very quickly. From mid 1980s, government support for science and technology increased sharply. Key centres at universities and public research institutes were funded. It was thought that the industrial structure, which was dominated by SMEs, would be slow to innovate, and experience difficulty absorbing foreign technology directly. Therefore cooperation between enterprises and research institutes was given high priority. Some successful consortia have emerged, combining basic R&D and its commercialization. The Industrial Technology Research Institute (ITRI) has been a key actor, whose experience we consider below. The Hsinchu Science-based Industry Park, established in 1980, likewise played a major role, especially in the development of a more sophisticated electronics industry (see Mathews and Cho, 2001, p. 257 ff).

While Taiwan weathered the Asian economic crisis more successfully than Korea, and its R&D output indicators suggest much has been achieved (eg, its firms have the largest

[12] Pack (2000, Table 3.3) draws attention to this phenomenon. Dr Ching-lung Tsay of the Academia Sinica, Taipei is currently undertaking detailed research on the issue which highlights its importance.

number of US patents among the four NIEs), there is concern that, as in Korea, the government is not moving quickly enough to develop the institutions required to support a modern, technologically progressive economy – for example, a high quality legal system, and adequate supervision of financial institutions and the stock market.

Indonesia

Indonesia is the poorest country in this East Asian sample, and the one most affected by the recent crisis. It is currently experiencing a major and prolonged economic and political transition, and thus technology and innovation issues are likely to be of secondary importance for at least a decade. The analysis here therefore focuses on the situation in pre-crisis Indonesia and on the issues which will again become important after the immediate challenges of economic restructuring and political stability are overcome.

In the 20 years to 1997, and briefly as president, Dr B.J. Habibie completely dominated Indonesian technology policy.[13] Indonesia had ambitious plans for technological development over this period. For example, in its Second Long-Term Development Plan (PJP II, 1994-2019), drawn up well before the current crisis, expenditure on R&D was projected to rise sharply, from around 0.2% of GDP to 2%. Government expenditure on R&D pre-crisis was quite modest, about $400 million, but was dwarfed by the huge investments in the nation's 'showcase' aircraft factory, IPTN, which totalled approximately $3 billion. Reflecting in part the background of the key personalities involved, program objectives also emphasized 'technological self-sufficiency', through a four-stage evolution from basic manufacturing capacity to the mastery of leading edge technologies as embodied in advanced manufacturing.[14]

According to all the standard indicators, Indonesia is very much an industrial latecomer. It is only since the late 1960s that it has been open to international technology markets and has had a government commitment to the development of any sort of scientific base. It allocates a little under 0.2% of GDP to formal R&D activities, on a per capita basis, equivalent to less than $1.5. The government is the dominant actor in formal R&D activity, both as a funder and as an 'implementer'. It provides about 80% of the resources, and directly carries out over 60% of the activities. A large government role in the early stage of industrialization is not unusual, but international comparisons suggest that the figures for Indonesia are exceptionally high.[15] Other indicators also underline Indonesia's latecomer status. Owing to its size, it has the largest stock of scientific personnel in ASEAN, but

[13] See the contributions to Hill and Thee (eds, 1998) for detailed analyses of the pre-crisis situation. Okamoto and Sjoholm (2001) provide a recent survey of the issues. The best study of the Habibie mega projects, though now very dated, remains McKendrick (1992).

[14] Dr Habibie's disdain for labour-intensive industries was also well known. He frequently singled out the garments industry, arguing that Indonesians don't want to be just 'tailors for the world'. These remarks indicate that he is apparently unaware of the fact that the people in Milan have prospered from their large fashion-intensive garment industry.

[15] The comparable figures for Korea are, for example, 17% (of funds) and 4% (of implementation), although indirectly government influence would certainly be much higher.

when adjusted for quality of training, hardware support and active scientific activity, its R&D effort is again much closer to that of the Philippines and Thailand.

Program implementation has always been a major challenge in Indonesia. Over the period 1967-97 the government achieved notable successes in macroeconomic management, promoting near universal education at primary and junior secondary levels, and pursuing a reasonably open trade and investment regime. But its microeconomic interventions, including technology and innovation policy, often resulted in gross distortions. For example:

- Programs have often lacked coordination across ministries.
- Corruption has been a continuing and serious problem. Especially during the last few years of Soeharto's rule, a virulent, 'palace-based' cronyism emerged.
- State enterprises have a poor financial record.
- Serious efforts to improve civil service efficiency – to increase accountability and to link performance and rewards more closely – have never been implemented in a determined and effective fashion
- Important services which only government can provide (such as an incorruptible police force, an efficient and clean judiciary, and a well-regulated financial sector) have not been supplied.

In such an environment, in which the evidence suggests that selective intervention has played a marginal role in the country's success, it is difficult to see a case for anything other than general technology programs, in which there is minimal scope for corruption and abuse of office, as being successful. Such an assessment is at odds with some literature emphasizing high quality, relatively corruption-free bureaucratic capacity and intervention, at both macro and micro levels, as a factor underpinning East Asian success.

Technology and innovation policies in the Philippines and Thailand share much in common with those in Indonesia. The formal R&D effort is very limited, no more than 0.2% of GDP and most of it is government-funded. The most important international transfers occur through FDI and a range of non-equity arrangements, while the major direct government policy contribution has been in the area of public education. Prior to the crisis, Thailand was experiencing extremely rapid economic growth (and attracting more export-oriented FDI than Indonesia), and real wages began to rise quickly from the late 1980s. It was thus about to face major challenges of upgrading, which have now been deferred pending resolution of its financial crisis.

(5) SELECTED ISSUES

(5.1) International Technology Flows

International connections critically shape a country's pattern and rate of technological development. This is a vast topic with many dimensions, including the following.

- R&D activity is heavily concentrated in a handful of rich OECD economies (the G7 account for over 90% of global R&D expenditure), and so a capacity to tap into global

technology markets quickly and smoothly is the first requirement for net technology importers in East Asia.

- The limited amount of documentation of international strategic technology alliances concludes that it is overwhelmingly an intra-triad (ie, US, EU, Japan) phenomenon (see Duysters and Hagedoorn, 2000).
- International technology flows are increasing rapidly and, like trade and investment, almost certainly growing faster than global output.
- Owing to this increasing globalization of technology flows, national technology policies need to be harmonized with trade and investment policy regimes as never before. A strategy which emphasizes autarchy in one of these areas will almost certainly have counterproductive effects in other areas.
- There is a steadily increasing array of suppliers in the international technology market place, although in selected technology-intensive activities markets are still oligopolistic in structure, and information flows are inherently imperfect.
- More so than any other form of major international commercial transaction, technology flows are poorly documented, not only because of conceptual difficulties in defining just what constitutes a 'flow of technological services', but also because of empirical limitations. In most cases, we have practically no means of quantifying these flows in any sort of detail in aggregate, much less by source country, channel or the recipient sector.

With the growing appeal of the new growth theories, the notion of international R&D 'spillovers' attracts great interest – countries can increase their growth rates not only by investing in R&D, but also through commercial relationships with other countries which possess large R&D stocks (Grossman and Helpman, 1991; Coe and Helpman, 1995). Modelling the international effects of one country's R&D effort on others' growth rates is still rudimentary. Owing to data availability, most of this research has concentrated on trade links as the transmission mechanism, but in practice FDI almost certainly has a larger impact. Incorporating FDI into these models is likely to become a major research endeavour as the data base improves.

Soesastro (1998) provides an overview of international technology flows in the Asia-Pacific region. He concludes that FDI is generally the most significant component of these flows, and he notes the shift from the public to the private sector as a generator of these flows. He emphasizes the rapid globalization of flows (including not just transfers but also the international relocation of R&D activity), albeit in the context of the OECD economies continuing to be the major suppliers. An underlying theme in his analysis is the difficulty of measuring technology flows. For example, most developing countries do not estimate with any reliability a 'technology balance of payments'. Even if they did, a measure based on royalty payments would not capture much of the story (which includes activities such as human capital flows, FDI spin-offs and direct licensing agreements). Soesastro also surveys various East Asian approaches to technology policy. In particular, he cautions that the earlier Korean approach of a highly restrictive policy towards FDI is neither feasible nor suitable for latecomers.

An important lesson from the Asian experience stressed by Soesastro is the need to link technology strategy to international commercial policy. Open economies with a good human resource base may achieve high pay-offs from carefully targeted science and technology policies – Taiwan, Hong Kong and Singapore all come to mind as nimble economies with until recently 'below average' (for their per capita incomes) R&D/GDP expenditures but effective innovation strategies. By contrast, India and Russia have devoted large budgets to R&D activities, but historically in the context of closed economies which thereby minimized the opportunities for a quite well-developed domestic research industry to interact with inter-national best practices. This issue has been emphasized by OECD (1997) which, in view of the rapid globalization of technology flows, proposes that a nation's technological effort should explicitly include acquired technology together with the national R&D effort. As the report points out, firms purchase 'R&D effort' in the international marketplace; the OECD estimates suggest that the magnitude of such acquired technologies may be at least as large as that of domestically generated R&D activities. In developing countries, with their limited local R&D expenditure, acquired (imported) technology would obviously be a larger proportion of the total. Ideally, international comparisons of R&D effort should make more explicit allowance for the mix of these two components.

Several East Asian countries attempt to monitor these technology flows, with limited success. Whether they should be regulated is an issue we address in the next sub-section, on FDI and technology transfer.

(5.2) FDI and Technology Transfer[16]

The literature on FDI and technology transfer, or 'spillovers', has proceeded in two main directions, a newer one which is macro, econometric and inferential, and traditional one which is more micro, qualitative and firm-based. The two approaches are usually particularly data-intensive, and so rarely, unfortunately, are both employed in the one study. The first of these employs a large secondary data set in which foreign and domestic firms are separately identified. It examines productivity (either total or partial) trends among the two groups and across industries to discern whether the foreign presence affects levels and growth rates among domestic firms.[17] These studies are generally not concerned with the transmission mechanism, nor are they able to estimate the relative importance of FDI among other factors explaining productivity growth in domestic firms. However, they do provide presumptive evidence of causation. The results vary across countries and industries, indicating that such spillovers do not occur automatically. It is hypothesized, and sometimes empirically demonstrated, that spillovers will be positively associated with the level of competition (which pushes firms to adopt improved technology) and negatively associated with the productivity gap between foreign and domestic firms (on the assumption that a very large gap renders absorption by domestic firms more difficult).

[16] Some of the material in this sub-section draws on Hill and Athukorala (1998).
[17] See Blomstrom and Kokko (1998) for a survey.

Few studies have so far employed this approach in developing East Asia. Fan and Warr (2000) examined spillovers, as measured by TFP growth, to state-owned enterprises (SOEs) and those which are collectively-owned (mainly the Town and Village Enterprises, TVEs) in China. Their results highlight the importance of the domestic policy and absorptive environment in maximizing the gains from FDI. Among the SOEs, negative spillovers were detected. They attribute this to these firms' operating environment, including their soft budget constraint, a deteriorating human capital base, and the absence of incentives to improve productivity. By contrast, in the flexible and dynamic TVEs, where appropriate incentives structures are in place, the FDI spillovers were found to be positive.

In various papers on Indonesian manufacturing, Sjoholm (eg, 1999) found that competitive pressures were significant in explaining inter-industry variations in productivity growth. Interestingly, domestic competition (that is, a firm concentration variable) was found to be more significant than foreign competition, as proxied by effective protection. Sjoholm also emphasizes that spillovers are effective only when local absorptive capacity exists, and the industry possesses an efficient productive base. Without these pre-requisites, it is likely that FDI will contribute just a once-for-all boost to productivity, rather than ongoing increases.

Ideally, one needs to supplement these studies with some more detailed industry-level work, to understand better how and why the spillovers work. This is where the earlier case study literature on technology transfer via MNCs continues to be of relevance, notwithstanding the limitations associated with small, micro-level samples with minimal quantification. The following discussion provides some snippets of this large literature, and does not pretend to be comprehensive.

One attempt to probe technology transfer mechanisms is Hou and Gee (1993) on Taiwan. They found labour mobility from foreign to local firms to be a key variable. They also pointed to the differences between medium-large and small firms. Whereas the former generally approached technology transfer through formal mechanisms such as joint ventures (including 'reverse engineering' via FDI abroad) and licensing agreements, the latter relied more heavily on informal channels such as copying and business liaisons.

There continues to be a debate about the effectiveness of Japanese technology transfer via FDI. The analysis has matured from the somewhat polarized debate in the 1970s, with the general conclusion being that Japanese firms are no better or worse than MNCs from other countries, especially after account is taken of linguistic differences and the industrial location of FDI. In an interesting study of Japanese FDI in the Indonesian auto industry, Sato (1998) finds a substantial transfer of managerial know-how from the Japanese investor to, and beyond, the Indonesian partner, which became deeply familiar with the technology, and adapted it to Indonesian conditions. Such a finding is of considerable significance in view of the widespread 'nationalist' sentiment (in Indonesia) that Japanese companies, long dominant in the industry, have contributed little to its technological development.

Another FDI-technology issue is the relationship between FDI and the location of R&D activities. As Dunning (1998) notes, the traditional model of FDI, which dominated through to the 1970s, involved firms investing abroad on the basis of a competitive advantage which was generally based around an advanced technological competence. During the 1980s, this close association between R&D capacity and outward investment, while still underpinning much FDI, began to evolve in at least two directions. First, as noted, cash-rich companies from East Asia and elsewhere sought to short-circuit the technology upgrading process by 'reverse engineering' investments abroad in firms with a strong R&D capacity. Second, the location of R&D activities within MNCs also became more international. Traditionally, and with few exceptions, such R&D was heavily located at the MNCs' headquarters, owing to the superior human capital base and economies of scope and scale, to maintain synergies between R&D and production, and to safeguard intellectual property rights. Just as comparative advantage factors have pushed production offshore, so too has the economics of R&D led to some international relocation of research activity, albeit on a smaller scale.

There is a clear consensus in the East Asian literature on the importance of 'leveraging' the MNC presence, as a means of maximizing the benefits for the domestic economy. Singapore has arguably had the greatest success in this regard, as the research alluded to above has described in great detail. The key feature of its policy regime has been to adjust the policy settings as the economy has shifted quickly from its labour-intensive industrialization phase to one which is highly technology intensive. Its government anticipated the shift out of low-wage activities, and developed several programs to upgrade local capacities. In the case of the Hard Drive Industry, which it pioneered in Southeast Asia, it set up the Magnetic Technology Center, later renamed the Data Storage Institute (see McKendrick et al, 2000, on which this draws). It recognized the support of clusters, and a base of small, specialist suppliers. Thus, for example, Seagate, the major multinational in the industry, 'started from nothing' in 1982, but within a decade a large industry cluster was operating effectively.

This was a successful example of efficient industry policy. In addition to its excellent infrastructure, critical for highly trade-intensive industries,[18] the government introduced a Local Industry Upgrading Program, as a means of tapping into MNCs' expertise. Technical skills were upgraded continuously through good quality technical, vocational and tertiary education. As the country began to lose comparative advantage in labour-intensive sectors, the government worked with MNCs to induce them to stay and upgrade, while shedding uncompetitive segments. On-the-job training was facilitated by the Skills Development Fund, funded in part by a levy on foreign workers. The Economic Development Board introduced schemes to fund MNCs' local R&D activities. The Board was also highly attentive to these firms' requirements, and was also willing to target specific MNCs it considered would be useful for future industrial growth.

Three additional elements of the Singaporean experience with MNCs are relevant. First, the technology transfers appear to have been both horizontal and vertical, the former

[18] For example, Singapore is generally credited with having the world's quickest port to factory clearance time.

occurring through emulation, demonstration effects, and inter-firm worker mobility, the latter via subcontracting and other supplier relationships. Secondly, there were distinct – though in the regional rarely appreciated – benefits for Singapore's neighbours from it's MNC-intensive, export-oriented strategy. It created a regional (Southeast Asian) reputation in the global economy. It showed the region a way forward, a successful model of development, with Penang the most obvious imitator in the neighbourhood. There were also marked cross-border spillovers, as Singapore-based firms relocated labour-intensive segments to nearby Johor (Malaysia) and the Riau Islands (Indonesia). Thirdly, given its size, Singapore's approach inevitably entailed some explicit targeting. That is, it was not feasible to develop competence across a broad range of industries, and thus scarce R&D resources were allocated to certain designated sectors, most prominently electronics. More recently, biotech, IT, and several services have been added to the priority sectors.

There is a view that, as a tiny, heavily managed city state, Singapore's experience is not internationally replicable. While of course its geography and history are unique, there is no reason in principle why other countries cannot learn from, and emulate, its success. But if countries are to follow its path, five features of its record deserve emphasis. First, its economy is completely open, and so firms are immediately subject to some sort of market discipline. Second, as part of the package to induce MNCs, it offers the world's best physical infrastructure, and an entirely predictable and business-friendly investment climate. Third, the government has demonstrated an unrivalled capacity to walk away from mistakes. A highly open economy reveals these mistakes quickly, and Singapore's meritocratic government is not hostage to the usual set of vested interests which constrain governments from adopting first-best solutions. Fourth, the government has revealed a willingness to open its labour market to an extent unparalleled among modern nation states. At least 25% of its workforce is foreign, and a much higher percentage born overseas. With its high salary structure, it is able to recruit in the most cost-efficient labour markets. Finally, Singapore has a seemingly completely incorruptible civil service. Its public sector remuneration is one of the highest in the world, and it is insulated from political pressures. Thus, a selective industrial policy is more likely to be successful there than in practically any other country in the world.[19]

Enthusiasts of the Singapore success and its lessons for other countries need to be cognizant of these features. The more follower countries depart from them, the less likely this model is likely to be replicable. Indeed, Singapore's neighbours have adopted a more ambivalent, more passive, and less hard-headed attitude towards FDI, and arguably have not extracted the same benefits from it. In the words of the country's principal economic architect, Dr Goh Keng Swee, Singapore '... had no xenophobic hangover from colonialism.' (quoted in Huff, 1994, p, 36). The closest exponent of the Singapore model has been Malaysia, particularly in its most industrialized and business-friendly state,

[19] The only caveat I would attach to this extraordinary development record is that the resources devoted to the country's R&D effort are not particularly transparent. Fiscal incentives are awarded to firms on the basis of performance requirements, and by definition these are 'commercial-in-confidence'. The presumption is that internal checks and balances, and high levels of government remuneration, ensure that there is no corruption. Owing to the absence of an effective parliamentary opposition and an independent press, one has to assume that this is the case.

Penang. But here and especially elsewhere, the ingredients of Singapore's success have been at best only weakly present: civil servants have been vulnerable to capture, economies are not as open, governments have not displayed such a ruthless commitment to development, the supporting infrastructure is not as good, the skill base is weaker, and aggressive 'leverage' strategies have not been employed. Consequently, the spillovers from MNCs have been much less.

A final general observation on technology and MNCs is to emphasize is that it is now very difficult for late-comer industrializers to achieve high rates of export growth without MNC participation. The earlier literature on this subject, in which Nayyar (1978) was the dominant study, argued that MNC involvement in export expansion from the NIEs (other than Singapore) was low by international standards. While this generally remains the case, it is important to note that in both Korea and Taiwan, the MNC share in exports did increase significantly from about the mid 1970s to mid 1980s, as compared to the figures reported by Nayyar for the late 1960s. Detailed case-studies of the export performance of these countries suggest that this increase reflected the important role played by MNCs in these countries, as they shifted from the early reliance on labour intensive, standard consumer goods sectors to assembly activities in vertically integrated high-tech industries, and subsequently to sophisticated consumer durables production.

Moreover, contrary to Nayyar's arguments, there is clear evidence that the strong export performance of developing countries since the 1970s has been closely associated with MNC involvement. In the early post-war years, it was in the Latin American countries where MNCs played the largest role in developing country manufactured exports. However, this pattern began to change quickly, as increasing numbers of countries in other regions embarked on more market-oriented, FDI-friendly policy reforms. The degree of MNC participation in the export industries of Latin American countries has remained more or less unchanged, or increased less rapidly compared to many countries in East Asia.

By linking individual country data on MNCs' shares in exports with general export data, Nayyar estimated the share of MNCs in total manufactured exports from developing countries to be not more than 15% *circa* 1974. Moreover, he found that the share had not registered any significant increase since 1966. By contrast, a similar calculation, based on unpublished estimates prepared by Professor Prema-Chandra Athukorala at the ANU, suggests that MNCs accounted for 24% of total manufactured exports from developing countries *circa* 1980. This figure had increased to 36% *circa* 1990. When Korea, Taiwan and Korea are excluded from the calculations, the latter estimate increases to 45%. Given the massive increase in manufactured exports from China (from $3.4 billion to $129.1 billion between 1990 and 1996), and the increased share of MNCs in this export expansion (from 17% to 48% between these two years), this figure would have surpassed 50% by the turn of the century.

(5.3) Industry Policy and 'Mega' Projects

What role has industry policy – defined here as a deliberately non-neutral incentives regime – played in East Asia's rapid industrialization? This is one of the most extensively debated development policy issues.[20] At the risk of over-simplification, two contending paradigms have emerged. According to one, the major contribution of governments has been in getting the 'fundamentals' right: macroeconomic stability, predictable and stable policy regimes, improved physical infrastructure and education, a reasonably adequate system of property rights and legal infrastructure, and increasing openness to international commerce. An alternative paradigm accepts some or all of the above prescriptions,[21] but argues that it is an insufficient recipe for industrial success. This school rejects an emphasis based primarily on economic liberalism and static comparative advantage. It argues that Korea, Taiwan and Japan owe their success to selective industrial policies – targeting industries, 'picking winners', and deliberately 'getting prices wrong' through fiscal incentives, subsidized credit, import protection and direct investment. In the words of one widely cited author: '… not only has Korea not gotten relative prices right, it has deliberately gotten them "wrong". Nor is Korea an isolated case. It is part of a general group of … late industrializers' (Amsden 1989, p. 139–40).

There has been less work on this issue among the ASEAN economies. Putting aside the special case of Singapore, Indonesia, Malaysia and Thailand have industrialized rapidly, and their governments, particularly in Indonesia, have intervened extensively at the industry level. Superficially at least, therefore, the ASEAN evidence might be interpreted as supporting the notion that selective industrial policies have contributed to their success. However, on closer examination such an argument receives little empirical support. For the arguments of the interventionist school to be convincing, it is obviously insufficient merely to point to the coexistence of selectivity and rapid growth. There has to be a demonstration of causality, and the research emerging on this topic finds little evidence of this kind.

The standard tools of industrial policy have been employed in all three economies, although over time deliberate policy-induced distortions have declined. Inter-industry variations in protection have been considerable, especially in Indonesia. A large state enterprise sector is present in several of them; again Indonesia stands out, as does Malaysia to a lesser extent. Subsidized credit and interest rate controls have existed in these three countries for at least some of the past 25 years. Fiscal incentives have also been employed.

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[20]The literature on this subject is now very large. Smith (1995) provides a comprehensive survey of the East Asian literature from a largely neo-classical perspective. Influential East Asian case studies among the interventionist school include Amsden (1989) on Korea and Wade (1990) on Taiwan. Hughes (ed) (1988) provides an important airing of competing views in the debate.

[21]Indeed, this school arguably takes achievements in these areas too much for granted, and downplays the fact that, with limited high-level bureaucratic resources available, a more activist strategy may be implemented at the cost of diminished performance in the core areas.

In reality, however, promotional measures in ASEAN have been prone to abuse, implementation has been sporadic and often short-lived, and there has been little systematic attempt to prescribe conditionality, in the sense of linking incentives to tightly defined performance criteria. It is therefore hardly surprising that studies which have examined the relationship between inter-industry variations in government assistance (for example, through protection and credit subsidies) and subsequent (lagged) performance, according to a variety of measures, have found little evidence of causality. In the case of Indonesia, a survey of selective policy instruments introduced or extended in the 1970s and early 1980s – protection, credit subsidies, state enterprises – detected very little evidence of such a strategy having 'worked' according to a range of subsequent performance criteria (Hill 1996).[22] Similarly, Warr's (1995) study of several policy correlates of export performance in Thailand over the period 1970–89 revealed a remarkably consistent picture of negative coefficients for all variables and time periods. In the case of Malaysia, it is very difficult to find any evidence in support of the proposition that the government's promotion of heavy industry over the period 1978–86 promoted efficient industrial growth (Athukorala and Menon, 1996).

The economic crisis has weakened still further the case for an interventionist industrial policy. Attempts to finance uneconomic, highly politicized industrial projects through a shaky financial system, or through foreign borrowings with implicit government guarantees, have contributed to the current difficulties. Moreover, senior technocrats in charge of macroeconomic policy have been distracted from their primary policy responsibilities in their efforts to oppose such grandiose projects. This was particularly evident in the late years of Soeharto's, as senior economic officials sought with limited success to contain the excesses of both the Habibie high-tech projects, and the ever-expanding business empires of the Soeharto family.

Finally, 'mega projects' in Southeast Asia have been spectacular and costly failures. Those which stand out are the Habibie-inspired strategic industries (principally aircraft, but also ship-building, munitions, and various other activities, 12 in total), and Malaysia's heavy industry programs (mainly autos and steel). The Philippines embarked on a similar set of grandiose schemes in the late Marcos period, but these were mostly aborted by that country's serious economic crisis in the mid 1980s, and almost all the projects were mothballed and never resurrected.

These have been essentially show-case political projects, involving back-to-front industrialization. They absorbed huge amounts of government funding (mostly not subject to usual auditing procedures), diverted scarce engineering skills from more important activities, involved very little technological advance outside their immediate operations, and survived only as long as their political patrons supported them. Thus, with the onset of the economic crisis and the subsequent demise of Dr Habibie, Indonesia's strategic industries have virtually collapsed, with little to show for the $3 billion (or more; no accurate estimates are available) of government investments. Some of Malaysia's heavy

[22] Indeed, what little systematic work to have been done on the political economy of trade policy in Indonesia has found a 'crony' variable to be consistently the most significant explanator of inter-industry variations in protection (see Basri and Hill, 1996).

industry investments were trimmed back during the mid 1980s fiscal stringency. But the auto industry endures, with prime ministerial backing. There is at least some prospect of the Proton making a (costly) contribution to technological learning: it has been subject to some sort of market test through (subsidized) exports, the government has relaxed its earlier opposition to foreign joint venture partners, and government subsidies are more easily costed and controlled.

(5.4) Enclaves and Electronics

The electronics industry is of particular interest because it dominates much of East Asian manufacturing exports, in several countries constituting over half of merchandise exports, and because it is a subject of controversy, attracting enthusiasts and critics alike.

As Hobday (1995, 2001) points out in several studies of the industry in the four Asian NIEs, virtually all combinations of policy regimes have been evident – extensive intervention and large firms in Korea and Singapore, which in turn have been distinguished respectively by closed and open policies towards FDI; and small local firms alongside larger foreign ones in Taiwan and Hong Kong, in the context respectively of partially liberal and laissez faire FDI and trade policies. It is important, however, to also emphasize the common elements across the four economies: export orientation, strong investments in human capital, generally sound macroeconomic management, and liberal policies towards technology imports (if not across-the-board then at least where it was recognized that the local base was inadequate).

There is a presumption in much of the literature, especially in Malaysia,[23] that the 'Southeast Asian model' of an MNC-led electronics industry is somehow inferior to that of Korea, which aimed to build up domestic technological capabilities with a quite limited MNC presence. Critics see the former as a case of shallow, enclave-based, foreign-dominated industrialization. The industry is sometimes admonished for the slow pace of backward integration.

However, Hobday (2000, 2001) and others have effectively rebutted these arguments. First, for the late-comer industrializers, labour-intensive electronics exports initially provided much needed employment when unemployment levels were high (eg, Singapore from the late 1960s onwards, Malaysia from the late 1970s, Philippines from the mid 1990s). This growth also established a form of 'country reputation' which was crucial in attracting other foreign investors (see Wells (1994) on this point in East Asian context). Moreover, there is a good deal of innovation already occurring within the industry, in response to rising real wages and increased domestic competence. In the case of Malaysia, according to Hobday (1999), this innovation is '... not radical or R&D-based, but [is] incremental ...'.[24] He concludes in another context (Hobday, 2001) that '[c]ontrary to

[23] See Mohd Nazari Ismail (1999) for an interesting and balanced account of the industry, with much useful material on instances of 'technological deepening' (especially pp. 30-34).
[24] The industry is particularly strong around its original base of Penang. For a recent report on the industry there, see the Far Eastern Economic Review, 12/iv/2001, 'Penang

popular wisdom, the Malaysian (and to a lesser extent the Thai evidence) shows that TNC-led development has proved to be a remarkably successful strategy ….'[25] Finally, arguments supporting the superiority of the 'Korean' approach to electronics (and other industries) overlook its weaknesses, some of which were alluded to above: SMEs were marginalized; despite a very large R&D effort, there were major weaknesses (eg, in design and marketing), and only a narrow range of goods were produced.

This is not to argue that this 'Southeast Asian model' is inherently superior, of course. It too has problems. The absence of backward linkages is a cause for concern, but it needs to be recognized that government policy has contributed to the problem. Export zones have been erected which effectively seal off the firms within them from the rest of the economy. There has been an under-investment in technical and vocational education in Malaysia and Thailand, which therefore limits the absorptive capacity of local SME supplier firms. Fiscal incentives for firms within the EPZs have arguably been excessively generous, creating in effect a new form of dualism, raising doubts about the fiscal sustainability of these arrangements, and clouding their benefit-cost ratios (on which see Warr, 1989). As noted above, only Singapore appears to have adopted a coherent strategy of dynamic comparative advantage, and developed local capacities to interact productively with the foreign presence.

(5.5) Small and Medium Enterprises

Much of the literature on technology and innovation focuses on activities within large firms and cutting-edge technology. This concentration is unfortunate, as it misses a lot of the minor, incremental progress in the rest of the economy. We attempt to redress this imbalance in this and the next sub-section with some case study material from Southeast Asia (mainly Indonesia) of innovation in SMEs and agriculture.

Several case studies have investigated the dynamics of SMEs in Indonesia, finding as would be expected cases of both success and failure. It will be useful here to refer to some success stories, both for the lessons learned and the policy implications. Two sets of studies are of particular interest: Cole's (1998) study of the Bali garment export

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Sees the Light'. An important recent trend has been the diversification from chip-making into 'photonics'.

[25] This curious impatience with export-oriented electronics is also evident in the Philippines. Electronics now dominates this country's merchandise exports, accounting for over 70% of the total. These exports continued to grow strongly through the Asian crisis, and were an important factor in the country's relative economic buoyancy in 1998-99. The fact that, after 15 years of miserable economic and export performance, the country was performing well in a major industrial sector might have been expected to be a cause for optimism. However, the industry has attracted much negative comment, focusing in particular on its enclave nature, and the absence of backward linkages.

industry, and research on the export-oriented SME furniture manufacturers in the town of Jepara, northern Central Java.[26]

The Bali garment industry, which grew spectacularly in the 1980s and almost exclusively based on small firms, was practically an 'accidental' case of industrialization. Foreign tourists, mainly surfers wishing to support a recreational life-style, saw commercial opportunities in Balinese garments and its indigenous design capacity. They were able to act as marketing intermediaries, connecting local producers with retail outlets abroad, in the process dispensing important information on designs and production techniques. Later, as the island's fame spread, these links developed quickly, and the industry mushroomed from its seasonal, cottage origins to larger production units and some local design capacity. The Jepara furniture industry had its origins further back, but it too began to grow quickly in the 1980s. The industry lacked the tourism connection, but it did have a good local skills base together with access to raw materials, and foreigners quickly saw the opportunities for profitable export as deregulation proceeded.

These studies suggest a model of successful and innovative SME development in which the following ingredients appear to be important:

- some basic industrial competence in a particular field of activity (eg, as in these cases, garment or furniture manufacturing);
- a conducive macroeconomic environment, including especially a competitive exchange rate;
- reasonably good physical infrastructure, extending in these cases (but especially Denpasar) to proximity to import and export facilities which function without too much inconvenience; and
- injections of technical, design and marketing expertise which link small producers to new ideas and major markets.

With the possible exception of the first ingredient, all four elements are directly amenable to public policy. They may also be present in different institutional arrangements, as for example in the emerging subcontracting networks found in the automotive and machine goods industries (see below). And the general model developed here is equally applicable in agriculture, and in larger scale industry, where barriers to the development of technology transfer channels are generally lower than in the case of SMEs. It might be argued that these examples are special cases, which are not easily transferred to the bulk of small firms, especially those operating in remote locations and catering to low income markets. But neither garments nor furniture could be regarded as 'niche markets'; on the contrary they are mass consumption goods. Admittedly Bali has intense exposure to international markets through tourism, but Jepara is some distance from a major port (Semarang) and is not a tourist destination.

These case studies also have important implications for government policy. Neither resulted from any deliberate government promotional measures. The government did play

[26] On the latter, see Berry and Levy (1999), Sandee et al (2000), and Schiller and Martin-Schiller (1997).

an important role in providing a supportive macroeconomic environment and in the provision of a rapidly improving infrastructure. In Bali, the local government generally adopted a fairly open policy towards the presence of foreign entrepreneurs, and export procedures were not unduly burdensome most of the time. The June 1994 reform of FDI regulations, lowering the minimum capital requirement from $1 million to $250,000, made it easier for small foreign investors to operate in the country without harassment. These of course hardly constitute 'contributions' from government, except in the negative sense of avoiding a harshly restrictive regulatory regime.[27] By contrast, reports from Jepara occasionally reveal that foreign workers, on whom the industry depends, are being harassed and sometimes deported.

Cole's study is also important because the dynamics of the process of SME technological adoption do not appear to be of interest to, or understood by, the relevant government agencies. Former President Habibie, for example, frequently dismissed the garments industry as irrelevant for Indonesia's technological future even though, as these and other studies have shown, a good deal of dynamic innovation is evident. Moreover, the intellectual framework of the relevant government department, Depkop (The Department of Cooperatives and Small-Medium Enterprise) has been almost completely irrelevant to the needs of the Balinese garment producers. Rather than Depkop's focus on partnership schemes (Kemitraan), subsidies, regulation, and protection from competition, these firms are more interested in efficiently functioning credit markets, good infrastructure, freedom from bureaucratic harassment, and perhaps some carefully targeted industrial extension support.

A second focus of SMEs case study research in Indonesia has been on subcontracting networks, especially over the past decade. The picture varies across industries and locations, as would be expected, but in general these linkages appear to be strengthening. Sato (2000) examined metal casting in the village of Ceper (Central Java), home to over 300 foundries of varying size. She found (p. 159): '[a] subcontracting system and a putting-out system coexist in this rural cluster. Subcontracting linkages with the urban modern machinery industry, with large assemblers at its apex, have reached top-layer firms in the cluster. At the same time, many firms have formed linkages with wholesalers outside the cluster.'

Assembler firms generally provided little assistance, but private business institutions and wholesalers are important means of channelling marketing, technology and financial assistance to the smaller firms. Among the former, the activities of an offshoot of the (long-time Toyota-linked) Astra conglomerate in nurturing potential future suppliers was considered significant, particularly for larger firms within the sample. The government and foreign donors were not major factors. The former in particular was criticized for programs which did not meet SMEs' major needs, and for concentrating more on targets than actual delivery.

[27] As Cole (1998) puts it, '[b]eyond these points, the role the government played seems more positive in its absence than in its actions.'

Hayashi (2000), in research-in-progress based on 58 firms in the automotive and motor cycle industries, also detected quite well developed subcontracting networks. Perhaps reflecting his choice of industries and firm locations, he found stronger assembler-supplier relationships. About 80% of the suppliers interviewed reported that they had benefited in some form from the ties, most especially in the areas of technology and marketing, but not much in finance. Quality control techniques were an important example, as was practical shop-floor advice. He also found that the strength of the ties varied according to the size of the firm and the ethnicity of the owner, with larger and non-pribumi firms better able to utilize opportunities arising from subcontracting relationships. Smaller firms were thought to lack absorptive capacity, and were more reliant on government programs.

(5.6) Agriculture[28]

It is often forgotten that arguably the most important technological revolution to occur in East Asian over the past four decades was the green revolution.[29] Beginning in the 1960s, it resulted in unprecedented increases in food production and transformed this sector in many countries, vastly improving the then precarious food supply equations. Although criticized at the time on both environmental and equity grounds, it energized agriculture and rural development, especially as it was largely scale-neutral in its application and impact. It made a major contribution to poverty alleviation, directly through agricultural growth and employment, and indirectly since it is well known that, in very poor countries, poverty reduction is more sensitive to growth in agriculture than any other sector (see Ravallion, and Datt, 1996). It is difficult to think of any other international investment, in the public or private domain, having such enormously positive impacts, high social rates of return, widespread adoption, and rapid domestic diffusion.

This was an excellent illustration of effective international assistance (now regrettably on the wane) combining with local innovation capacities. Its success did depend on this combination of inputs, and inevitably therefore its impacts were spatially uneven (Pingali, 2001). Much of Sub-Sahara Africa missed out until recently, for example (and was therefore doubly affected, since real food prices fell as a consequence of the green revolution). Upland agriculture, more remote regions, and those not reliant on the favoured crops (rice and maize) also did not participate to the same extent, even in successful adopter countries (eg, Indonesia and the Philippines). As in the industrial sector, where private suppliers dominate, these internationally funded programs required effective domestic absorptive capacity, particularly agricultural extension services, and physical infrastructure to connect farmers and consumers, and to make markets work.

Agricultural sectors are now very much smaller, but they still employ at least one-third of the workforce in the poorer East Asian economies in our group (and much more in some of the very low-income economies in mainland Southeast Asia). There is no reason in

[28] I wish to thank Colin Barlow, Wally Falcon, and Jim Ryan for much useful advice on this sub-section.

[29] See Evenson and Gollin (2001), who summarize a large research project on this subject, and provide a good retrospective.

principle why, with modification, such a model cannot continue to energize agriculture. National agricultural research institutes are now much less significant actors, with both international and domestic support now considerably reduced. They also need to be reformed (Byerlee and Alex, 1998): there needs to be increased linkages with private sector and universities, more competition for grants, a more demand-driven outlook, and a critical review of staffing and functions.

As public sector support, both domestic and international, has dried up, attention has focused on ways of attracting increased private funding. While in principle desirable, it will be important not to lose sight of the public good dimensions of international support for agricultural research, that is, its non-rival and non-excludable nature (see Herdt, 1999). Shifting to private sector funding on a large scale runs the risk of jeopardizing the key elements of the past record. There is already concern that private sector patenting will adversely affect developing country agriculture. The ten largest firms, for example, now control 30% of global seed sales, and their share is increasing. These firms arguably have little interest in basic, long-term research, and they are also able to attract many of the developing world's most able scientists (eg, plant biologists) away from poorly paid national research institutes. Of course, there is still much agricultural research conducted in OECD-country institutes, but their work focuses on an economic and ecological setting which is generally very different from that of low-income tropical agriculture. The work of international centres with a specific developing country focus would appear to deserve much more support.

A second strand in the literature on agricultural innovation and diffusion has focused on the cash crop sector. Here there have not been the major breakthroughs or large-scale international support that were evident in the food crop sector, but rather a more incremental and gradual process. Experience here shares much in common with the SMEs sector, with the major difference being the critical importance of physical infrastructure as a means of ensuring that markets work effectively.[30]

Indonesia, Malaysia, and Thailand are the three largest producers of natural rubber, but their institutional and economic environments have differed greatly. Malaysia was for many years the world leader, with its highly efficient plantation sector established during the colonial era, alongside a productive smallholder sector. The foundations of this efficiency were an open economy, good macroeconomic management, and excellent physical infrastructure. The industry was supported by good quality research institutes, and excellent extension networks, the latter receiving strong political backing since the majority of smallholders have traditionally been bumiputeras (indigenous Malays). The industry became practically self-supporting, through the imposition of an effectively utilized cess on exports.

By the 1980s it was evident that Malaysia was losing comparative advantage in rubber, even with the large inflows of mostly illegal immigrant labour. Indonesia, for long the second the largest producer, assumed that it would quickly overtake Malaysia. However,

[30] The following draws in particular on Colin Barlow's analysis of the rubber industry in Southeast Asia. See for example Barlow (2000, 2001).

Thailand, a relatively minor producer as recently as the 1960s, was the industry's great success story, and by 1990 it became the world's largest producer, overtaking both Malaysia and Indonesia during the 1980s. Unlike its two neighbours, the Thai industry is almost entirely smallholder. The government began to pay attention to it in the early 1960s, to combat poverty and to overcome a communist insurrection in the south (where the industry is mainly located). It borrowed freely and informally from Malaysia, but adapted technology to local needs.

Several ingredients underpinned the Thai success. Its agricultural extension staff were effective, and there was excellent officer-farmer interaction. Physical infrastructure, especially roads, was developed, and this in turn led to the rapid spread of motorized transport (especially motor cycles). Central government nurseries were established initially to distribute improved seed varieties, but these spread rapidly to many small private operations. There was also a need to overcome the moral hazard problem of over-tapping of rubber trees – which leads to their premature aging – and the assumption that the government would come to rescue. This was achieved through effective local community organization. These initiatives were generally not high-cost, and were funded by a combination of a small levy on rubber exports, plus development assistance and central government funding.

Indonesia's record, by contrast, was less successful. Government-owned estates (inherited from the 1957-58 nationalizations and never returned to their owners) dominated the industry. These were bureaucratic, politicized and subsidized entities, with low levels of efficiency and little incentive to innovate. Moreover, the various schemes to promote smallholders prior to the 1980s were largely unsuccessful. The emphasis was on government-initiated enclaves, featuring intensive, top-down interventions. Although yields increased, these were expensive programs, and diffusion was slow. Arrears on credit extended as part of the package were high.

Things began to improve in the 1980s. Large government infrastructure investments funded from the 1970s oil boom began to come on stream. Falling oil prices resulted in a sharply depreciating real effective exchange rate, boosting competitiveness. Private traders became more active, transport costs fell, and the industry was opened up to private investors. (Malaysian firms in particular, losing comparative advantage at home, became active.) Private nurseries became more active. More generally, there was an influx of entrepreneurs who worked out '… new nursery production and marketing arrangements, and, in doing so, brought home to farmers and others the new possibilities springing from the increased knowledge and techniques now available.' (Barlow, 2000, p.33). In consequence, Barlow concludes (p. 32), 'It was only in the 1980s, after 70 years of using the old technology, that a combination of disequilibrating influences created the impetus for private nurseries and a certain kind of smallholding block scheme as substantial innovations, effectively encouraging the adoption of high-yielding trees.'

In contrast, Indonesia's cocoa industry has been a success story (Takamasa and Nishio, 1997). Comprising mainly smallholders in Sulawesi, output has grown rapidly, by an annual average rate of 26% 1980-94. The key factors appear to have been the provision

of reasonably good physical infrastructure (especially roads), a competitive exchange rate and the absence of government distortions in marketing. (Indonesian farm-gate prices are a comparatively high proportion of export prices, and quality-based price differentials are needed to encourage farmers to upgrade quality.) In such a scenario of 'hands-off policy success', the key role for government (as in the case of the Bali garments industry referred to earlier) is to continue to provide more of the same, together with a range of agricultural extension services (to combat disease, for example) to facilitate continuous productivity growth.

What lessons for technology and innovation policy emerge from these agricultural studies? The key role of governments is to spur innovation and to make markets work. Incomplete markets are clearly a major barrier to innovation. Thus the most effective strategies for governments – apart from the obvious ones of good macroeconomic management, universal basic education, law and order, etc – are:

- good quality physical infrastructure (which introduces more competition among traders, and lowers transport and information costs);
- efficient financial intermediation (particularly small-scale and informal credit, on which see Patten, Rosengard, and Johnston 2001), which inter alia rests on secure and transparent property rights;
- particularly in the early stages, rural research institutes which can assist small farmers to absorb, assimilate, and adapt new technologies; and effective agricultural extension staff; and
- more controversially, modest and strictly time-bound subsidies may be useful to induce risk-averse farmers to adopt new technologies and commercial inputs.

One additional implication is that in spatially diverse and fragmented economies, such as Indonesia and China, a 'one-size-fits-all' strategy may not be appropriate. 'Markets' obviously work better in regions with established physical infrastructure, good international connections, a well-educated populace, and plentiful commercial expertise. Thus, for example, agricultural development policies which work well in Java won't necessarily do so in Irian Jaya.

(5.7) Public Research Institutes and Vocational Education

Public research institutes (PRIs) are critical actors in the early stages of technology and innovation. Typically, most commercial entities are too small to sustain a major R&D effort. A culture of R&D has generally not yet taken root, and thus these institutes can act as catalysts. Moreover, the institutional supports necessary to maintain a modern R&D effort – from protection of intellectual property rights to a venture capital market – are generally under-developed.

East Asian governments have experimented with a wide variety of institutional arrangements in support of PRIs. The general record has been one of limited success, since the institutes are typically poorly funded and their links to universities and firms are weak.

A widely cited success story of clever and nimble intervention is Taiwan's Industrial Technology Research Institute (ITRI).[31] Founded in 1973, the institute expanded rapidly in the 1980s; by 1994 it had 6,000 employees, 560 of whom possessed doctorates. ITRI is now the largest industry-oriented research institution in Taiwan, and has working relations with some 20,000 companies. It has received significant public sector funding, absorbing about 25% of the government's non-defence technology projects between 1983 and 1994. The Hsinchu Science-based Industry Park, established in 1980, has been an effective means of disseminating new technologies. In both cases, Taiwan's industrial structure was such that government funding of these initiatives was a necessary pre-requisite for upgrading. Possessing few very large conglomerates, the Korean strategy of promoting R&D within large firms was not an option.

Central to their success, according to Lin, were six factors: a strong national human resource base on which to draw; access to international technology markets; a competent domestic R&D base; an emphasis on diffusion and commercialization of domestic and international know-how; strong ties to the private sector; and supportive intellectual property rights. The technology diffused very quickly to SMEs, through the movement of personnel between firms and research institutes, and direct observation and learning. Joint ventures with foreign firms adjacent to these scientific facilities hastened the process. As Westphal (2001) notes, ITRI entirely funded Taiwan's first DRAM (dynamic random access memory), which in turn underpinned much of the subsequent success in electronics (Mathews and Cho, 2000).

ITRI appears to be one of the most effective institutions of its kind in East Asia.[32] At the other extreme, but perhaps more typical of the broader developing country context, are the much less effective R&D institutions in Indonesia (on which see Lall, 1998a; Thee, 1998), in which two interrelated weaknesses are generally present. First, their funding base is generally inadequate, which results in (a) salaries too low to attract high-calibre staff, (b) facilities (including equipment, sometimes from myriad, unconnected foreign aid programs) that do not meet best practice requirements, and (c) especially in those agencies working in remote rural communities, a limited capacity to engage in meaningful outreach activities for the targeted client groups. Obviously, given a more or less finite R&D budget, there is a direct and causal relationship between the resource poverty of these institutes and the extremely expensive mega-projects mentioned above.

The second problem relates to the objectives and functioning of these institutes. Their mission statements and philosophies are supply rather than demand driven. Their ties with the private sector are generally weak: there is little staff mobility, and even their physical location is not always based on the needs of their client groups. Not infrequently, the institutes have a welfare rather than an efficiency orientation, and their staff have a tendency to regard foreign and non-pribumi-owned enterprises with suspicion. Such an

[31] See Lin (1998), on which this paragraph draws.

[32] Although there are skeptics. According to Hobday (2001), it is not clear what contribution it has made to the development of Taiwan's electronics industry. He also notes that many Taiwanese SMEs are inherently suspicious of government.

approach compounds their funding problems, since they do not have an influential private sector constituency advocating a stronger resource base. Few attempts have been made to augment institute resources in exchange for more relevant service delivery to the private sector.

Other countries are located somewhere between the extremes of Taiwan and Indonesia. Malaysia has a mixed record (Rasiah, 1999). It was historically perhaps the most successful exponent of high quality agricultural extension services, particularly for cash crops. In the development of its electronics industry, a state instrumentality, the Penang Development Corporation, has been effective, albeit with limited policy reach (McKendrick, et al, 2000). But the more general pattern is one of weak linkages between PRIs and domestic firms. In part, this has been because of the country's ethnic politics, with a Malay-dominated public sector and Chinese-dominated SMEs. (Penang is the only state in which the ethnic Chinese community is in the majority.)

In Korea, as noted, most R&D has been undertaken within the chaebol rather than PRIs, and links between the two, and universities, have been rather weak. Very little of the country's spectacular advances in electronics, for example, have originated from PRIs (Mathews and Cho, 2000). Indirect government support for the chaebol's R&D programs has of course been massive. Post-crisis, the policy regime is emphasizing the importance of these linkages, along with a more open foreign investment regime.

Similarly, these links have not been well established in Singapore (Wong, 2001). This is changing, however, and in any case the public sector (both the so-called Government Linked Corporations and government departments) has been a particularly active innovator, with rapid diffusion to private firms. Historically, aided by public funding, MNCs have been the principal innovators, certainly in the dominant electronics sector. Thus, as noted, the major focus has been on diffusing this innovation both horizontally and vertically to domestic SMEs.

Related to funding for research institutes, is there an argument for government subsidies for vocational and technical education? There is a well-established case, on both equity and efficiency grounds, for governments to subsidize the provision of education, especially at primary and junior secondary levels. But the general presumption is that the case for intervention (and subsidy) in technical and vocational education is less persuasive, since well-functioning markets will signal their demand for a particular skill mix, and it will be privately profitable for individuals to undertake the requisite training. Where there may be a role for governments is as a catalyst, to stimulate the market for private education, perhaps to provide some initial subsidies to demonstrate the profitability of such training, and to provide a regulatory environment which covers such matters as skills certification. A further issue concerns institutional development and the problem of appropriability. A substantial amount of specialist training is industry and even firm-specific, and is undertaken within firms. It is sometimes argued that, left to the market, firms are likely to under-invest in such training, owing to their short-term planning horizons and the frequent hijacking of trained staff. If industry associations functioned effectively, such training could be undertaken at the industry level, thus ameliorating 'free-rider'

concerns. Unfortunately, industry associations in East Asia are still rather weak, thus limiting the scope for effective collective action solutions.

This too is an unresolved issue in the literature. In an Indonesian case study, Manning (1998) questions the case for a significant government involvement in vocational education and training. He maintains that it is preferable to concentrate scarce educational resources in the general education system, which is starved of resources. He is not convinced that technical education currently constitutes an obstacle to industrialization, since the limited firm surveys thus far undertaken are ambiguous on this issue – some report skilled labour shortages, but these often rank below other problems (including physical infrastructure and corruption). He also maintains that private education markets generally work in responding to skill shortages and in delivering market requirements. Finally, he cautions against a headlong rush into interventionist strategies on political economy grounds. There is a danger, already evident, of bureaucratic capture (sometimes in association with a fragmented foreign donor community): of supply rather than demand-driven programs, of excessive credentialism in the setting of standards, and of straight-out corruption in the delivery of services.

(5.8) Data Base and Research Priorities

As is evident from the discussion above, there are significant data deficiencies, especially outside the NIEs. Korea, Singapore and Taiwan now produce useful annual statistical series on technology and innovation and, as an OECD member, Korea is now included in major comparative series for developed economies. However, the R&D data base for the ASEAN Four countries is very weak. Moreover, it is difficult to obtain internationally comparable series for East Asian economies as a whole.

It is virtually impossible to quantify the overall magnitude of international technology flows, let alone the major constituent elements. The closest approximation is royalty payments, but few non-OECD countries publish such data. It is widely assumed that FDI is the most important component of these international transfers (Soesastro, 1998), but the available secondary data are at best indicative. It is not possible to aggregate the various flows with a technology component (eg, data on FDI, capital goods imports and human capital flows are non-additive). Moreover, it is possible that some very large FDIs (eg, mining investments) may be enclave in nature with little technological spillover, whereas smaller manufacturing and service FDIs in the presence of a strong local absorptive capacity may have a significant technology impact.

Perhaps the major research deficiency is that we lack detailed micro-level case studies of the process of innovation at the enterprise level (notwithstanding several illuminating studies referred to in this paper).

A key policy challenge lies in understanding when, how and why government intervention has been successful. We have a general understanding of the dynamics here: governments are most effective when they are catalysts, in inducing firms to embark on

an effective innovation trajectory, in making markets work effectively through investments in the missing ingredients (eg, basic R&D, effective agricultural extension, etc). But so often ‘government failure’ is a more serious problem than ‘market failure’. Even well intentioned programs are frequently captured by vested interests, let alone blatant cases of lobbying to protect ‘infants which never grow up’. Such sentiments are highly relevant to the debate over industry policy referred to above. Much depends in this case on an assessment of government capacity: what may work in the highly open Singapore economy with its seemingly incorruptible civil service, almost certainly would not apply in Indonesia, where the possibility of corruption must surely rule all but the most basic functions of government. The other East Asian economies in this survey are probably between theses two extremes.

(6) SUMMING UP

Our paper has emphasized a number of issues.

One is that technology and innovation are gradual processes of evolution, especially for developing East Asian economies, which with a few exceptions are ‘followers’ and net technology importers. The issue is how to import, absorb, assimilate, and diffuse technology, rather than to undertake new R&D at the frontiers.

Second, these are extraordinarily diverse economies in their histories, levels of development, international orientation and institutional capacity. As a result, there is no one unique path of technological development. It is clear, though, that the role of the government shifts over time. Among the late industrializers in Southeast Asia, the principal role of government is to provide competent macroeconomic management, an open economy, and good basic public services (education and health especially) and infrastructure. Explicit technology and innovation policies are not central to this mission, although extension services and other agencies which diffuse technology are important.

However, as countries approach middle-income status, and there is a loss of comparative advantage in labour-intensive activities, governments need to play a role in the upgrading process, in strengthening institutions, building supply-side capabilities, and encouraging the emergence of a national innovation system. The major challenge here is to decide where markets work and don’t work, and to intervene cautiously. Much depends in this context on administrative capacity.

Finally, all countries present a mixed record of notable strengths and persistent weaknesses, and it will be useful here to summarize some of the salient features. An emphasis on challenges is not of course meant to imply that past achievements have been insignificant.

Korea stands out for its major commitment to building domestic R&D capacity, its high level of educational achievement, and its ability to contemplate daunting development challenges. But:

- it has paid a high price for restricting firms' access to international know-how;
- its industrial policy has been adventurous and sometimes costly;
- it lacks the flexibility of a dynamic SME base and a capacity to incubate start-ups;
- universities' research capacities are limited;
- linkages between its chaebol and government institutes and universities are weak;
- owing to past restrictions (now significantly relaxed) its firms have difficulty developing international networks; and
- corporate governance (including minority shareholder confidence in the stock market) is poor by OECD standards.

Singapore scores highly for its extremely open economy, its high quality public administration, its major recent commitment to higher education and research, its aggressive innovations practices in the public sector, its 'insulated' public policy processes which include a capacity to quickly discard unsuccessful experiments, and its capacity to leverage the MNC presence to its own advantage. But:

- worries about a lack of domestic entrepreneurship and creativity reflect in part the fact that the government has avowedly sought to attract the top talent to its ranks, with the world's best-paid civil service;
- an over-bearing government may stifle somewhat the very creative spirit it seeks to ignite;
- fiscal incentives are in likelihood awarded effectively and contribute to progressive technological upgrading, but there is little transparency in the process; and
- links between public research institutions and universities, on the one hand, and firms on the other, are still rather weak.

Indonesia's many impressive development achievements during the first quarter century of the Soeharto era were marred in the case of technology policy by the massive investments in the Habibie mega projects, particularly the aircraft factory, while basic education and the agricultural and industrial extension services were starved of resources. In the post-Soeharto era, the challenge is to overcome the financial and fiscal crisis, maintain past investments in physical and social infrastructure, and re-establish a business-friendly environment in the context of highly fluid and uncertain political structures. Explicit technology and innovation programs will inevitably receive a low priority during this transition period.

Taiwan has achieved unparalleled development success over more than four decades, and survived the recent Asian crisis more successfully than any other NIE. Its industrial and technology model is unique, with its emphasis on a highly flexible, resilient and internationally oriented SME sector. Although not as open to FDI as the city states and Malaysia, its international connections are well developed, aided by the return in recent years of much high-level human capital. It was able to develop a strong R&D base through public funding in the 1980s, which diffused quickly to SMEs. Apart from the general challenge of integration with Greater China, its major weaknesses would appear to be weak corporate and political governance.

Malaysia too has been a striking success story for most of its independent history, but now has to manage the challenge of upgrading its R&D base and capacity for innovation. Specifically:

- its formal technology policy has made little contribution to this success;
- the quality of higher education has arguably deteriorated (the elite generally attend universities abroad);
- most of the high technology projects launched in the early 1980s have been costly failures;
- it could have done more to leverage the MNC presence and maximize potential spin-offs (the state of Penang has been the major success story in this respect); and
- many highly educated non-bumiputeras have felt excluded from politics and society, and have decided to emigrate.

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